Comparative study of some species of the genus *Acer* L. in the Hirkan flora using dendrochronological methods

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ABSTRACT. Recently, due to global climate change and unregulated human economic activities, biodiversity has significantly degraded, which has led to changes and reductions in the ranges of species. Observations show that there is no comprehensive conservation strategy to protect certain regions where rare and endangered species of woody plants of the flora of Azerbaijan live. With the increase in the number of rare species and the decrease in the number of endangered plants, identifying the causes of these problems and preventing their further degradation is an urgent issue for both government agencies and scientific institutions. The main objective of this scientific study is to conduct a biometric and dendrochronological analysis of the processes occurring in the populations of rare species of the Hirkan flora. The study also includes monitoring the areas where rare and endangered species are found and developing action plans to assess and protect these ecosystems. The article presents studies conducted on samples of old species *Acer hyrcanum and Acer mono*, selected from the flora of Hyrcanus. Comparative analysis of the species was carried out using dendrochronological methods. Modern equipment was used to determine the age of species, study the dynamics of their development and assess the impact of environmental factors on them. As is known, woody plants experience radial and vertical growth, forming annual rings, although there are exceptions due to a number of complex factors. Among them, climatic conditions, habitat features, as well as genetic and age characteristics of plants play a particularly important role.

Keywords: flora of Hirkan, dendrochronology, *Acer hyrcanum* Fisch and C.A.Mey, *Acer mono* maxim, climate, radial growth.

1 Introduction

According to the Decree of the President of the Republic of Azerbaijan No. 1368 dated March 24, 2006, the "National Strategy and Action Plan for the Protection and Sustainable Use of Biodiversity in the Republic of Azerbaijan" for 2006-2010 and 2017-2020[5] considered such

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important issues as the repatriation of rare plants of our republic, the preservation of the gene pool, increasing the biodiversity of flora, restoring ecological balance, reducing anthropogenic impact on the environment, creating the necessary conditions for conducting scientific research in specially protected natural areas. Observations have shown that there is no protection strategy for part of the areas where rare and endangered woody plant species are located in the flora of Azerbaijan. Due to the increasing number of rare plant species and the decreasing number of endangered plants, identifying the causes of these problems and preventing them is one of the urgent issues facing state structures and scientific institutions. Research has shown that many species in our flora are on the verge of extinction, and it is crucial to implement a number of measures to preserve such species in nature. National parks, nature reserves, and sanctuaries created for this purpose play a significant role in the protection of plants. Hirkan National Park was established on February 9, 2004, by the Decree of the President of the Republic of Azerbaijan, with the aim of protecting the relict, endemic, rare, and endangered plants of Azerbaijan. The main goal of establishing the National Park is the comprehensive protection of nature in the area, including the protection of relict and endemic plant species from the Tertiary period and the preservation of typical flora and fauna species listed in the "Red Book" of the Republic of Azerbaijan [1].

The main objective of the research work is to identify old species, study the influence of climatic factors on plant development and find ways to solve the problem of individuals with reduced development. Dendrochronology plays a special role in this. Dendrochronology is a science that studies the age of trees and the changes that occur in them based on annual rings (dendro-tree, chronos-time, logos-science) [7]. In this scientific field, modern devices and programs are used. With the help of special dendrochronological equipment, it is possible to determine climate changes on the planet. The advantage of this equipment is that it allows obtaining information about the growth of trees with minimal damage to them. The Hyrcanian National Park was chosen as the research area.

Hirkan National Park is located in the southeast of Azerbaijan, in the Lankaran and Astara administrative regions. The park was established on February 9, 2004, and its territory was expanded by 13,037 hectares in 2008, increasing from 29,760 hectares to 42,797 hectares. It is the 4th largest park in the republic [1]. The territory of Hirkan National Park was created from the forestry lands of Lankaran and Astara [1]. The park is divided into plain and mountainous parts based on its terrain. The plain part of the National Park covers 91 hectares, and it is the only preserved Hyrcanian Forest type in the Talish region. The area is 21.4 meters below sea level and is rich in relics from the Tertiary period. Despite its small size, Hirkan National Park has a very diverse land surface. This diversity is directly linked to the characteristics of soil-forming rocks with macro-, meso-, and micro-relief, the local climate, and the evolution of plants. The land in the national park is mainly divided into the following regions based on its diversity [4]:

1. Yellow (light and dark) podzolic soils belonging to the lower soil region.
2. Yellow (gray and brown) dark-colored and light-colored forest soils belonging to the central soil region.
3. Brown forest and podzolic soils belonging to the upper soil region [4].

