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ОЦЕНКА ЗАГРЯЗНЕННОЙ ТРАНСПОРТНОЙ СРЕДЫ ИСПОЛЬЗОВАНИЕМ ДРЕВЕСТНЫХ РАСТЕНИЙ *PINUS ELDARICA* MEDW

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PINUS ELDARICA MEDW. AS INDICATOR OF VEHICULAR POLLUTION

Аннотация. Проведены работы по изучению стабильности развития *Pinus eldarica* Medw. в условиях атмосферного загрязнения автотранспортом. Исследования были выполнены в течение 3 лет (2017–2019 гг.) на территории Апшеронского полуострова. Цель работы − оценка морфофизиологических изменений *Pinus eldarica* Medw. при загрязнении автотранспортом на территории Апшеронского полуострова, выявление биоиндикационных свойств сосны. Основные методы исследования − морфологические, физиологические и статистические. Результатом работы стало получение данных по показателям флуктуирующей асимметрии и наличию некроза *Pinus eldarica* Medw. в районах с различной степенью атмосферного загрязнения. На основе полученных данных проведено экологическое районирование с применением ГИС-технологии и составлена карта экологической оценки автотранспортных территорий. В дальнейшем рекомендуется использовать *Pinus eldarica* Medw. в качестве фитоиндикатора.

Ключевые слова: фитоиоиндикация; флуктуирующая асимметрия; *Pinus eldarica* Medw.

Abstract. This paper presents a study of developmental stability of *Pinus eldarica* Medw. in conditions of airborne traffic pollution. The study has been performed over the period of 3 years (from 2017 to 2019) in the Absheron Peninsula, Azerbaijan. The purpose of the study was to assess the morphophysiological changes in the species *Pinus eldarica* Medw. Exposed to pollution from motor vehicles and thus identify the bioindicator properties of pine trees. The study used morphological, physiological and statistical methods. The indicating data on fluctuating asymmetry and necrosis in *Pinus eldarica* Medw. was obtained in areas with varying degree of atmospheric pollution. Based on these data, ecological zoning was carried out using GIS technologies, and an environmental map of the studied territories was compiled. Species *Pinus eldaric*a Medw. can be used as a phytometer for the purpose of environmental monitoring.

Key words: phytoindication; fluctuating asymmetry; *Pinus eldarica* Medw.

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Introduction

The problem of environmental conservation in densely populated territories is rather urgent due to the inevitably increasing quantity and toxicity of pollutants. The bioindicator method is widely used in practice, and researchers are collecting data on indicator species and evaluate their abilities to respond to pollution and adapt to changing environment [1, 2].

Although publications covering the level of pollution, the state of environment, and the changes in the properties of the environmental media in the Absheron Peninsula are available, research in this area remains relevant [3, 4]. This is due to the obvious relationship between the environment and the public health. The ecological conditions of the territory determine the living conditions and well-being of the population.

The prevailing winds on the Absheron Peninsula blow from the north. The main factors that combine to create the frequency and the high speed of these winds are the prevalence of certain atmospheric processes over the peninsula and the adjacent areas (the Caucasus, the Caspian Sea, Turkey, Iran, Iraq, Central Asia, the Black Sea and the southern part of Europe) and, in particular, the physical geographical features (the presence of the Greater Caucasus Range, the Caspian Sea and, in the south-west, vast lowlands of Azerbaijan).

The frequency of north-east winds in the Absheron Peninsula is insignificant, from 5% to 10% on average for a long-term period. They have been mostly observed in the northwestern part of the Absheron peninsula in the summer [13].

The Absheron Peninsula, with its industrial sites, interconnected highways and high-density traffic, stands out in the Republic of Azerbaijan in terms of environmental stress. Motor vehicles are intensively used in production and agriculture, and this increases the ecological burden every day. Currently, there are studies on the properties of soil and water, vegetation and crops [5–8] and the topic of pollution by emissions from vehicles attracts increasing research interest.

It is known that the operation of motor vehicles and the traffic along the numerous roads of the peninsula contribute to air pollution and accumulation of harmful compounds in the soil. These pollutants include heavy metals that negatively affect the population [9].

This paper aims to assess the morphological changes and physiological disturbances of *Pinus eldarica* Medw. resulting from air pollution by motor vehicles in the Absheron Peninsula. The research focused on determining the biological characteristics of Eldar pine and its bioindicator properties in relation to pollutants from motor vehicles.

The most observable, and widely applied in research, morphogenetic measure of developmental instability is fluctuating asymmetry that indicates an organism's inability to develop according to a precisely defined pattern. Fluctuating asymmetry is manifested in small non-directional deviations from the symmetric state [7].

