

Morphological and anatomical parameters of *Forsythia suspensa* (Thunb.) Vahl leaves in the urban environment

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Abstract

The anatomical and morphological parameters of the leaf blade of *Forsythia suspensa* were investigated to determine the species' stability in the Kyiv metropolis (Ukraine) conditions and monitor environmental pollution. The leaves of *F. suspensa* were selected at four monitoring sites in Kyiv, which differed in their distance to highways and the intensity of traffic. The histological structure of *F. suspensa* leaves changed toward xeromorphism in the variants where plants were exposed to increased vehicles' emissions. In particular, the thickness of the cuticle and adaxial epidermis increased, the stomatal size decreased, the degree of stomata opening decreased and their density increased, and the stomatal index and xeromorphism index increased. In general, such changes in the structure of *F. suspensa* leaves increased the plants' resistance to pollution. This indicates the plasticity of *F. suspensa* plants and a sufficient level of their adaptation to the urban environment. Hence, the parameters of the stomatal apparatus of *F. suspensa* leaves can be applied as test indicators for biomonitoring of urban pollution. This species can be recommended for creating stable culturphytocoenoses in conditions of a high level of technogenic influence.

Keywords: *Forsythia*, environmental conditions, pollution degree, leaf anatomy, plasticity, xeromorphism

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Introduction

In the modern world, environmental pollution is one of the main problems of humanity. The effect of emissions from industrial enterprises and thermal power plants in large cities, particularly Kyiv, is intensified by the

ever-increasing emissions of vehicles. This trend is explained by the high population density, intensive capital development, and high level of motorization. The share of harmful substances from motor vehicles in the air increased to 85–90% (Yatsenko et al., 2018; Ecological Passport, 2019). On

the city's main highways, the traffic flow load exceeds the carrying capacity by two to three times. Therefore, substantial traffic jams occur daily (Dubova & Pomazkova, 2017). Overloading highways leads to high gasification of atmospheric air, increased noise and vibration, and exceeding the maximum permissible concentrations of harmful substances, negatively affecting the urban biota and people's health. Air pollution causes respiratory infections, heart disease, asthma, stroke, lung cancer, and pregnancy-related complications (Kim et al., 2018; Zhang et al., 2021).

In such a situation, one of the effective means of improving the urban environment is creating green areas, which neutralize unfavorable factors. Plants clean the air (retain from 21 to 86% of dust, and part of the emissions are absorbed), create a favorable microclimate (reduce air temperature, increase humidity), lower noise, and create a comfortable environment for living and recreation of the population, support the ecological balance in the urban ecosystem (Levon & Kuznetsov, 2006; Wróblewska & Jeong, 2021; Kończak et al., 2020). At the same time, plants in urban green areas are exposed to direct long-term environmental pollution, affecting their vitality over time and requiring particular adaptations (Nikolayevskiy, 1979). Some plants are severely damaged in the urban environment, while others adapt well to the stress factors with the help of physio-chemical and morpho-anatomical mechanisms (Balasooriya et al., 2009; Mitu et al., 2019). Therefore, various indicators of plants are often used in bioindication, which makes it possible to assess the state of the environment and predict the level of allowable anthropogenic loads on the environment under certain conditions (Didukh, 2012; Hrytsak et al., 2017). The degree of adaptability of plants depends on the species, the complexity of ecological growth conditions, and the nature of the species-specific reaction of plants to the influence of environmental pollutants of different origins (Kapelyush & Bessonova, 2005; Chipilyak & Grishko, 2008; Ilyas et al., 2021). Often, anatomical and morphological parameters of the leaves are used to diagnose the nature of the effect of technogenic emissions on plants. The leaves are one of the most sensitive and plastic plants' organs,

which usually have direct contact with toxic substances in the urban environment (Jahan & Iqbal, 1992; Leshcheniuk & Mazura, 2021; Muthu et al., 2021).

Representatives of the genus *Forsythia* Vahl., having high decorative properties due to bright early flowering in spring and purple-red color of leaves in autumn, are often used in urban landscaping (Goncharenko, 2009). Besides decorative value, *Forsythia* species have therapeutic properties and are used in medicine (Luo et al., 2020; Gong et al., 2021). Some *Forsythia* species are effectively utilized in phytoremediation (Kończak et al., 2020).

