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Biocomprehensive ecomonitoring of *Tilia cordata* Mill. to assess the quality of the urban environment

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The paper presents the results of complex ecological studies of the urban environment on the reaction of *Tilia cordata* Mill. grown in the recreational zone of Astana. The authors studied the features of surface horizons of soils on their toxicity using tracer test-object *Raphanus sativus* and heavy metal pollution. The quality of the environment is assessed by bioindicator indicators of fluctuating asymmetry of the linden leaf.

Keywords: *Bioindication, phytotoxicity, heavy metals, fluctuating asymmetry, the quality of the environment*

INTRODUCTION

Increasing anthropogenic impact on the natural and urban ecosystems leads to environmental degradation and reduces habitat quality. It is known that transportation vehicles and industry are the main sources of environmental pollution in major settlements. Among all environmental factors, soil cover is the main source of all pollutants. Toxic substances in soil are absorbed by plants and lead to a deterioration of their quality, reducing their function in the natural environment (Mamedov, Hasanova, 2016; Andrianjara et al., 2021). Fluctuating asymmetry of the linden leaf is a recognized biological indicator parameter for assessing the quality of the natural environment (Kalaji et al., 2018).

Conducting complex ecological monitoring research for cities, such as Astana is the most actual, since the intensive urbanization process can lead to considerable negative environmental consequences if no action is taken to improve the state of the environment. In this regard, the main objective of the study was to conduct a comprehensive environmental monitoring of the urban environment to assess its quality. Biotesting and evaluation of phytotoxicity of soils, determination of heavy metal content in the soil surface, studying the response of *Tilia cordata* Mill. introduced in the park area of the city were the tasks of the research. *Tilia cordata* Mill. has a very difficult time adapting to the climatic conditions of the Absheron Peninsula, it was widely used in landscaping the city of Baku. At the same time, monitoring was carried out to protect the environment (Martynova et al., 2020).

Tilia cordata Mill. is a plant belonging to the *Malvaceae* family, genus *Tilia* L.

It is widespread in large areas of the Crimean Peninsula and the Caucasus Mountains. In its natural (wild) form, this tree species grows in the middle and southern latitudes of the European part of the Russian Federation, in mixed forests. In our country, this genus of trees is widespread in the mountainous regions of the eastern part of the Greater Caucasus and the Lesser Caucasus. This tree is most often found in different types of brown mountain forest soils (Hasanova et al., 2024).

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MATERIALS AND METHODS

Tilia cordata Mill. is a good ornamental plant, which is widely used in parks and squares of populated areas. We investigated the state of bioindicator parameters of trees and soils in the territories of the Institute of Dendrology of the Ministry of Sciences and Education of the Azerbaijan Republic and Footballers Square in Astana.

The ecological monitoring studies began in the summer of 2021.

Tilia cordata Mill. seeds from the city of Ganja (Azerbaijan) were introduced and propagated at the Institute of Dendrology of the Ministry of Sciences and Education of the Azerbaijan Republic. A number of scientific workers at the Institute studied the bioecological properties of this tree and recommended its use in the landscaping of Baku city. The appearance of the plants is shown in Figure 1.

The soil samples on the territory of the city park "Square of footballers", representing the lime avenue, *Tilia cordata Mill.* leaf samples served as material for research. Soil sampling was conducted by an envelope with an area of 200 m^2. Soil samples were collected from the surface horizon of 0-10 cm.

This tree species was propagated by seeds, stem cuttings, and cuttings.

Fig. 1. Flowers of *Tilia cordata* Mill.

Heavy metals in soil water extracts were determined by the conventional method of atomic absorption spectroscopy (Guidelines for laboratory…, 1995). The biological effects of environmental influences on organisms were evaluated by the fluctuating asymmetry parameter of *Tilia cordata* Mill. leaf. Sampling the leaves in the crown was made from leaves 30-50 from all tiers of each tree (Ajmone, Biasioli, 2010; Hasanova, 2021).

