








# Impact of Environmental Factors on *ex situ* Phanerophytes

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**Abstract.** The study provides valuable insights into how environmental conditions shape the physiological and morphological characteristics of introduced phanerophytes in the Absheron Peninsula of Azerbaijan. The results indicate that light, wind, and heat are critical ecological determinants influencing the adaptation, distribution, and survival of these species. The dominance of heliophytes (311 species) over sciophytes (51 species) demonstrates that most of the studied plants are well adapted to open and sun-exposed habitats. This finding aligns with the climatic conditions of the Absheron Peninsula, which is characterized by high solar radiation and limited shaded environments. Wind resistance was also found to be a significant adaptive feature, with 298 species showing strong tolerance to wind stress. This resilience is likely related to the peninsula's semi-arid climate, where frequent and strong winds are a defining environmental factor. Plants exhibiting high wind resistance often possess flexible stems, reduced leaf size, and robust root systems that minimize mechanical damage and water loss. The classification of species into high (54–56 °C), moderate (52 °C), and low (48–50 °C) temperature resistance groups reveal substantial variability in their tolerance to heat stress. This variability reflects both genetic diversity and ecological plasticity, allowing species to persist under fluctuating thermal regimes. Overall, the research highlights that light intensity, wind exposure, and heat tolerance are interrelated factors that collectively determine the ecological success and evolutionary trajectory of introduced phanerophytes in the Absheron Peninsula.

**Keywords:** Phanerophyte, environmental factors, light, temperature,

## 1 Introduction

Plants are exposed to a number of environmental factors that have different characteristics in the range they spread. These environmental factors affect the plants directly or indirectly. These factors affecting plants sometimes reduce the number of individual species, negatively affect to their reproduction and other developmental characteristics [1,2]. These factors affecting to the growth and development of plants are divided into two group of living and lifeless factors. In the research work has been reflected light, wind, heat as the affects of environmental factors to studied plants.

Environmental factors such as temperature, light, and wind, as well as management practices, play a crucial role in shaping the microclimate around trees. These factors directly influence tree physiology, particularly during winter, affecting processes such as dormancy, water balance, and frost resistance. Understanding how trees respond to both abiotic conditions and silvicultural interventions is essential for improving their survival and growth under changing climatic conditions. This study examines the interactions between environmental conditions, management strategies, and their effects on tree winter physiology and frost tolerance [3].

Under extreme conditions, such as frozen soils, substantial embolism can occur in the xylem vessels, disrupting water transport from roots to leaves. This blockage reduces hydraulic conductivity and can lead to winter drought, even when soil moisture is present but inaccessible due to freezing [4,5]. Repeated embolism events can weaken the tree's overall water transport system, increasing susceptibility to frost damage and limiting growth in the following growing season. Frost resistance in plants is influenced by a variety of factors, including plant height, local microclimatic conditions, and soil characteristics; however, these factors are often difficult to isolate and study independently. Consequently, relatively few studies have specifically examined the role of plant age in determining frost tolerance. In general, seedlings and young saplings exhibit greater susceptibility to frost damage compared with mature individuals. For instance, juvenile *Rhododendron* spp. demonstrate notable year-to-year increases in frost resistance, whereas adult plants show little to no such improvement [6].

While both water excess and deficiency directly influence microclimatic conditions, their impact on plant phenology and the length of the growing season remains uncertain. Drought effects are often intensified under higher temperatures. Nevertheless, experiments using rain exclusion by [7]. indicated that water availability has only a limited effect on the initiation of growth in aboveground tissues. Although plants preferentially utilize locally stored water, drought conditions can lead to premature cessation of growth. Conversely, delayed budburst in water-limited environments may reduce overall water demand, potentially allowing trees to extend their growing season [8].

Studies on plant responses to environmental conditions in the Greater Caucasus have highlighted the importance of both abiotic and biotic factors in shaping plant morphology and reproductive success. Comparative research on *Pyrus* L. species has shown that pollen morphology and fertility vary significantly between natural (*in situ*) and controlled (*ex situ*) environments, making pollen analysis a valuable indicator of environmental quality and plant stress [9]. This variability reflects how environmental conditions influence reproductive traits and developmental stability in woody plants, which

is particularly relevant for understanding adaptation under different growth regimes. In addition to reproductive traits, the attitude of *Pyrus* species to key abiotic factors such as temperature, light, and soil conditions has been documented, indicating that these factors play a critical role in plant performance and stress tolerance in mountainous ecosystems [10].