One of the most widely introduced *Forsythia* species in Ukraine is *F. suspensa* (Thunb.) Vahl (Goncharenko, 2009). In Kyiv, it is grown in various places – botanical gardens, parks, squares, residential areas, and along the streets, where it is exposed to constant anthropogenic pressure. However, the persistence of this species in urban environments has not been studied. Because of this, it was advisable to investigate the influence of the ingredients of vehicles' emissions of different intensities on the histological structure of *F. suspensa* leaves to determine the cultivation stability of this species in urban conditions of the Kyiv metropolis and to evaluate the possibility of this species application during the monitoring of environmental contamination.

Material and methods

The leaves of *F. suspensa* were collected from culturphytocoenoses of Kyiv. According to the Sereznevskiy Central Geophysical Observatory (CGO), the overall level of air pollution according to the Air Pollution Index (API) in Kyiv was estimated as high (Yatsenko et al., 2018; Ecological Passport, 2019). The excess of the average daily maximum permissible concentrations of nitrogen dioxide was recorded at 3 times, formaldehyde – at 2 times, sulfur dioxide – at 1.5 times, phenol – at 1.3 times, and nitrogen oxide – at 1.2 times. The highest concentration of pollutants was observed in places with heavy traffic (Ecological Passport, 2019).

To determine the level of influence of pollutants on the structure of *F. suspensa* leaf blade, four monitoring sites with different

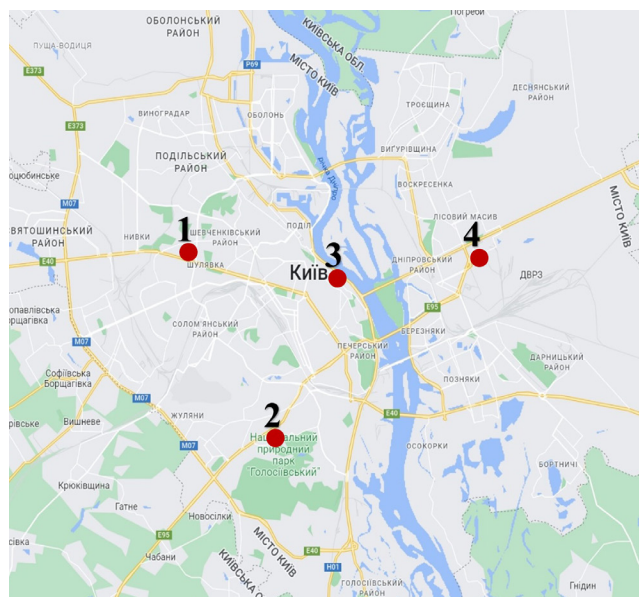


Figure 1. The location of monitoring sites in Kyiv: 1 – Peremogy avenue (Shulyavska metro station); 2 – Holiivskyi avenue (M. Rylskyi Holiivskyi Park); 3 – M. Hrushevskiy street (City Garden Park); 4 – Gagarin avenue (DShK Park).

distances to highways and traffic intensity were selected. The considered research sites are conditionally divided into three groups: with an average level of pollution (with traffic from 1100 to 2600 cars/h), heavily polluted (with traffic from 2600 to 3400 cars/h), and very heavily polluted (traffic intensity exceeds 4000 cars/h) (Serdyuk, 2016).

The very heavily polluted areas includes the site 1 on Peremogy avenue of the Shevchenkivskiy district (near the Shulyavska metro station, distance from the highway is 11 m, and the average traffic intensity is 5260 cars/h) and the site 2 on Holiivskyi avenue of the Holiivskyi district (M. Rylskyi Holiivskyi Park, distance from the highway is 7 m, and the average traffic intensity is 4600 cars/h). The highly polluted zone includes the site 4 on Gagarin avenue of the Desnyanskyi district (the place of sampling is the DShK Park, the distance from the highway is 15 m, and the average traffic intensity is 3296 cars/h). The site 3 on M. Hrushevskiy street in the Pechersk district (City Garden Park, distance from the road is 29 m, and the average traffic intensity is 1350 cars/h) belongs to the territories with a moderate level of pollution (Fig. 1).

To maximize the values of the content of nitrogen dioxide, formaldehyde, and API,

which are highest in the summer period (Ecological Passport, 2019; Yearbook, 2021), the samples were taken in June 2020.

The temporary microscopic preparations were made from morphologically mature leaves collected from the southern side of the middle part of plants in a 20-fold repetition following standard protocols (Barykina et al., 2004). Cross-sections were prepared by hand with a razor on the level of one-third of the leaf's length. The slides were examined with a Nikon Eclipse E100 microscope at $\times 10$ and $\times 40$ magnifications. The leaf, epidermis, and mesophyll thickness were measured at the same distance from the edge of the leaf and the central vein. The preparations were examined using Vasiliev's (1988) terminology.

