*Baku State University Journal of Life Sciences & Biology **2025**, v.2 (1), p. 1-4*

journal homepage: http://bsuj.bsu.edu.az/en

https://doi.org/10.30546/300045.2025.2.1.2001

FITOINDICATION OF ENVIRONMENTAL QUALITY UTILIZING THE MAPLE SOFTWARE PACKAGE

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Received 02 february 2025; accepted 19 march 2025

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The article presents the results of an environmental quality assessment conducted using the phytoindication method. This approach is based on measuring the bilateral asymmetry of leaves of two oak species: the holm oak and the long-stem oak. A statistical analysis was performed to track changes in the bilateral asymmetry of selected morphometric traits of these oak species' leaves. For each oak species, samples were taken from two different environments that varied in levels of environmental pollution. ANOVA, two-way T-test and χ^2 test were performed separately in the MAPLE software package for each environment. We built a regression model for both plants in both environments to determine how the bilateral asymmetry depends on the leave length. It was observed how the tendency coefficients there changed depending on the environment.

Keywords: *phytoindication, bilateral asymmetry, MAPLE software package, χ^2 test, ANOVA test, two-way T-test*

1. Introduction

Recently, the quality of the natural environment has deteriorated both nationally and internationally, making environmental monitoring essential. The purpose of environmental monitoring is to provide information for environ- mental management. Biological monitoring, along with other methods, is widely used to assess and forecast the ecological state of the natural environment. It is considered one of the most reliable methods, as bioindicators are natural indicators that have adapted to specific conditions of the environment over long periods of evolutionary development [1, 2].

Modification variability and the ability to adapt, ensuring homeostasis of both a specific organism and the population as a whole, is the most important process that ensures the organism's response to changes in environmental factors. The symmetry (asymmetry) phenomenon in living organisms is one of the key characteristics in relationships with environmental factors. The bilateral asymmetry is recommended to be

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used as indicator of deviation of ecological conditions from optimal values [3].

Plants play a crucial role in the ecosystem. Due to their sensitivity to various pollutants, they can help determine the level of human impact on the environment and forecast its future state. When changes occur in the natural environment, the bilateral symmetry of plant leaves can be disrupted, resulting in asymmetry [4, 5]. Minor deviations from this bilateral symmetry are known as fluctuating asymmetry. By examining the fluctuating asymmetry of plant leaf structures, we can evaluate the ecological health of an area. This method of assessing environmental quality is currently a priority because it is cost- effective and provides reliable results without requiring significant financial resources for implementation and analysis [6].

One of the actual problems of the practical use of the level of fluctuating asymmetry is the statistical reliability of the results obtained on its basis. This article offers a brief overview of the common indicators and indices of asymmetry currently in use, along with a description of their statistical properties and significance. Statistical tests are analytical tools that help researchers or data scientists evaluate the validity of hypotheses or analysis results on their data. They help determine whether there are relationships or differences between variables or groups in a data population.

2. Materials and methods

The objects of the study were leaves of two species from the genus *Quercus* of the family *Fagaceae*: *Quercus longipes* Stev. (long-stem oak) and *Quercus ilex* L. (holm oak). Both species are known for their resistance to frost, drought, and strong winds, making them robust woody plants. They are commonly used for landscaping in urban areas.

Test sites were chosen in the city of Baku, Azerbaijan. For each of the two species under study, two test sites were selected, varying in their levels of environmental pollution. The pollution degree of atmosphere and soil samples was assessed through analyses conducted in relevant laboratories. Areas identified as ecologically clean are referred to as ecological control sites, while those with higher levels of pollution are referred as ecologically risky sites. Control sites were selected in specially protected areas, and ecologically risky test sites were selected in areas near highways with heavy traffic flow.

The stability of plant development at the selected test sites was assessed using the method of bilateral asymmetry in leaf morphological traits. We measured the length of the main vein and the maximum width of the leaf blade on both the right (R) and left (L) sides of the main vein [3, 4]. These data were statistically analyzed in the MAPLE software package. ANOVA, two-way - T-test, and χ^2 test were used as methods. Regression equations were constructed [7, 8, 9, 10].