This region is characterized by various landscape-climatic conditions. The climate of the lowlands and foothills of the National Park is similar to that of the Mediterranean, characterized by dry summer months. Humidity gradually decreases in the northern and northeastern parts of the park.

The inclusion of continental and marine air masses (characteristic of the cold period), southern cyclones, subtropical anticyclones, continental anticyclones and Central Asian anticyclones in the climate changes of the region creates significant opportunities for atmospheric circulation. Continental and marine air masses enter the region from the north and northeast, coinciding with the cold months of the year. During this period, the air temperature drops by 8-10°C, and windy and cloudy days are observed in these conditions [4].

The local atmospheric circulation has caused an increase in the relative atmospheric pressure differences between the Caspian Sea and the Talysh mountains, giving it a distinctive character. The area is characterized by hot "Garmichi" winds in autumn, which can sometimes cause fires. In recent years, an increase in fires has been observed in the Hirkan forests, resulting in serious damage to the area and its biodiversity.

Thus, the daily, monthly, and yearly climate variations in the National Park are influenced by the interaction of local physical-geographical and geomorphological factors with atmospheric winds. In the lowlands and foothills of the National Park, the weather is mild or relatively warm, but temperature variations are present throughout the area [1].

Moisture from the sea has a direct effect on the formation and development of vegetation. As is known, in the spring and autumn months, when the weather is relatively cool, moisture rising from the sea forms fog at an altitude of 700-900 meters and is accompanied by rainy days. This contributes to the humidification of the area. The average annual temperature, rising above 14°C, creates favorable conditions for the development of plants [1, 4]. The wind regime in the area has a unique character due to the physical and geographical conditions. North, northwest, and southwest winds are predominant. The physical-geographical conditions play a key role in the formation and distribution of vegetation. In this context, climate and terrain directly influence the area's vegetation. The Caspian Sea is the main source of precipitation in the Lankaran region. The highest rainfall in the Lankaran and Astara regions covers the entire National Park, and these environmental conditions allow the formation of many endemic and relict species, as well as a number of broad-leaved, evergreen plants [1,4].

Research has shown that climate change in the area occurs every 8-10 years. In the lowlands and foothills, heavy snowfall is likely every 10-12 years [4].

Table 1. The following indicators are typical for the area where the National Park is located [4].

Annual average temperature	14.5^0C
Absolute minimum temperature	16^0C
Absolute maximum temperature	40^0C
Average annual temperature of the land surface	16^0C

The Lankaran-Astara region, where the Hirkan National Park is located, exhibits various climate types: dry desert-like hot summers and cold winters in the north, humid subtropical mild winters and relatively mild summers in the central part, and dry highlands in the upper mountains, with relatively hot and cool summers [1,4]. It can be concluded that the summers are dry, while autumn and winter are rainy throughout the region, which shows similarities to the Mediterranean climate. Due to the average annual temperature and the amount of precipitation, humid subtropical climatic conditions are created in certain areas. The Talysh Mountains have a significant influence on the area's temperature regime, preventing continental air masses from entering from the forestless regions of Iran [4].

The average annual air temperature in the area ranges between 12-14°C depending on the altitude. The average air temperature in January is 1-3.7°C, and in June it is 22-24.5°C. The absolute minimum temperature recorded was -16°C, and the absolute maximum was 38°C. [4].

Acer hyrcanum Fisch. & C.A. Mey *and Acer mono* Maxim. were studied as the main objects of research.

Acer hyrcanum Fisch. & C.A. Mey has a natural range that includes Asia Minor, Russia (Dagestan), Turkey, Lebanon, the Balkans, and Iran. In Azerbaijan, it is naturally distributed in the Greater and Lesser Caucasus, the Alazan-Eyrichay valley, Nakhchivan Autonomous

Republic, and the Lankaran mountains (Diabar) [2]. It is a rare plant in Azerbaijan and is classified as NT (Near Threatened). It grows on calcareous and light dry slopes, from the lower montane belt to the upper montane belt. The climate of the Hirkan forests is relatively humid and temperate, which makes it favorable for the healthy growth of this birch in moist and warm climates. Maintaining a certain level of humidity in the summer is also important for this tree [3].