RESULTS AND DISCUSSION

This tree species grows well under conifers and *Quercus* L. being a shade-tolerant tree species, it is also found under beech cover in the Azerbaijan forest. This indicates that the tree species has the ability to reproduce well in relatively humid and shady environments. The *Tilia cordata* Mill. is a tree genus of first-rate size. The height of this tree species is 30-35 meters, and the diameter of the trunk varies between 80-100 cm. It has a tent-shaped umbrella. It is a long-lived tree species. In natural conditions, it can live for 400-500 years (sometimes 1000 years).

When young, the bark is gray, but also thick and smooth. In old age, the bark darkens and becomes brown-gray, with longitudinal furrows. Pollinated by insects, mainly honey bees. It has oval or rounded heart-shaped leaves. In the territory of our country, *Tilia cordata* Mill. blooms in late June and early July (for about 10-15 days). This species of tree grown in the open field bears fruit after 8 years, and in forest conditions after 20 years. Fruits ripen in August-September. Its fruits are spherical or oval-shaped nuts, thin-skinned, with one or two seeds. The fruits of this tree species remain on the trees throughout the winter. It has a strong spindle root

that works deep into the soil. *Tilia cordata* Mill. is a frost-resistant tree species. So, this type of tree can withstand frost at - 48°C. In the first years of its life, it grows 5-10 cm per year. After 4-5 years, it grows by 30 cm per year. After 10 years, it grows 2-2.5 meters per year. At the age of 60, its growth rate slows down, after 130-150 years, it stops completely (Bayer et al., 2018; Urošević et al., 2019).

Tilia cordata Mill. alley was divided into a central crossroads in 2004 for the purpose of landscaping park areas in Astana. Small-leaved *Tilia cordata* Mill. is the basis of the range. Conducting visual observations, it was established that all the trees were growing moderately. The average length of the annual branch's growth was 0.17-0.23 m in 2020-2021. The compositions of different wood species such as white *Betula verrucosa* Erh., varieties of maple, willow were created alongside linden in the square. Individual specimens of conifers: *Pinus sylvestris* L., *Picea pungens* E. were planted.

Considering that a number of instrumental and biological methods of analysis are used to control environmental contamination, biological methods that more objectively reflect the ecological state of the system, in particular, the self-cleaning capacity of the soil, and its response to a particular stimulus were picked up by us. The biological method is highly effective in determining the overall phytotoxicity of the soil. It is simple in execution, operative, and allows for the quick determination of the total soil phytotoxicity. The principle of the method of biological indication is based on the relationship between the dose of the toxicant and the effect of its action on the test object. The main requirement for the test object is a high sensitivity to soil toxicants or their decay products. The coefficients of soil phytotoxicity computed from soil biotesting of linden alley by using Raphanus sativus are shown in Figure 2.

Studies of soil phytotoxicity have identified a number of characteristics. It is shown that in comparison with indicators of control samples, the deviation of length of radish roots grown in the soil recreational area is insignificant and equal to 18%. This indicates a low degree of phytotoxicity of the soil in a recreational zone.

The length of the roots of radish grown in suspension from the soil near the road was reduced by 3.8 mm compared to controls, indicating a pronounced degree of soil phytotoxicity near the main tracks. The deviation of root length of the test plants of the control parameter is set to 2.4 mm in the study of recreational zone soils. It is estimated as a slight excess of the benchmarks. A different picture is revealed for the site located in the depth of the square at a considerable distance from the road. Derivation from control indicators made 0.6 mm. In studying the phytotoxicity of soil taken from different zones of the investigated square found that indicators of soil phytotoxicity in the recreational zone changed in "the depth of the square near the mainline areas". The most typical characteristics of soil phytotoxicity – *Tilia cordata* Mill. alley corresponded to squares of the first row, at points 11,21,29, as shown in Figure 2.