The stomata index was calculated by the formula Vasiliev (1988):

$$I_{st} = \frac{Kn}{Ke+Kn} * 100\%, \text{ where}$$

Kn – the number of stomata per 1 mm^2 of the leaf surface,

Ke – the number of epidermal cells per 1 mm^2 of the leaf surface.

The palisade coefficient indicates the percentage of palisade mesophyll in the total mesophyll layer. It was calculated by Vasiliev's (1988) formula:

$$K = \frac{Mp}{Mp+Ms} * 100\% , \text{ where}$$

Mp – the height of the layer of palisade mesophyll on the cross-section of the leaf, in μm ,

Ms – the height of the spongy mesophyll layer on the leaf cross-section, in μm .

The xeromorphic index was determined by the formula (Zhaldak, 2000):

$$I_{xr} = \frac{Ne+Nn}{100\%}, \text{ where}$$

Ne – the number of epidermal cells per 1 mm^2 ,

Nn – the number of stomata per 1 mm^2 .

Measurements were performed in the AxioVision 4.8.2 environment. Data were statistically processed through the dispersion analysis, according to Lakin (1990) using MS Excel 2003.

Table 1. Anatomical parameters of the leaf blade of *Forsythia suspensa* in the conditions of Kyiv metropolis.

Parameters		Site 1 (Shulyavska metro station)	Site 2 (M. Rylskiyi Holosiiv Park)	Site 3 (City Garden Park)	Site 4 (DShK Park)	
Average traffic intensity, cars/h		5260	4600	1340	3296	
Leaf blade thickness, μm	M \pm m	280.6 \pm 7.0	280.1 \pm 4.5	284.2 \pm 4.7	265.8 \pm 4.2	
	CV, %	7.52	8.6	8.4	11.5	
Cuticle thickness, μm	M \pm m	8.5 \pm 0.4	8.4 \pm 0.3	7.2 \pm 0.3	8.1 \pm 0.3	
	CV, %	21.8	16.7	18.9	15.4	
The thickness of adaxial epidermis, μm	M \pm m	29.8 \pm 1.4	30.9 \pm 0.8	21.2 \pm 0.7	29.3 \pm 0.6	
	CV, %	15.5	12.3	15.6	9.6	
The thickness of abaxial epidermis, μm	M \pm m	20.6 \pm 0.74	20.9 \pm 0.6	19.6 \pm 0.6	18.8 \pm 0.4	
	CV, %	12.4	10.1	13.7	10.6	
The thickness of the total mesophyll, μm	M \pm m	222.2 \pm 6.9	226.5 \pm 5.3	217.6 \pm 3.5	213.1 \pm 3.8	
	CV, %	8.0	9.8	8.8	8.1	
The thickness of the palisade mesophyll	M \pm m	82.2 \pm 3.3	91.0 \pm 3.7	83.0 \pm 1.6	81.7 \pm 2.0	
	CV, %	11.7	14.8	9.6	12.49	
The thickness of the spongy mesophyll, μm	M \pm m	140.2 \pm 7.2	133.7 \pm 2.9	133.1 \pm 2.8	130.9 \pm 2.2	
	CV, %	15.9	11.3	10.57	8.39	
Palisade coefficient, %	M \pm m	37.8 \pm 1.0	40.4 \pm 1.3	39.3 \pm 0.8	38.3 \pm 0.75	
	CV, %	8.61	11.7	6.4	7.03	
The diameter of the vascular bundle, μm	transverse diameter	M \pm m	284.6 \pm 12.9	260.9 \pm 15.7	252.5 \pm 11.5	182.5 \pm 9.3
		CV, %	15.46	12.03	13.5	11.4
	longitudinal diameter	M \pm m	451.2 \pm 17.6	354.7 \pm 20.1	341.7 \pm 19.4	305.9 \pm 16.3
		CV, %	9.5	11.3	13.7	11.7

Note. M \pm m – the arithmetic mean and standard deviation; CV – coefficient of variation.

Results and discussion

The leaves of *F. suspensa* are ovate-oblong, with a wedge-shaped base, toothed-serrated edge, and pointed tip. The length the leaf varied from 7.3 \pm 0.1 cm (site 4) to 7.7 \pm 0.1 cm (site 3), and the width of the leaf varied from 3.0 \pm 0.04 cm (site 3) to 3.3 \pm 0.07 cm (site 2). The area of the leaf plate did not differ significantly between different sites and ranged from 18.1 \pm 0.9 cm² (site 1) to 19.3 \pm 0.7 cm² (site 2).