3. Results and discussion

The results of computer processing of the measured studied leaf traits showed that in both studied oak species, under conditions of environmental risk, the asymmetry of the studied bilaterally symmetrical morphological traits of the leaves increases. The indicator of bilateral asymmetry in the sample of holm oak leaves from the ecologically risky site increased 2.00 times**.** And in the leaf sample of the long-stem oak**,** from the zone of ecological risk, this indicator increases by 2.87 times, compared to the ecological control zone [Table 1 (a) and (b)]**.** This shows that the stability of the development of holm oak is higher than that of long-stem oak**.**

To assess the statistical reliability of the obtained results, a two-way T- test was conducted in two different environments to evaluate the average value of bilateral asymmetry (Δd) in the leaves of both studied oak species. The data was loaded into the MAPLE software package for analysis. Our dataset shows no relationship between environments, and the parameter is not normally distributed. However, with a sample size greater than 124, the results are valid, and all conditions for the t-test are met [Table 1 (a) and (b)].

Table 1 (a). Results of the analysis of the indices of bilateral asymmetry based on a two-way T-test for

Quercus longipes Stev

Standard T-Test on two Samples (Unequal Variances)					
Null Hypothesis: Alternative Hypothesis:		Sample drawn from populations with difference of means equal to 0 Sample drawn from populations with difference of means equal to 0			
	Sample Size	Sample Mean	Sample Standard Deviation	Difference in Means	
Sample 1 Sample 2	150 150	0.494000 0.172000	0.399199 0.148875	0.322000	
Distribution		Computed Statistic	Computed p value	-Confidence Interval	
Student T (189.659368281145589)		9.25625	4.55946×10^{-17}	0.253380..0.390620	
	Result		**Rejected**: This statistical test provides evidence that the null hypothesis is false		

Note: sample 1- ecological control site; sample 2- ecologically risky site

Table 1 (b). Results of the analysis of the indices of bilateral asymmetry based on a two-way T-test for *Quercus ilex* L. (b)

Standard T-Test on two Samples (Unequal Variances)				
Null Hypothesis: Alternative Hypothesis:		Sample drawn from populations with difference of means equal to 0 Sample drawn from populations with difference of means equal to 0		
	Sample Size	Sample Mean	Sample Standard Deviation	Difference in Means
Sample 1 Sample 2	150 150	0.0826667 0.161538	0.0849371 0.0781418	— 0.0788718
Distribution		Computed Statistic	Computed p-value	Confidence Interval
Student T (276.9940491128847621)		—8.08928	1.89448×10^{-14}	—0.0980656..—0.0596780
Result		**Rejected**: This statistical test provides evidence that the null hypothesis is false		

The results show that the deviation of the mean value of bilateral asymmetry in the sample of leaves of long-stem oak in the ecological control site is 2.7 times lower than that in the ecologically risky site**.** While there is an insignificant deviation from the average value of bilateral asymmetry in the leaves of holm oak, and under conditions of environmental control and risk, it hardly differs. We conclude that although holm oak trees were in different ecological environments, the standard deviation of the average value of Δd is the same in each environment. The ecological state of the environment did not have any effect on the morphological characteristics of the leaves of this tree.

χ^2 test for Δd in control and risky environment for both studied oak species was conducted. In the data we studied, the null hypothesis was rejected, meaning that the values of Δd in the polluted environment are not equally distributed in each interval. This indicator is distributed differently from the continuous one.

Also, it was built a regression model for both plants in both environments to determine how Δd depends on the leaf length. It was obtained that for long- stem oak in a control environment, our regression model is in the form of $4 + 31.07 * \Delta d = \text{length}$. In a risky environment, it is in the form of $3.8 + 13.73 * \Delta d = \text{length}$. From here, it is clear that our slope is quite different in these two environments. For holm oak, our regression model is in the form of $1.5 + 29.36 * \Delta d = \text{length in}$ a clean environment. Our regression model for holm oak is of the form $1.19 + 33.18 * \Delta d = \text{length}$ in a polluted environment. Here the slopes do not change that much.

