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STRUCTURAL AND FUNCTIONAL VARIABILITY OF HOLM OAK (*QUERCUS ILEX* L.) IN DIFFERENT CONDITIONS OF WATER AVAILABILITY

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We must protect existing forests and take the necessary measures for afforestation for fight with global warming. That is why in this abstract we studied the variation of morphological and physiological parameters and adaptation ability of the holm oak species (*Quercus ilex* L.) in different ecological conditions, which introduced to Azerbaijan. Our goal is to determine the feasibility of introducing holm oak to the natural flora of Azerbaijan. Result of morphological polymorphism (CV(LA)=47.29%; CV(F)=38.63%; CV(LL)=24.52%) and indexes of foliar moisture (RWC=89.34±2.90%; LMA=11.74±1.34 mg cm^2 (in Shaki); RWC=71.34±2.92%; LMA=9.23±0.97 mg cm^2) allows us to say that it is possible to transfer holm oak to natural areas. In our study, holm oak showed tolerance to the drought of Baku, and cold weather of Sheki. These suggest that holm oak can be successfully used in afforestation and transferred to the natural flora in any region of Azerbaijan, including the Nakhchivan Autonomous Republic, which has extremely hot summers and extremely cold winters.

Keywords: *Q. ilex*, polymorphism, ANOVA, adaptation, RWC

Forests protect water supplies and soil. They regulate climate by increasing air humidity and decreasing the intensity of droughts, constitute a barrier against soil erosion (Matías, Jump, 2014). Forests are also very important for atmospheric carbon sequestration with their extraordinary biomass production capacity (Tsoumou et al., 2016). In regions, tree growth is limited by the amount of water available in the soil.

A decrease in the amount of available water in the soil causes a decrease in carbon assimilation (Limousin, 2009).

Oaks (*Quercus*) are a diverse group of trees and shrubs that have adapted to a wide range of climates throughout their evolutionary history (Cavender-Bares, 2018; Sork et al., 2022). The ability of oaks to adapt to climate may contribute to the high species richness and wide distribution of oaks across the northern hemisphere. If adaptation to a given condition is able to evolve in multiple ways – either through multiple different phenotypes, or the same phenotype accomplished through different mechanisms – beneficial standing genetic variation is likely to be present in populations, which would facilitate adaptation to new environmental conditions (Mead, 2023). Since phenotypic plasticity influences environmental tolerance, different plastic responses may contribute to differences in the range of environments that species inhabit (Ackerly et al., 2000). In particular, the environment can induce changes in the individual's behavior at a morphological and/or physiological level (Price et al., 2003) and such changes may be crucial to survival in heterogeneous and variable conditions (Zunzunegui, 2011). The leaf morphological traits of many species vary with elevation (Cordell et al., 1998; Bresson et al., 2011; Guerin et al., 2012). Those variations are mainly shaped by fluctuations in environmental factors (Yin et al., 2004; Wang et al., 2014). For example, the lower temperatures found at higher elevations can restrict the extension of leaves and reduce their size (Magnani, Borghetti, 1995). Stronger solar radiation at higher elevations may lead to lower leaf dry matter, smaller overall sizes, and shorter petioles (Niinemets et al., 2004; Pan et al., 2009). Under drought conditions, plants commonly produce smaller leaves and have a thinner vapor boundary layer so that evaporative water losses are decreased (Nicotra et al., 2008).

Oaks made up a major part of forests of Azerbaijan. There are seven oak species in Azerbaijan flora. Holm oak was introduced to Azerbaijan in 1880. Currently available in some parks and gardens. There are no natural populations of holm oak in Azerbaijan. In this study, we analyzed the leaf morphological polymorphism and variations of foliar moisture in Holm oak trees to determine adaptation ability in different ecological conditions.