The content of heavy metals in the soils of the square was studied in the surface horizons to a depth of 10 cm. The concentrations of elements such as Zn, Cu, Cd, Pb, Sr, Cr from aqueous extracts of soil were determined by us to establish parkland soil contamination with heavy metals. The research results are presented in Table 1.

Among the heavy metals, we determined Zn, Cu, Cd, Pb, Sr, Cr in soils, as they are considered the most toxic components of the natural environment.

Many of these elements are noted in the surface layer of soil samples "Square of footballers" in Astana. A considerable range of elements except Sr, registered in samples taken near the highway. It found that certain concentrations of all the elements Zn, Cu, Cd, Pb in the present conditions vary in very low limits which constitute 0.002-0.004 mg/kg.

Transportation emissions which are increasing in a geometrical progression due to the population growth and infrastructure development of the young capital are the main source of environmental contamination in Astana.

The absence of significant industrial enterprises in the city contributes to the slightest environmental pollution and subsequent escrow of heavy metals in land cover. As can be seen from the results of laboratory analyses, the cases of MPC excess for any of the studied elements haven't been revealed in the surveyed territories.

The organization of ecological monitoring will allow tracking of the growth dynamics of anthropogenic load on components of nature in the city by increasing the intensity of vehicular traffic.

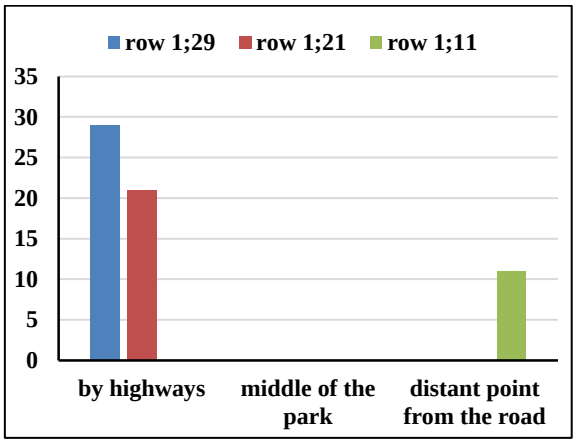

Fig. 2. Change in the coefficient of soil phytotoxicity in the "Square of footballers", %.

The fluctuating asymmetry of the linden leaf was determined to characterize the biological response of trees to environmental conditions. *Tilia cordata* Mill. is a perspective species for urban planting. It is relatively stable and has a high capacity for self-renewal. The study of morphometric parameters of leaves of woody plants in the streets with different movement intensities of vehicles revealed their specific variability. Results of scrutiny of fluctuating asymmetry of *Tilia cordata* Mill. leaves are shown in Table 2.

Ten-day observations of the biological condition of *Tilia cordata* Mill. trees showed that the square of necrosis increased towards the end of the summer (3rd decade of August) to 50% of the total square of leaves. Undoubtedly, this process is significantly affected by a change in the photosynthetic capacity of foliage. Morphologically, basically, as seen from the figures, the edge necrosis was observed in leaves. The number of damaged leaves increased from the bottom up. Supposedly the lower leaves are exposed to the gas emissions before the leaves of the upper tiers. Laboratory analysis showed that the level of transport pollution in the atmosphere affects the studied morphometric indicators of the linden state as the average size of the leaf blades.

Research of fluctuating asymmetry of the leaf blades showed that the asymmetry is an informative indicator of leaves: it was higher in stressed conditions than in an area remote from the highway at all studied plants. Certain parameters of the average value of fluctuating asymmetry for the group of trees near the highway amounted to 0.307. These same values for a group of trees from a remote highway section are 0.14. Response reactions of all tree crops are practically identical - values of fluctuating asymmetry of leaves of all the selected wood species are amplified. The studied indices of the mean value of fluctuating asymmetry of *Tilia cordata* Mill. can be used as test indicators of urban air pollution.