Based on the ANOVA test it was established that F statics and since df1=1 and DF2=148, we found the p-value using the table, which is 1.11 x 10 $^{-16}$ and this is smaller than 0.05, so the H_0 hypothesis is rejected and it is accepted that the coefficients of at least one explanatory variable in the regression model of Δd of the Long-stem oak tree in a polluted environment are significant. The model is generally suitable.

4. Conclusions

The analysis of long-stem oak and holm oak stability revealed that holm oak is more stable than long-stem oak in varying degrees of environmental pollution. This is confirmed by the results of statistical analysis of the indices of bilateral asymmetry of leaves of the studied oak species. The two-way T-test showed that both oak species are sensitive to the ecological environment. As a result, we get that the values of Δd in both ecological environments are not regularly distributed. But long-stem oak is more sensitive than holm oak. From both the two-way T-test and the χ^2 test, we get that the Δd indicators of the leaves of the holm oak tree do not differ much in environments with various degrees of pollution. That is, the morphological characteristics of the leaves of this tree do not change much depending on the environment in which they are. Based on the data obtained, it can be concluded that the long-stem oak is a reliable bioindicator of environmental quality, and the holm oak, as a stable species, is suitable for landscaping ecologically polluted areas.

References

[1] Mammadova A.O., Mammadova R.N., Ashurova N.D. Ecological assessment of pastures semi-deserts and dry steppes of Azerbaijan // International Journal of Advances in Applied Sciences (IJAAS), 13(2), 2024. P.439-446. http://doi.org/10.11591/ijaas.v13.i2.pp439-446

[2] Mammadova A., Ismayilov N., Mammadova R. The role of systemic bio-diagnostics in stabilizing and improving the ecological state in Azerbaijan within the framework of sustainable development // Baku State University Journal of Life Sciences & Biology, 2024, v.1 (3), p. 1-6.

[3] Mammadova A.O., Mammadova R.N. A study of bioindicative properties of *Quercus castaneifolia* C.A.Mey. in naturaland urbanized sites in Azerbaijan // Bulletin of Nizhnevartovsk State University. - 2019. - N. 2. - P. 71-79. doi:10.36906/2311- 4444/19-2/09

[4] Mammadova R. N., Mammadova A.O. Study of Bio-ecological Indicators of Oak Species in Azerbaijan // Proceedings of the Bulgarian Academy of Sciences. 77, 10 (Oct. 2024), p. 1466–1473. DOI:https://doi.org/10.7546/CRABS.2024.10.06.

[5] Mammadova A., Muhammad Z., Mammadova R. Indicative and remediative properties of *Vicia Faba* L. // Baku State University Journal of Life Sciences & Biology 2024, v.1 (1), p. 3-12

[6] Mammadova A., Farzaliyeva N., Mammadova R. Environmental Assessment of the Tree Plant Leaves According to their Physiological State and Fluctuating Asymmetry Indices of Morphological Features, Which Widely Spread in Baku // Journal of Ecology of Health & Environment. 2017. Vol. 5. P. 19–21. http://dx.doi.org/10.18576/jehe/050103

[7] Tang R., Guo Y., & Tang Z.. Intraspecific variation in leaf morphology of three widespread woody species along climatic gradients. *Journal of Plant Ecology*, 2024. https://doi.org/10.1093/jpe/rtae091

[8] McDonald J. H. (n.d.). Chi-square test of goodness-of-fit. In Handbook of Biological Statistics, from https://www.biostathandbook.com/chigof.html

[9] McDonald J. H. (n.d.). *Two-sample t-test*. In *Handbook of Biological Statistics*, from https://www.biostathandbook.com/twosamplettest.html

[10] Statology. (n.d.). *Choosing the right statistical test: A decision-tree approach*. Statology. from https://www.statology.org/choosing-the-right-statistical-test-a- decision-tree-approach/