Abiotic and biotic stresses can disrupt the physiological processes described above. According to Sala [11] the adverse effects of drought on a tree's carbon balance typically become evident only after carbon reserves begin to decline. This effect is particularly pronounced when drought responses are constrained more by water transport and accessibility than by carbon availability. As a result, summer droughts can substantially deplete carbon reserves, potentially influencing frost resistance in the subsequent winter [12,13]. Raise in atmospheric CO<sub>2</sub> concentration generally enhances photosynthesis and biomass production in many plant species, particularly in those using the C<sub>3</sub> photosynthetic pathway, as increased CO<sub>2</sub> improves carbon fixation efficiency by reducing photorespiration. Elevated CO<sub>2</sub> also influences stomatal conductance and water-use efficiency, affecting the overall physiological performance of both C<sub>3</sub> and C<sub>4</sub> plants under varying environmental conditions [14].

Over the past few decades, there has been growing concern about the impact of environmental factors on plant growth, driven by climate change and intensified human activities that degrade soil, water, and air quality [15]. Recent research suggests that fluctuations in temperature and humidity can strongly influence plant metabolic processes, altering photosynthesis rates and affecting plants' resilience to other environmental stresses [16]. Moreover, environmental pollution—such as soil contamination from heavy metals or air pollution from toxic chemicals—poses significant threats to plant health and development [17]. Beyond species-specific responses, broader ecological studies have revealed that anthropogenic impacts — including land use change, deforestation, and agricultural pressure — strongly affect arid and semi-arid forest landscapes in Azerbaijan, altering habitat structure, resource availability, and overall ecosystem health [18]. Together, these findings support the need for comprehensive studies on how introduced phanerophytes respond to multiple environmental drivers, both natural and human-mediated, in *ex situ* conditions to inform conservation and management strategies

Plants respond to temperature fluctuations through various adaptive strategies. One key mechanism is the production of heat shock proteins (HSPs), which help protect cells from thermal damage. Additionally, plants adjust the lipid composition of their cell membranes to preserve cellular stability and maintain normal physiological functions during temperature stress. According to Johnson and Wang [19] while moderate temperature changes influence photosynthesis rates, extreme temperatures can induce heat stress. Similarly, Lee and Kim [17]. reported that low temperatures can hinder plant physiological processes, slowing growth and limiting water uptake.

Light intensity is a crucial factor for photosynthesis, as it directly affects chlorophyll production and the efficiency of light utilization. High light intensity can enhance energy availability for photosynthetic processes, promoting greater food production. However, excessive light can damage chlorophyll and trigger the production of reactive oxygen species (ROS), leading to oxidative stress within plant cells [16].

Conversely, insufficient light restricts plant growth by limiting energy production, reducing photosynthetic efficiency, and slowing metabolic activity, which ultimately inhibits development [19,20].

Atmospheric carbon dioxide (CO<sub>2</sub>) levels play a crucial role in plant growth and photosynthesis. Elevated CO<sub>2</sub> concentrations can boost photosynthetic rates and enhance carbohydrate production. This effect is particularly pronounced in C3 crops, such as wheat and rice, because these plants rely heavily on CO<sub>2</sub> for photosynthesis, leading to accelerated growth [14].

In contrast, C4 plants like maize exhibit less pronounced responses, as their photosynthetic systems are already highly efficient, allowing them to maintain strong growth even under lower CO<sub>2</sub> levels. As CO<sub>2</sub> levels rise, plants often enhance their uptake capacity by increasing stomatal openings in leaves, which facilitates greater carbohydrate synthesis. Additionally, structural adjustments in leaves, such as changes in shape and size, can expand the surface area for CO<sub>2</sub> absorption, further optimizing photosynthetic efficiency [16].

Plants exhibit a variety of adaptations that enable them to cope with environmental changes and sustain their growth and survival across diverse conditions. These adaptations include both physiological and anatomical mechanisms that enhance a plant's ability to withstand stressors such as drought, extreme temperatures, or variations in light intensity [21,22].