In general, a slight increase occurs in the average square of leaves in different habitat characteristics. The existing trend of reducing the size of woody plant leaves with an increase in the road transport load is confirmed by correlation analysis for linden. The asymmetry of the leaves is a more informative indicator: It varies depending on the location of the key areas in all the studied plants. The study of the bio-indicative properties by the quality of leaves allows us to note the linden as the most sensitive biological indicator. Analysis of the obtained experimental data shows that the small-leaved *Tilia cordata* Mill. reacts to anthropogenic pressure, the growth of which is associated with the intensification of car traffic.

Table 1. Heavy metal contamination of soils of city square territory in Astana

Key areas	Zn, mg / kg	Cu, mg / kg	Cd, mg / kg	Pb, mg / kg	Sr, mg / l	Cr, mg / l
The standard content of heavy metals [10].	23.0	33.0	0.5	32.0		6.0
1- near the highway territory	0.002	0.004	0.003	0.003	0.0	0.112
2- the central part of the square	0.0	0.0	0.0	0.0	0.06	0.0
3- the depth of the square, close to residential houses	0.0	0.0	0.0	0.0	0.03	0.0

Table 2. Indicators of linear parameters of *Tilia cordata* Mill. leaves from different parts of the alley in modern ecological conditions Astana, cm

Indicators	Near the motorway, number 1, point 29	Away from the motorway number 1, point 11
The width of the leaf blade halves	0.307	0.102
The length of the second leaf blade veins	0.364	0.145
The angle between the central and second veins of the leaf blade	0.29	0.14
The distance between the first and second veins of the leaf blade	0.22	0.12

Thus, the complex ecological monitoring of *Tilia cordata* Mill. to assess the quality of the environment shows that the selected object confirms its high sensitivity to environmental changes. The study of this breed is promising because the linden proves resistant to various anthropogenic influences, has a high capacity for self-renewal, has high aesthetic qualities, acquiring a more compact shape when pruning the crown. Soil cover in places of *Tilia cordata* Mill. growing has a slight contamination by studied heavy metals. The cases of exceeding maximum permissible concentrations of certain elements Zn, Cu, Cd, Pb, Sr, Cr have not been identified. This feature of soil contamination of "Square of footballers" confirmed the integrated assessment of the degree of soil phytotoxicity in recreational areas. Indication index of *Tilia cordata* Mill. reaction on the fluctuating asymmetry characterizes the state of the trees as having a tendency to reduce the size of the leaves with an increase in the road transport load.

CONCLUSIONS

The conducted studies allowed us to draw the following conclusions.

1. The results of the experiments showed that there were no cases of exceeding the maximum permissible concentrations of individual elements Zn, Cu, Cd, Pb, Sr, Cr in the soil samples of the linden alley.

2. Studies of the fluctuating asymmetry of leaf blades of *Tilia cordata* Mill. indicate that asymmetry is an informative indicator of leaves: under stressful conditions, it was higher than in the zone remote from the highway, for all the plants studied. The determined parameters of the average value of fluctuating asymmetry for a group of trees near the highway were 0.307. The same values for a group of trees from a site remote from the highway are 0.14, which is almost 2 times lower.

3. The parameters of fluctuating asymmetry of linden leaves obtained during monitoring will be comparable in subsequent years when analyzing bioindication indicators when assessing the state of the natural environment in urbanized areas (using the city of Astana as an example).

The study of bioindicator parameters of *Tilia cordata* Mill. in urban conditions showed that *Tilia cordata* Mill. is a promising species for landscaping parks and squares in populated areas.

The results of the research have shown that in the future it is necessary to develop a system of criteria differentiated by the composition of pollutants and levels of chronic pollution, which would allow us to reliably assess the levels of atmospheric air pollution by indicators of the state of plants and ecosystems, and vice versa. It will increase the efficiency of bio-indicative works and lay the scientific foundations for ecological forecasting and expertise.

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