MATERİAL AND METODS

This study was carried out on Holm oak. The comparison of holm oak trees at different bioclimatic zones was carried out in two ecologically different stations: Mardakan Arboretum (Baku) and Shaki Park

(Shaki region). About geographical condition, altitude, mean annual precipitation, mean annual temperature of study area areas were given in table 1. The City of Winds is an unofficial, literary name for Baku, mainly because it is windy throughout most of the year. The average annual wind speed in Absheron is 8.6 m/s. The soil cover is represented by various soil combinations, 80-85% of the Mardakan Arboretum is covered with limestone. The soils of the study area in Shaki were natural brown and gray anthropogenic chernozems. (Museibov, 1998; Mammadov et al., 2010). It is located in the southern part of the Greater Caucasus mountain range, 240 km from Baku.

Ten leaf samples per tree were collected from 20 trees for studing morphological pholymorphism. A total of 200 leaves (ten leaves per tree) were morphometrically measured by CI-202 LESER AREA METER, USA (Jensen, 1990; Viscosi, Cardini, 2011). Sampling was done at midday and only mature leaves were considered. The following parameters were examined: some morphometric traits (leaf area (LA), leaf length (LL), leaf width (LW), leaf perimeter (LP), the ratio of leaf length to width (LL/LW) and shape factor (F)).

Table 1. Geographic location and climate conditions of the sampled populations of *Q. ilex*

Locality	Geographic coordinates	Altitude (m)	Pa (mm)	T (°C)
Baku	40°23'43''N 49°52'56"E	-28	247	14.4
Shaki	41̊ 11′31″ N 47̊ 10′14″ E	636	692	12.5

Note: Pa: mean annual precipitation (mm), T: mean annual temperature (°C) (1,10).

The sclerophylly indices were calculated after certain measurements on the leaves with the accuracy of 0.1 mg using EK-610i electronic scales: leaf mass per area (LMA=DW/LA (mg cm^{-2})), fresh weight (FW); fresh weight at full turgor (saturated weight=SW, after immersion of leaf petioles in demineralized water for 24 h in the dark); dry weight (DW, after drying in an oven at 70 °C for 72 h.). Then foliar moisture parameters were calculated (Filippo et al., 2002):

Water Content (WC; %)=[1− (DW/FW)]100%;

Relative Water Content (RWC;%)=[(FW−DW)/(SW−DW)]100%;

Succulence: (S mg, cm^{-2})=(FW−DW)/LA.

The variation of morphological traits was performed by Randomized Complete Block Design (RCBD) method. The value of the variance coefficient of all morphological traits, which we get using RCBD method, represents the high reliability of the variance analysis. In turn, this result was the beginning of the performance of other statistical analyses based on studied parameters. Thus, if there is no significance difference of any trait during ANOVA, it means that statistical analysis for this trait discontinues. Least Significant Difference (ANOVA–LSD) test was used to compare the mean traits. All statistical analyses were conducted using the program Statistical Product and Service Solutions16 (SPSS 16).

RESULTS AND DİSCUSSİON

Leaf morphological traits varied noticeably among 2 study areas (table 2). Among the six traits investigated here, leaf area (LA) showed the widest variability, ranging from 28.97 cm^2 to 48.94 cm^2, and having the maximum coefficient of variation (CV=47.29%) (table 3). High variation of leaf area among the morphological parameters indicator species adaptation ability (Sun et al., 2016) .By contrast, the ratio of leaf length to width (LL/LW) varied the least (CV=11.69%), with a range of 2.66 to 3.65 (table 2). The leaf length (CV=24.52 %) and the leaf parameter (CV=19.26 %) among the populations differed on average. Only the leaf width parameter presented last in table 2 did not differ significantly among the study areas (CV= 15.60%). Morphological parameters of Holm oak leaves got decreased by effect of high temperature and low precipitation in Baku (LA=38.05±1.35cm^2). The largest leaves were observed in Sheki Park (LA=44.79±1.29 cm^2).

We found that leaf morphological traits of *Q. ilex* varied significantly across our 2 study areas (table 2). This indicated that those traits had significantly adaptive plasticity under different environmental conditions (Abrams, 1990). There are significant ecological differences in the study areas, so significant differences have been observed in vegetation cover. These could potentially facilitate the high adaptive ability of *Q. ilex* in small precipitation, strong wind and high temperature in summer, even so severe frost in winter.