## 2 Materials and methods

The study was conducted on 362 species of trees and shrubs introduced in the Absheron greenery system under *ex situ* conditions. The research applied well-established methodologies developed by Ahmatov [23], Bazilevskaya [24], Beideman [25], Henkel [26], Kurbanov [27], Molchanov [28], Semyonova [29], and Zaitsev [30],

Compared with contemporary research practices, these classical methods remain fundamental but are now complemented by modern technologies such as remote sensing, chlorophyll fluorescence imaging, infrared thermography, and GIS-based ecological modeling. The combination of these traditional and advanced approaches provides a comprehensive and precise framework for assessing the adaptability and resilience of introduced phanerophytes to the climatic conditions of the Absheron Peninsula.

## 3 Results and discussions

Light is one of the most essential environmental factors influencing plant growth, morphology, and physiological processes. Approximately 50% of the total solar radiation reaching the Earth's surface is in the visible spectrum, which plays a decisive role in photosynthesis and other photobiological processes [31,32]. During nighttime, the primary light sources are the moon and stars; however, their longer wavelengths and lower intensity make their ecological significance minimal compared with sunlight. The infrared portion of solar radiation, although chemically inactive, contributes to heat

transfer within plant tissues and the surrounding environment, thus influencing microclimatic conditions [32].

Light directly affects fundamental plant functions such as seed germination, stem elongation, and leaf morphogenesis [33]. Ultraviolet rays, in particular, have significant roles in pigment synthesis, such as the formation of anthocyanins in higher plants, and they influence phototropic and hormonal regulation processes that modulate plant growth and development [34,35].

Visible light is vital for photosynthesis and the formation of plant cover. Leaves typically absorb only about 10% of incident light, with much of the remainder either reflected or transmitted through the canopy [36]. The spectral composition of transmitted light varies depending on vegetation type. In coniferous forests, the spectral quality of light remains relatively stable, whereas in deciduous forests, red wavelengths predominate while violet and blue components diminish during the growing season [36]. This variation affects the stratification of light within plant communities, creating ecological niches for species with different light requirements.

Species such as *Tilia caucasica* Rupr., *Quercus castaneifolia* C.A. Mey., *Platanus orientalis* L., and *Zelkova carpinifolia* (Pall.) C. Koch, as well as xerophytic taxa including *Celtis caucasica* Willd., *Celtis australis* L., and *Pyracantha coccinea* Roem., are identified as highly light-demanding plants. Field observations revealed that when these species are cultivated in shaded conditions, their growth and developmental rates significantly decline due to insufficient light absorption [1].

Moreover, light availability within a plant community affects not only plant physiology but also broader ecological parameters such as soil moisture, temperature, and wind circulation. A reduction in light penetration below the vegetation canopy—particularly when light availability falls below 20%—can markedly alter the microclimate and inhibit the development of autotrophic understory plants [32,2]. Therefore, the assessment of light influence should not be considered in isolation, as its interaction with other abiotic factors determines the overall ecological stability and productivity of plant ecosystems [27,37].

In a study conducted by Goodfellow and Barkham [36] it was observed that in *Fagus sylvatica* L. forests, as the canopy becomes thinner and growth progresses, the proportion of blue light waves within the internal forest light spectrum increases, while on cloudy days a decline in blue wavelengths occurs. In areas with dense vegetation cover, the spectral changes are predominantly expressed through the intensification of infrared radiation. This phenomenon is more pronounced in deciduous forests than in coniferous ones and varies seasonally according to vegetation dynamics .

Light profoundly influences plant life by regulating physiological processes, growth patterns, and ecological interactions. Among its most vital functions is its role in photosynthesis, the primary mechanism for energy conversion in plants [32]. Based on light preference, plants are classified into two principal ecological groups—heliophytes (light-loving species) and sciophytes (shade-tolerant species). Each of these groups is

further divided into *facultative* and *obligatory* types. The present study revealed that among the examined plant species, 311 were heliophytes and 51 were sciophytes (Figure 1).

Observations indicated that under varying light conditions, plants display distinct adaptive responses. Light-loving species cultivated in shaded environments often develop morphological and physiological traits typical of shade-tolerant plants, demonstrating ecological plasticity. For instance, *Buxus hyrcana* Pojark. is capable of growing in both sunny and shaded habitats due to its flexible adaptation mechanisms [32,37].