This tree grows mainly along the shores of the Caspian Sea in a humid subtropical climate zone because both the soil and weather conditions in this region are suitable for its natural requirements. In the wild, its distribution is limited. It is a tree that can grow up to 18 meters tall and 30 cm in diameter. Young branches are reddish-brown, while older branches turn gray-brown. The shoots are brown. Initially, the leaves are covered with yellowish hairs, but these hairs disappear as the leaves mature. The leaves are 5-lobed, 10-12 cm wide, and 5-10 cm long, with a heart-shaped base. The top of the leaves is dark green, while the underside is whitish or yellowish and densely hairy when young. As the leaves age, the hairs remain only in the corners of the main leaf veins. The lobes are wide, oblong-ovate, and sharp. The tips of the lobes are blunt to sharp. The flowers are grouped together [2].

Its flowers form in small clusters, and when fruit is formed, they appear as a cluster of flowers. The calyx leaves are glabrous, inverted ovate, and 3.5 mm long. The petals are small and yellowish, slightly longer than the calyx leaves. The stamens are twice as long as the petals. The winged fruits are bare, 2.5-4.5 cm long, and are positioned almost parallel. Sometimes the edges of the wings intertwine. The wings are yellowish-brown in color, and the fruit capsule is smooth and shiny brown. The tree blooms in July and bears fruit in September. It is propagated by seeds and roots [2].

The reasons for changes in natural resources are primarily due to human activity. No protective measures have been taken for this species. It is necessary to include *Acer hyrcanum* Fisch. & C.A. Mey in Azerbaijan's "Red Book" and protect it. *Acer hyrcanum* Fisch. & C.A. Mey thrives mainly in fertile and well-drained soils. The suitable soil types for it include gravelly or sandy soils, which retain moisture well and allow air circulation, beneficial for tree roots. The soil's pH level should be neutral to slightly acidic (6.0-7.0). When the acidity is too high or too low, the tree's development can be stunted. This plant prefers a moist environment but does not grow well in waterlogged or overly wet soils. Well-drained soils are more favorable for its growth [2].

Although *Acer mono* Maxim. grows naturally in Japan, Korea, China, and Mongolia; it has also been found in the Hirkan forests [2].

It is a pyramidal tree with a branched canopy, reaching a height of 20-25 meters. The bark is initially smooth but later becomes yellow-gray. The leaves are five- or seven-lobed, 8-15 cm wide, green on both sides, with weak lobes or truncate at the center, smooth on the edges, and either glabrous on the underside or with soft hairs along the main veins [2]. The leaves are triangular, symmetrical, with pointed tips. The stems are long. In autumn, the leaves turn yellow and red. The flowers are yellow and grouped in clusters, 4–6 cm long on flower stalks. They appear either simultaneously with or before the leaves. Each tree bears either male or female flowers, but not both. In winter, the shoots are dark red. It blooms in April-May, and fruits appear in September. The fruit consists of paired, elongated wings, 1–1.5 cm wide and 3–3.5 cm long, with a smooth nut-like cone that is 1–1.3 cm long and 8–10 mm wide. The wings are arranged at different angles. The tree grows in forests, on rocky terrain, and in mountainous areas at elevations up to 1800 meters above sea level. It adapts quickly and grows well in moist, well-drained soils, even in areas with limited sunlight [2].

2 Literature review

In the study, some species of Acer L. were dendrochronologically analyzed in the Hirkan flora. The main goal of the research work is to identify old species, to study the influence of climate factors on plant development, and to find ways to solve the problem of individuals with reduced development. Several sources were used for this purpose. Natural geographical conditions of Hirkan National Park, climate, some bioecological characteristics of plants, distribution areas, dendrochronological method, methods, etc. researched and studied from literature materials.

Primary sources are books H.M.Safarov, V.S. Farzaliyev “Flora and vegetation of Hirkan National Park”; T.S.Mammadov, Dendroflora of Azerbaijan, T.S.Mammadov, E.O.Isgender, T.H.Talıbov. Rare trees and shrubs of Azerbaijan and Samira Bagirova “Acclimatization and dendrochronological analysis of Eucalyptus species in Azerbaijan”.

The climate changes of recent years have not left an impact on biodiversity. For this purpose, it is appropriate to investigate new endangered and non-protected species and include them in the "Red Book" of Azerbaijan. New methodology and methods should be organized in order to optimize research.

3 Material and Methods

3.1 The research methods

Species ring data were analyzed using the Schweingruber method. The Cook-Kairiukstis method was used to identify rings under the microscope, and TSAPwin and Crossdating software, as used by Reen, were used to detect false and missing rings [5,7] Specimen names and collection dates were recorded on containers, and species ring change data were collected every 10 years during the study [8].

Fig. 1. Samples taken.