Table 2. Variation of morphological parameters of the *Q. ilex* leaf (leaf area (LA), leaf length (LL), leaf width (LW), Perimeter (P) the ratio of leaf length to width (R), and shape factor (F)) in different environmental conditions

Traits / Populations	LA (cm^2)	LL (cm)	LW (cm)	P (cm)	R	F
Mardakan Arboretum	38.05±1.35	3.52±0.56	2.44±0.11	152.32±2.03	3.8±0.18	0.01±0.001
Shaki Park	44.79±1.29	4.07±0.81	4.61±0.23	161.11±3.43	3.14±0.20	0.03±0.001

As seen in table 4, the lowest values of the physiological parameters – foliar moisture indices (LMA=9.23±0.97 mg cm^2; WC=65.27±2.17%; RWC=71.34±2.92%; S=3.67±0.09 mg cm^2) and the lowest leaf area (LA=38.05±1.35cm) (table 2) were found in the Mardakan Arboretum. Trees with low LA can reduce the excessive loss of water by evaporation and make water use more efficient, generating an important mechanism to address the scarcity of water resources. The smallest value of leaf mass per area, and the relative water content indicators of drought stress factor.

Table 3. Statistical parameters for the studied traits in *Q. ilex,* Anova-test

Traits / Statistic indicators	Area (cm^2)	Length (cm)	Width (cm)	Perimeter (cm)	Ratio	Factor
Min	28.97	2.97	1.83	95.87	2.66	0.01
Max	48.94	5.52	4.59	164.44	3.65	0.03
Average rate	41.05	3.69	3.31	131.16	3.04	0.02
Standard error	±1.48	±0.62	±0.12	±2.54	±0.21	±0.001
Variation	174.15	2.24	1.07	220.10	5.43	0.0002
Standard discriminant	9.23	1.20	9.10	10.42	1.51	0.015
Median	45.45	12.27	6.47	134.38	1.05	0.032
CV (%)	47.29	24.52	15.60	19.26	11.69	38.63

Physiological parameters of oak leaves are showed higher values in Shaki region than Baku. In Shaki region the value of RWC in oak leaves were less than 90% indicate low drought stress (table 4). Generally, high RWC in plants helps regulate cellular turgidity and osmotic potential (Mukherjee, Agrawal, 2018).

Table 4. Variation of physiological parameters of the *Q. ilex* leaf (leaf mass per area: LMA: water content: WC: relative water content: RWC, and succulence: S) in different environmental conditions

Locality	LMA (mg cm^2)	WC (%)	RWC (%)	S mg cm^2
Mardakan Arboretum	9.23±0.97	65.27±2.17	71.34±2.92	3.67±0.09
Shaki Park	11.74±1.34	78.33±2.65	89.34±2.90	5.56±1.23

Abiotic conditions are the major factors that shape plant traits in different environmental conditions (Guerin et al., 2012) also implied that water is a key determinant of leaf size, whereas temperature is relatively less critical. Because precipitation influences water availability, one might expect that plants at higher elevations would experience more drought stress. Although MAP is less in Mar-dakan, the irrigation conditions eliminated this difference and RWC higher than 50%. These show that holm oak has a high adaptive potential and can change the morphometric and physiological parameters of the leaves according to environmental conditions. Therefore, these trees can be successfully used for landscaping parks.

CONCLUSION

We observed high morphological and physiological variations in the trees for adaptation to different ecological conditions. It has been documented that the leaf morphological variability of species is related to environmental factors identified a strong relationship between morphological features and environmental factors (mainly water availability). In our study, holm oak showed tolerance to the drought of Baku, and cold weather of Sheki. These suggest that holm oak can be successfully used in afforestation and transferred to the natural flora in any region of Azerbaijan, including the Nakhchivan Autonomous Republic, which has extremely hot summers and extremely cold winters.

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