Heliophytes exhibit structural adaptations that enable them to withstand intense light, such as thickened stems, small simple leaves, and dense branching, which reduce excessive transpiration and maximize light use efficiency. These species typically display vigorous flowering and fruiting, delayed leaf fall, and early blooming. They are also more resistant to drought and heat stress. Representative examples include *Pinus* L., *Crataegus* L., *Celtis caucasica* Willd., *Acer velutinum* Boiss., *A. ibericum* M. Bieb., *Juniperus foetidissima* Willd., *Pistacia mutica* Fich. et Mey., *Pyrus salicifolia* Pall., *Quercus iberica* Stev., and *Rhus coriaria* L. [1,34].

In contrast, sciophytes, characterized by low photosynthetic light compensation points, are sensitive to high light intensities due to the absence of photoprotective adaptations. In mixed plant communities, light availability influences leaf arrangement and canopy stratification, which are critical for maintaining ecological balance, particularly in moist habitats [32,37]. Moreover, photoperiodism—specifically the ratio of day to night length—affects key phenological processes such as leaf fall, sprouting, flowering, pigment formation, and fruiting [32]. Consequently, plants are categorized as short-day or long-day species, each adapted to the photic conditions of their native regions. The findings of this research confirm that the studied species in the Absheron Peninsula are ecologically differentiated into two main light preference groups: heliophytes and sciophytes (Fig. 1).

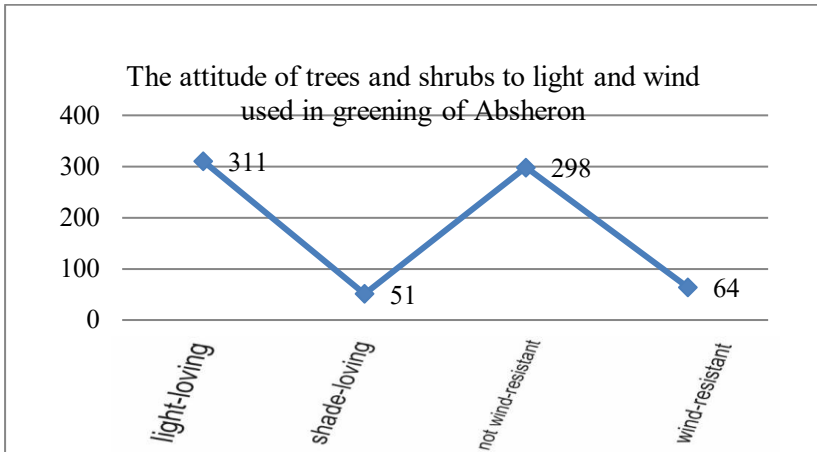


Fig. 1. Light and wind adaptation characteristics of the studied plant species

Field observations revealed that shade conditions significantly influence the growth and morphology of several studied species, including *Acer campestre* L., *Acer platanoides* L., *Acer tataricum* L., *Buxus hyrcana* Pojark., *Camellia japonica* L., *Corylus colurna* L., *Danae racemosa* (L.) Moench., *Albizia julibrissin* Durazz., and *Diospyros lotus* L. Under insufficient light, these plants exhibited weakened development, reduced flowering intensity, increased branching, and leaf thinning, indicating physiological stress and morphological adaptation to low-light environments [32]. Such changes suggest that while some species possess limited shade tolerance, prolonged light deficiency negatively affects their reproductive and vegetative functions.

Given that the Absheron Peninsula experiences strong and persistent winds throughout the year, assessing wind resistance in plants was essential. The study identified 64 species as highly wind-resistant, while the remaining 298 species exhibited varying degrees of mechanical deformation and morphological damage under wind exposure [27]. Wind-tolerant species typically develop flexible stems, reduced leaf surfaces, and strengthened root systems, which mitigate the effects of continuous air movement.

Another major environmental factor influencing plant adaptation in the region is temperature. Solar radiation absorbed by the Earth's surface is converted into heat, creating a thermal gradient in which the air near the ground is warmer than the upper layers [11]. The climatic conditions of the Absheron Peninsula are shaped by its subtropical location, proximity to the Caspian Sea, and the moderating influence of the Greater Caucasus Range. Summers are generally hot and dry, although strong northern winds can occasionally reduce extreme heat.