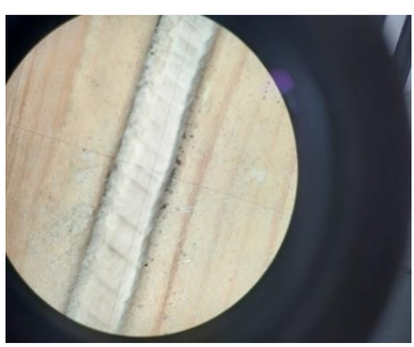

Fig.2. The appearance of annual rings under a LINTAB6 binocular microscope.

Experiments to quickly obtain all relevant information on *Acer hyrcanum Fisch. & C.A.Mey* and *Acer mono* Maxim were carried out using improved systems that meet international standards and are adapted to local conditions. Observation, recording, data collection, and quality studies were conducted in accordance with existing methodological guidelines. Using the LINTAB6 equipment and TSAPwin statistical software, the age and growth dynamics of the species, in relation to climatic factors, were analyzed. The samples were cleaned, cut, and prepared for microscopic examination and data collection in the "Dendrochronology" laboratory under sterile conditions.

A Suunto incremental auger was used to collect wood samples from the trees. For larger trees, an 85-90 cm auger was used, and for smaller trees, a 45-50 cm auger was used. Using the Suunto auger, 4-5 samples were taken perpendicular to the vertical axis of the tree, placed in containers and dried in the laboratory. The growth rings in the samples were then prepared for examination by cutting them to ensure that the boundaries were clearly visible.[6]

The LINTAB6 device, produced by the German company RINNTECH, was used to analyze annual ring widths and wood growth in horizontal sections. Global environmental changes are studied using the LINTAB6 binocular microscope and the TSAPwin statistical program for annual ring analysis. The width of the annual rings, observed with a binocular microscope, is measured to an accuracy of 0.01 mm using the LINTAB6 device. Data on changes in the species' rings were collected, with one registration point representing 10 years, two points 20 years, and three points 30 years. TSAP-Win™ is a software program developed by the German company RINNTECH [14].

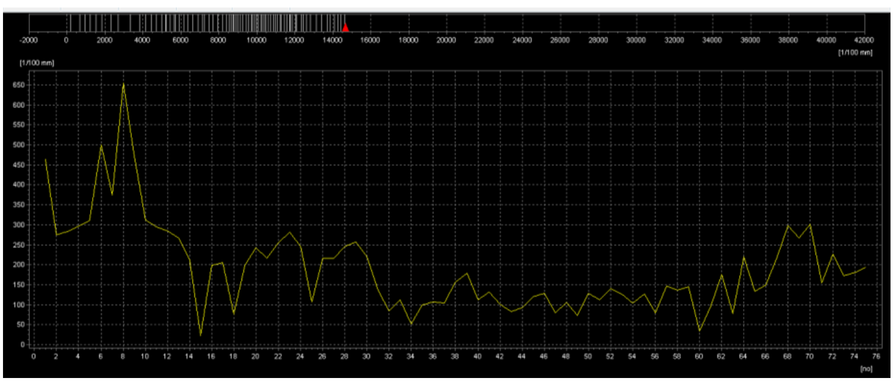

Fig. 1. Development dynamics of the *Acer hyrcanum* Fisch& C.A.Mey from Tsapwin program (by age).

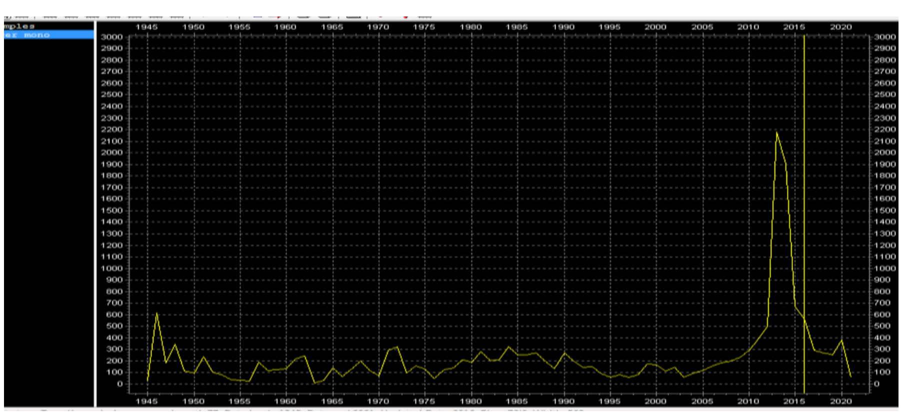

Fig. 4. Development dynamics of the *Acer mono* Maxim type from the Tsapwin program (by years).