Materials and Methods

The object of study was *Pinus eldarica* Medw. (Eldar pine) growing along the highways in the Absheron Peninsula, located on the western coast of the Caspian Sea.

The peninsula extends 60 km into the sea and reaches a width of 30 km. The climate is dry subtropical. The average temperature is +3 ℃ in January and +25 ℃ in July. The annual precipitation is from 140 mm in the southwestern part to 250 mm in the northern part. The peninsula has cold winter, mild spring, and hot arid summer.

The factors considered in the research were the traffic congestion in the highways and species composition of woody plants of generative age. The leaves were examined for morphological changes, discoloration and necrosis.

One hundred and fifty pairs of leaves were sampled. The length and weight of the left and right needle in the pairs were measured. To quantify the fluctuation asymmetry, the morphological variance in *Pinus eldarica* Medw. needles was measured, and the degree of developmental stability was examined [8; 11].

The damages in needles were assessed according to Kozlov's scale [7].

Results and Discussion

Eldar pine is an excellent bioindicator. It has the property, like all pine trees, to acquire modified alternations, which can be considered as a mechanism of adaptation to the environment. Fluctuating asymmetry is an easily determined metric exposing a plant's reaction to environmental changes, in particular, to the content of pollutants in atmospheric air [8; 9].

The indicative signs of *Pinus eldarica* Medw. were categorized into two groups. Group I included the differences in size, and Group II, in weight of needles.

Table 1 presents data on the fluctuating asymmetry of paired needles of *Pinus eldarica* Medw. growing along the highways in the Absheron Peninsula.

Table 1

Fluctuating asymmetry *Pinus eldarica* Medw. growing along the highways in the Absheron Peninsula

Station	quantity auto N/1 t	I Indicative signs, x_1±m (mm)	D_1	II Indicative signs, x_2±m_i (mq)	D_2	КАФ	V	Mod	R	E_b
Institute of Dendrology	0	0,28±0.002	0,12	0,26±0,04	0,12	0,034	0,0090	0,1	0,5	100
st. G.Aliyeva	140	0.95±0,003	0.67	0.69±0,003	0.48	0.075	0.0089	0.5	2.9	70.36
st. K.Ragimova	54	0,63$^+$±0,003	0,48	0,56±0,003	0,25	0,070	0,0109	0,2	2,7	80,3
st. F. Khoysky	72	1,03±0,002	0,77	0,99±0,001	0,53	0,113	0,0094	1,0	3,3	67,80
st. J. Safarova	60	0,997±0,003	0,70	0,773±0,004	0,44	0,098	0,0089	0,5	3,1	68,87
st. Matbuat	57	0,996±0,003	0,88	076±0,004	0,77	0,095	0,0095	1,2	4,9	68,85
st. K.Kyazymzade	39	0.791±0,003	0.59	0.61±0,003	0.59	0.070	0.0096	0.2	3.2	75.32
st. Bakikhanova	103	1,22±0,005	0,89	1,009±0,001	0,67	0,075	0,0089	1,0	2,6	61,9
st. M. Abbasova	58	0,91±0,003	0,64	0,77±0,004	0,51	0,077	0,0086	0,5	3,7	71,4
Binagadi highway	95	1,06±0,004	0,79	0,73±0,004	0,47	0,092	0,0087	0,7	3,6	66,9
Baku - Airport	700	1,05±0.004	0,72	0,996±0,001	0,77	0,065	0.0081	0,7	3.4	67,2

$^{+}p<0{,}01$, $p<0{,}001$

As the data in Table 1 suggests, the indicative sign most sensitive to air-born pollution is the bilateral difference in the length of paired needles (X). It is also worthy to note the parameters pointing to the changes in their internal indicators. Despite the absence of more pronounced and regular bilateral difference in the weight of paired needles (M), the obtained data can serve as a phytoindicative sign in a comprehensive assessment of the state of environment. Therefore, the weight of leaves can be used as an additional sign that is informative in combination with other indicators.

Desiccation and necrosis in leaves are observed at minor changes in the composition of atmospheric air and, therefore, can be recognized as a very informative sign for express methods for assessing the state of environment. The number of necrotic zones increases in adverse conditions. As follows from the data in Table 2, desiccation and necrosis in the studied needles were pronounced as much as the signs fluctuating asymmetry. The number of necrotic zones through the full length of the needles increased depending on the degree of pollution along the highways. Qualitative changes in the needles (from small spots to complete drying) were also observed, and in some cases the shape of the needles changed.

The plants with a more pronounced fluctuating asymmetry had thicker needles, often discolored from light to dark brown. The observed necrosis mainly occurs in the period from June to September.