Soil characteristics also play a crucial role in temperature dynamics. Light-colored soils reflect sunlight, leading to cooler surface temperatures, whereas dark soils rich in organic matter and vegetation absorb more heat, creating warmer microclimates [34]. To

examine the effects of temperature on plant growth, a controlled experiment was conducted in July on 56 woody species used in the region's greening efforts (Table 1). Results indicated that the highest temperature values were consistently recorded near the soil surface between at 1-2 pm, emphasizing the critical role of near-ground heat accumulation in influencing plant physiological processes and overall microclimate formation [32,27].

**Table 1.** Diurnal Temperature Fluctuations and Heat Resistance Patterns in Selected Woody Plant Species Used for the Greening of the Absheron Peninsula (July 2017)

№	Species	Height Above Ground Surface (Trunk Measurement Point)		
		Temperature (C <sup>0</sup> )		
		0	Average (C <sup>0</sup> )	Canopy (C <sup>0</sup> )
1	2	3	4	5
1.	<i>Albizia julibrissin</i> Durazz.	31,0±1,5	27,0±1,3	24,0±1,2
2.	<i>Acer platanoides</i> L.	30,0±1,5	26,0±1,3	24,0±1,2
3.	<i>Buxus hyrcana</i> Pojark.	26,0±1,3	23,0±1,1	22,0±1,1
4.	<i>Buxus colchica</i> Pojark.	27,0±1,3	24,0±1,1	23,0±1,1
5.	<i>Buxus microphylla</i> Sieb.	28,0±1,3	24,0±1,1	23,0±1,1
6.	<i>Celtis caucasica</i> Willd.	32,0±1,6	26,0±1,3	24,0±1,2
7.	<i>Celtis australis</i> L.	31,0±1,5	26,0±1,3	24,0±1,2
8.	<i>Colutea cilicica</i> Boiss. ef Bal.	31,0±1,5	26,0±1,3	24,0±1,2
9.	<i>Colutea orientalis</i> Mill.	30,0±1,5	27,0±1,3	25,0±1,2
10.	<i>Colutea arborescens</i> L.	30,0±1,5	27,0±1,3	25,0±1,2
11.	<i>Cotoneaster lucidus</i> Schltld.	26,0±1,3	25,0±1,2	24,0±1,2
12.	<i>Cotoneaster horizontalis</i> Decne.	26,0±1,3	25,0±1,2	24,0±1,1
13.	<i>Cotoneaster serotinus</i> Hutch.	25,0±1,2	24,0±1,2	23,0±1,1
14.	<i>Cotoneaster melanocarpus</i> Load.	26,0±1,3	25,0±1,2	24,0±1,1
15.	<i>Diospyros lotus</i> L.	29,0±1,4	27,0±1,3	25,0±1,2
16.	<i>Diospyros kaki</i> L.	28,0±1,4	26,0±1,3	26,0±1,3
17.	<i>Euonymus japonicus</i> Tunb.	30,0±1,5	27,0±1,3	25,0±1,2
18.	<i>Euonymus europaea</i> L.	31,0±1,5	30,0±1,5	26,0±1,3
19.	<i>Euonymus latifolia</i> (L.) Mill.	31,0±1,5	30,0±1,5	26,0±1,3
20.	<i>Ficus hyrcana</i> A. Grossh.	30,0±1,5	27,0±1,3	25,0±1,2
21.	<i>Gleditsia triacanthos</i> L.	30,0±1,5	27,0±1,3	24,0±1,2
22.	<i>Ilex aquifolium</i> L.	26,0±1,3	23,0±1,1	22,0±1,1
23.	<i>Laurus nobilis</i> L.	27,0±1,3	22,0±1,1	21,0±1,1
24.	<i>Ligustrum japonicum</i> Thunb.	26,0±1,3	22,0±1,1	21,0±1,1
25.	<i>Ligustrum ibota</i> Sieb.	27,0±1,3	22,0±1,1	21,0±1,1
26.	<i>Ligustrum lucidum</i> Ait.	26,0±1,3	23,0±1,1	22,0±1,1
27.	<i>Ligustrum vulgare</i> L.	32,0±1,6	29,0±1,4	27,0±1,3
28.	<i>Padus mahaleb</i> Borkh.	31,0±1,6	28,0±1,4	26,0±1,3
29.	<i>Parrotia persica</i> (DC.) C.A.	27,0±1,3	26,0±1,3	24,0±1,2