All steps from measurement to the evaluation of tree annual ring sequences are handled by TSAP-Win™. TSAP-Win™ provides a wide range of graphical and statistical functions, including database connections, to help manage the data. The data obtained from the LINTAB 6 equipment is transferred directly to the computer, where graphs and tables regarding the tree's annual rings are generated using the TSAP-Win™ program. This allows for the study of the tree's age and development dynamics [10,14].

4 Results and Discussions

As is known, woody plants experience radial growth and a certain amount of height growth, typically forming a ring each year, with exceptions due to a number of complex factors. Among these factors, climatic conditions, the growing environment, genetic traits, and the age of the plants play a critical role [8,15].

The effect of recent temperature changes on wood growth in different periods of the year has been investigated using tree-ring patterns. In areas favorable to tree growth, wide tree rings are formed and the growth rate varies little between successive years [9,11]. This indicates that tree growth under these conditions does not strongly reflect the variability of environmental factors. However, under unfavorable conditions, tree rings become narrow, their width varies considerably from year to year, and ring loss is common. These series are called sensitive. The greater the annual variability of tree growth, the more reliable it is as an indicator of changing environmental conditions [12,16,17].

Acer hyrcanum Fisch. & C.A.Mey., one of the dominant species during the monitoring of senopopulations in their phytocenosis in the Hirkan flora, was sampled from the Khanbulan area with a trunk diameter of 186 cm. During the dendrochronological analysis, the species was determined to be 76 years old based on its annual rings and age structure, as outlined in its dendrochronological history. The development dynamics were recorded (Table 2), with high radial growth observed in 2016 and 2018. In the early stages of development, particularly during juvenile and reproductive periods, growth was more vigorous than in the senile phase. However, at the ages of 15, 18, 34, and 60 (in 1963, 1966, 1982, and 2008), and in recent years, a sharp decline in growth was noted (fig. 3).

In a second sample, the stem diameter of *Acer mono* Maxim was measured at 220 cm, with the species determined to be 77 years old. Looking at its development, growth was relatively high in the early years of its life, particularly from 1947 to 1950, after which growth weakened. The highest development occurred in 2015-2016. However, in recent years, particularly from 2019-2024, a decline in growth was observed, likely due to climate change (fig. 4).

Table 2. Indicators of samples.

Species	Diameter of the trunk	Area Coordinates	Tree age	High development (Year)	Poor development (Year)
Acer hyrcanum Fisch. & C.A.Mey	186 cm	Lankaran N 38^0 40,445 E 48 44,237	76 (1948)	1954, 1957, 2016, 2018	1963, 1966, 1982, 2008 2019-2024
Acer mono Maxim	220 cm	Lankaran N 38^0 40,761 E 48 48, 290	77 (1947)	1946, 1948 2013	2015-2024

Against the background of increasing anthropogenic impacts such as the development of agriculture and livestock farming, expansion of the mining industry, construction of new settlements, construction of oil and gas pipelines, natural ecosystems have faced serious degradation [11]. These factors have also affected forest ecosystems, resulting in a reduction in forest area, density, quality and productivity. Natural regeneration has weakened, low-value species are replacing more valuable ones, forest litter and dead cover have degraded, and forest types are changing [18,19]. The dominance of xerophytic and mesophytic species is increasing, and some trees and shrubs are becoming rare and are on the verge of extinction. In the last decade, forest fires have become characteristic of the forests of the Hyrcanian region, causing significant damage to biodiversity. In addition to these factors, visual inspection of trees revealed sap flow in the trunks, as well as cracks and holes in the bark. Various pests have also been found on the trees, primarily wood-boring beetles (Scolytinae), which pose a threat to these trees. These insects burrow under the bark and partially damage the internal tissues. As a result of such damage to the bark, the trees may lose vital nutrients and begin to dry out. Such pests and diseases can seriously affect the health of the Hyrcanus flora. To mitigate these threats, appropriate control measures should be implemented, including both biological and chemical methods. In addition, maintaining favorable environmental conditions for the trees can increase their resistance to pests.

4 Conclusions

In forest environments, neglect of many trees contributes to the predictable spread of pests. To prevent these pests and diseases from infecting other trees, monitoring should be carried out by experts several times a year, and diseased or aging plants should be documented [13]. Tree ring analysis has been used to assess the health of forests for over 80 years. Modern dendrochronological methods can determine the damage caused to trees by fires, climate factors and pests [15]. Taking all this into account, priority should be given to more efficient use of natural resources, increased environmental control and comprehensive efforts in similar areas. To this end, it is necessary to re-evaluate rare and endangered plants and add new species to the Red Book.

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