The leaf blade of *F. suspensa* is bifacial and thick. Its thickness in places with different traffic intensities is almost the same, except for samples from the site 4, where it was the thinnest in the heavily polluted conditions (Table 1). The dorsoventral mesophyll consists of two layers of elongated cells of the palisade parenchyma and three-four loose layers of spongy parenchyma. The spongy parenchyma

is formed by rounded-oval cells elongated in the tangential direction with a small number of intercellular spaces (Fig. 2 C).

A somewhat higher mesophyll thickness was found in plants that grew in the roadside zone with intensive traffic near the highway (sites 1 and 2). The palisade coefficient and the ratio of the height of the palisade mesophyll to the spongy one are almost the same in all studied samples. The average values of the height of the layer of palisade parenchyma varied at the monitoring sites with different pollution levels (Table 1). However, no statistically significant difference was found despite the data obtained by other researchers (Dineva, 2004; Rashidi et al., 2012; Muthu et al., 2021), who observed changes in these leaf parameters depending on pollution level as a species-specific reaction of plants.

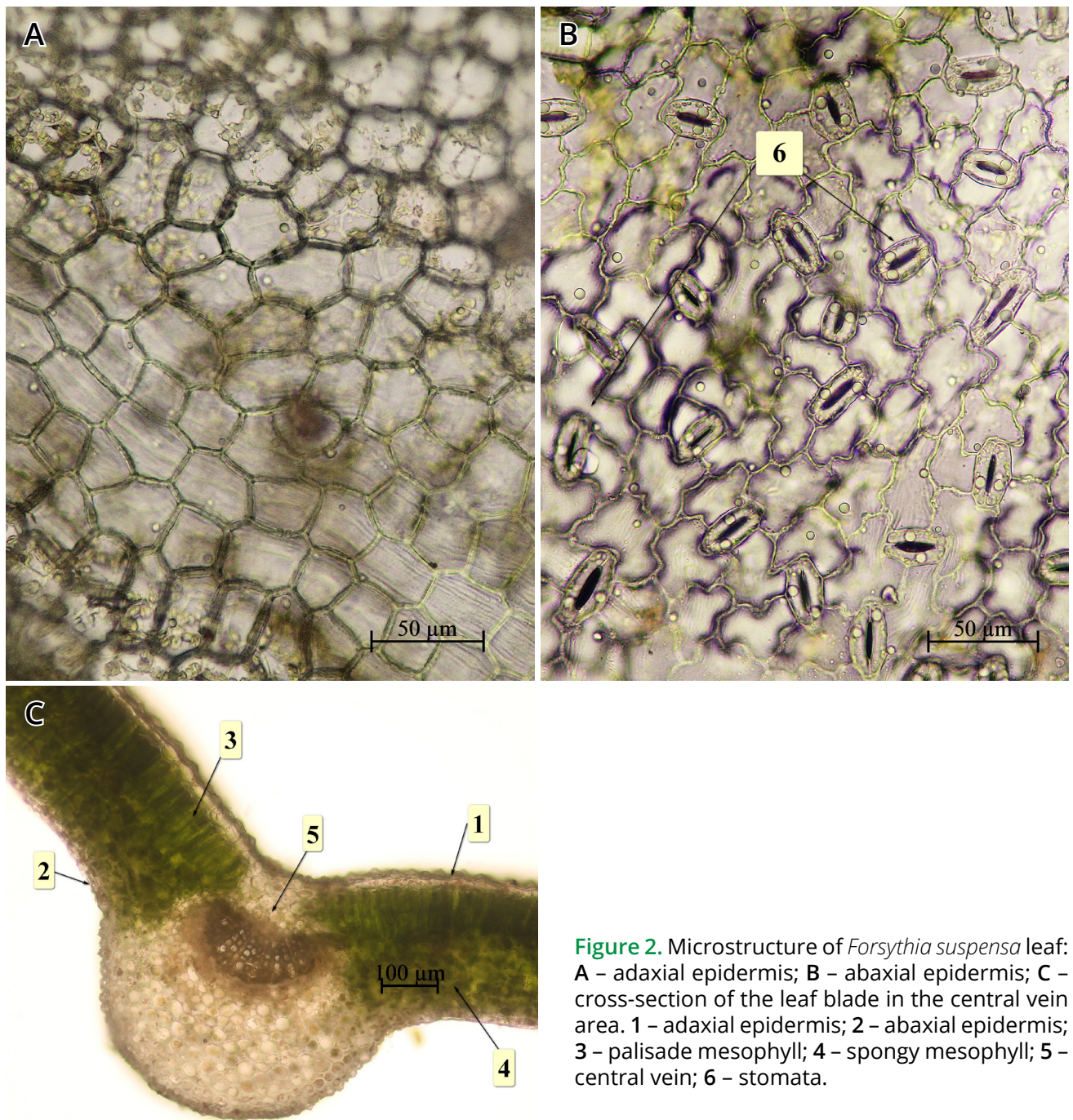


Figure 2. Microstructure of *Forsythia suspensa* leaf: A - adaxial epidermis; B - abaxial epidermis; C - cross-section of the leaf blade in the central vein area. 1 - adaxial epidermis; 2 - abaxial epidermis; 3 - palisade mesophyll; 4 - spongy mesophyll; 5 - central vein; 6 - stomata.

The vascular bundles of the leaf blade of *F. suspensa* are collateral of open type (Fig. 2 C). The largest (central) bundle has well-developed xylem and phloem. The xylem consists of vessels, xylem parenchyma, and radial rays. The phloem is represented by sieve-like tubes, satellite cells, and phloem parenchyma. The most considerable indicators of both the transverse and longitudinal diameter of the central bundle were found in the samples from the site 1 growing in conditions of a high pollution (Table 1). Mechanical parenchyma is represented by cells of different sizes with thickened walls of angular collenchyma. The

lateral vascular bundles and their ramification are smaller and have simpler structure than a central vein.