	Mey.			
30.	<i>Paulownia tomentosa</i> Stendel.	30,0±1,5	23,0±1,2	21,0±1,1
31.	<i>Platanus orientalis</i> L.	31,0±1,5	24,0±1,2	22,0±1,1
32.	<i>Platanus occidentalis</i> L.	31,0±1,5	23,0±1,2	22,0±1,1
33.	<i>Persica vulgaris</i> Mill.	33,0±1,6	27,0±1,3	24,0±1,2
34.	<i>Pistacia mutica</i> Fich.et Mey.	32,0±1,6	29,0±1,4	26,0±1,3
35.	<i>Pistacia vera</i> L.	31,0±1,6	28,0±1,4	25,0±1,2
36.	<i>Populus hyrcana</i> Grossh.	31,0±1,5	28,0±1,4	25,0±1,2
37.	<i>Populus euphratica</i> Olivier.	32,0±1,5	29,0±1,4	26,0±1,2
38.	<i>Populus hybrida</i> M.B.	30,0±1,5	27,0±1,3	24,0±1,2
39.	<i>Pyracantha coccinea</i> Roem.	31,0±1,5	26,0±1,3	23,0±1,1
40.	<i>Pyracantha angustifolia</i> Franch.	32,0±1,5	27,0±1,3	23,0±1,1
41.	<i>Pyrus caucasica</i> Fed.	32,0±1,6	26,0±1,3	24,0±1,2
42.	<i>Pyrus communis</i> L.	32,0±1,6	27,0±1,3	25,0±1,2
43.	<i>Pyrus salicifolia</i> Pall.	33,0±1,6	29,0±1,4	27,0±1,3
44.	<i>Quercus iberica</i> Stev.	30,0±1,5	27,0±1,3	24,0±1,2
45.	<i>Quercus ilex</i> L.	30,0±1,5	28,0±1,4	25,0±1,2
46.	<i>Quercus macranthera</i> Fisch. M.	30,0±1,5	27,0±1,3	24,0±1,2
47.	<i>Quercus castaneifolia</i> C.A.Mey.	31,0±1,5	28,0±1,4	25,0±1,2
48.	<i>Robinia pseudoacacia</i> L.	32,0±1,6	28,0±1,4	25,0±1,2
49.	<i>Robinia hispida</i> L.	32,0±1,6	27,0±1,4	26,0±1,3
50.	<i>Rosa canina</i> L.	33,0±1,6	28,0±1,4	26,0±1,3
51.	<i>Rosa damascena</i> Mill.	33,0±1,6	29,0±1,4	26,0±1,3
52.	<i>Salix caucasica</i> Anderss.	32,0±1,6	27,0±1,4	26,0±1,3
53.	<i>Salix babylonica</i> L.	32,0±1,6	26,0±1,3	25,0±1,2
54.	<i>Tilia caucasica</i> Rupr.	32,0±1,5	29,0±1,4	26,0±1,2
55.	<i>Ulmus minor</i> Mill.	31,0±1,5	28,0±1,4	25,0±1,2
56.	<i>Zelkova carpinifolia</i> (Pall.) K.Koch.	32,0±1,6	28,0±1,4	26,0±1,3

Observations indicated a decline in temperature with increasing distance from the soil surface. Depending on the species, temperatures near the soil surface ranged from 25–33°C during the measurement period (Table 1). The temperature measured at the crown of the plants was 5–9°C lower than at the soil surface, depending on the species [23,32,27].