Based on the data obtained in polluted conditions (Table 3), an environmental assessment was carried out. The integral assessment, based on fluctuating asymmetry of morphological characters of leaves, characterizes the state of the environment in ontogenesis, and this technique can be used in an environmental monitoring system.

Table 2

Desiccation and necrosis *Pinus eldarica* Medw.

Station	Desiccation, %					Necrosis, %				
	in total	1-15	16-30	31-50	51-100	in total	1-15	16-30	31-50	51-100
Institute of Dendrology	3	2		1		8	2	4	1	1
Mardakan, st. Yesenina	5	2		1	2	14	2	3	3	6
Botanical Garden	0	0	0	0	0	32	28	2	2	0
National Embankment Park	7	3	1	1	2	24	12	11	0	1
Tbilisi Ave	29	16	3	3	7	77	13	13	30	21
square Dede Gorgud	8	2	2	3	1	22	1	1	0	20
Koroglu Square	24	3	3	10	8	50	2	12	17	19
roadside economy M. Hadi	15	4	7	4	00	58	2	7	33	16
st. O. Velieva	16	4	5	4	2	59	3	10	25	21
st. Babek	28	4	4	8	12	65	2	11	30	22
st.G. Mehmandarova	28	3	2	8	15	65	3	12	28	24
Naples Circle	21	4	2	6	9	49	2	4	24	19
settlement Bakikhanova	7	2	1	3	1	19	2	5	5	7
st. M. Aliyeva	29	4	8	14	3	67	3	5	35	24
st. Promenade	34	4	6	10	14	67	6	11	24	26
st. Geleb	8	2	3	3	0	34	12	6	12	4
Sumgayit, st. Narimanova.	7	3	2	2	0	20	10	4	6	0
G. Sumgayit, st. Mira	8	2	3	3	0	19	8	4	4	3
G. Sumgait, st. G. Aliyev H.	7	3	2	1	0	18	6	3	4	5
Baku-Airport	28	12	6	7	3	71	8	9	30	24
Baku-Sumgait	25	11	8	4	2	75	14	8	22	31

Table 3

Evaluation indicators fluktiruyuschey asymmetry in the leaves *Pinus eldarica* Medw.

Station	Confines	
	Lower bound	Upper bound
Control	0.03	0.13
st.Mattbuat	0.22	0.35
st. Bakikhanova	0.89	1.05
st. G. Aliyev	0.22	0.35
st. Babek	0.23	0.36
st. M.Abbasova	0.21	0.36

Baku-Airport Highway	0.72	0.89
Binagadi highway	0.79	0.99

The data on size and weight of the needles and the correspondent statistical indicators make it possible to timely identify the territories affected by air-born pollution from traffic and monitor the quality of the environment. Thus, *Pinus eldarica* Medw. can serve as a bioindicator in environmental monitoring and initial forecasting of the state of environment.

Table 4 demonstrates the scale of environmental assessment of the development asymmetry in *Pinus eldarica* Medw.

Table 4

Environmental assessment

Mark	development asymmetry
I optimum	<0.12
II relative pollution	0.15-0.20
III low pollution	0.21-0.25
IV medium pollution	0.26-0.31
V severe pollution	0.32-0.40
VI risky pollution	0.41-0.50
VII critical pollution	>0.51

The difference between the left and right needle of the pair correlates with the degree of general environmental disturbance and serves as an indicator for a number of plant and animal species. The method of this research is based on the theory of "developmental stability" ("morphogenetic homeostasis") developed by Yablokov and Zakharov who studied the consequences of radioactive contamination, including the Chernobyl accident [8, 9]. It is proved that the stressful effects of various types cause a change in homeostasis (developmental stability) in living organisms. The main indicators of such changes in the homeostasis of morphogenetic processes are the signs of fluctuating asymmetry, in particular, random differences between the right and left sides of various morphological structures that normally have bilateral symmetry. Such differences results from errors in the development of the organism. Under normal conditions, their occurrence is minimal, but under any stressful effect it increases and this leads to frequent asymmetry. Assessment of fluctuating asymmetry of bilateral organisms has proven itself as a reliable method of determining the overall level of anthropological impact [9].

Conclusions

Pronounced fluctuation asymmetry was observed in the leaves of *Pinus eldarica* Medw. growing along the highways with heave traffic.

The most informative and sensitive sign of *Pinus eldarica* Medw. was the bilateral difference in the length of needles.

The state of the environment can be assessed based on fluctuating asymmetry of the morphological characteristics of leaves in tree species. Fluctuating asymmetry characterizes the state of environment, the state of bioindicators in ontogenesis, and can be used in an environmental monitoring system.

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