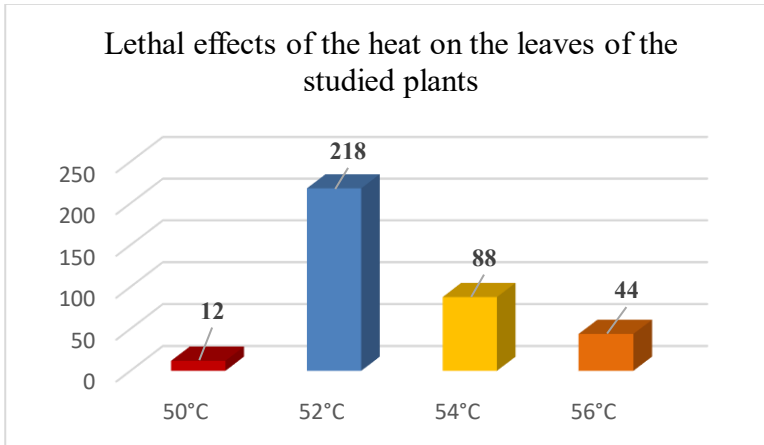
Analysis revealed that prolonged high temperatures during hot summer days inhibited growth in several studied species and caused leaf scorching. Extended periods of heat combined with drought resulted in protein degradation in plant tissues. Consequently, accumulation of ammonia disrupted cellular structures, leading to plant mortality [23,32,27].

The Absheron Peninsula is characterized by dry summers, with annual precipitation ranging between 250–350 mm and evaporation reaching 1000–1200 mm. Adaptation of plants to these climatic factors is therefore critical. Plants introduced to Absheron

during hot, dry months face significant water stress. Observations showed leaf yellowing and abscission in some species under these conditions, including *Parrotia persica*, *Populus hyrcana*, *Platanus orientalis*, *Euonymus latifolia*, *Albizia julibrissin*, and *Acer platanoides* [32,27].

Growth in these species was temporarily halted due to elevated temperatures and drought. Later, as temperatures decreased, delayed leaf emergence occurred. Leaf scorching was observed in some rare species (*Acer platanoides*, *Diospyros lotus*, *Euonymus latifolia*, etc.), originating from the leaf margins and progressing toward the center, eventually covering the entire lamina before abscission. Leaf burn occurred at temperatures of 35–40°C in July 2017 [23,27].

To evaluate the heat resistance of 362 studied species, thermos containers were employed according to Ahmatov's method [1] (Diagram 1). This approach allowed accurate measurement of species-specific responses to extreme heat conditions in the Absheron region.



**Diagram 1.** Heat-Induced Leaf Damage in Studied Plant Species

## 4 Conclusion

The experimental results allowed the classification of the studied plant species according to their leaf heat resistance into three categories:

1. Highly heat-resistant species (54–56°C): *Cryptomeria japonica*, *Picea excelsa*, *Juniperus foetidissima*, *Amorpha californica*, *Colutea caucasica*, *Morus alba*, *Olea europaea*, *Danaea racemosa*, *Buxus colchica*, *Buxus hyrcana*, *Ficus hyrcana*, *Pistacia mutica*, *Pistacia vera*, *Pyracantha coccinea*, *Populus euphratica*, *Ruscus hyrcana*, *Ulmus laevis*, *Zelkova carpinifolia*;
2. Moderately heat-resistant species (52°C): *Abelia grandiflora*, *Acacia*

*dealbata*, *Acer ibericum*, *Acer platanoides*, *Corylus colurna*, *Celtis caucasica*, *Diospyros lotus*, *Gleditsia triacanthos*, *Laurocerasus officinalis*, *Parrotia persica*, *Platanus orientalis*, *Pyrus caucasica*, *Pyrus salicifolia*, *Quercus castaneifolia*, *Quercus iberica*, *Quercus pontica*, among others;

3. Low heat-resistant species (48–50°C): *Albizia julibrissin*, *Caesalpinia gilliesii*, *Cornus mas*, *Hedera helix*, *Hedera pastuchowii*, *Liriodendron tulipifera*, *Ligustrina amurensis*, among others.

These findings indicate that the leaves of the studied species experience thermal stress within the range of 48–56°C. Furthermore, the analysis demonstrates that leaf heat resistance is closely associated with the intrinsic biological characteristics of each species. Consequently, the studied plants exhibit variable tolerance to heat and drought, which is critical for their growth and survival under cultural or controlled conditions.

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#### **Disclosure of Interests.**

The authors declare that they have no competing interests that could have influenced the work reported in this manuscript. This includes personal or professional relationships that could be perceived as having affected the research, analysis, or interpretation of data.

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