The upper and lower surfaces of the leaves are covered with unicellular and multicellular trichomes and a large number of peltate glands, the highest number of which is concentrated along the central and lateral ribs on both lamina sides. The adaxial and abaxial epidermises consist of a single layer of parenchymal cells and are covered with a layer of combed cuticle. The cuticle is much thicker on the adaxial side of the lamina. The upper epidermal cells are five-

Table 2. Indicators of the stomatal apparatus and covering structures of *Forsythia suspensa* leaf blade under different pollution level.

Parameters		Site 1 (Shulyavska metro station)	Site 2 (M. Rylskiy Holosiiv Park)	Site 3 (City Garden Park)	Site 4 (DShK Park)
Stomata length, μm	M \pm m	25.4 \pm 0.5	26.6 \pm 0.7	30.3 \pm 1.1	26.2 \pm 0.6
	CV, %	11.7	7.4	15.5	11.3
Stomata width, μm	M \pm m	16.7 \pm 0.3	17.0 \pm 0.5	18.1 \pm 0.4	16.6 \pm 0.5
	CV, %	7.1	6.2	13.0	9.2
The number of stomata per 1 mm ² , pcs.	M \pm m	283 \pm 7.4	250 \pm 6.5	161 \pm 5.8	233 \pm 7.7
	CV, %	11.7	10.3	12.2	8.7
The width of the stomatal gap, μm	M \pm m	6.4 \pm 0.2	6.3 \pm 0.4	7.3 \pm 0.2	6.5 \pm 0.2
	CV, %	17.8	15.26	12.1	16.5
The number of cells of the adaxial epidermis per 1 mm ² , pcs.	M \pm m	1209 \pm 49	1128 \pm 21	881 \pm 41	1217 \pm 18
	CV, %	18.1	7.2	11.5	8.6
The number of cells of the abaxial epidermis per 1 mm ² , pcs.	M \pm m	1272 \pm 47	1263 \pm 39	926 \pm 32	1343 \pm 46
	CV, %	10.3	8.2	11.1	10.4
The stomatal index, %	M \pm m	17.3 \pm 0.9	16.7 \pm 0.3	13.2 \pm 0.5	15.1 \pm 0.4
	CV, %	12.3	7.6	13.3	9.4
The xeromorphism index, %	M \pm m	14.9 \pm 0.8	15.2 \pm 0.3	11.0 \pm 0.2	15.5 \pm 0.4
	CV, %	12.4	10.6	8.5	10.12

Note. M \pm m – the arithmetic mean and standard deviation; CV – coefficient of variation.

six-angled, with straight or slightly curved walls, different in size. The regular cells of the abaxial epidermis are elongated with strongly sinuous anticlinal walls (Fig. 2 A & B). The leaves are hypostomatic; the stomata are oval, anomocytic, placed randomly at the same level as the regular epidermal cells, and more densely concentrated near central vein (Fig. 2 B).

It was found that the ingredients of vehicles' emissions primarily affect the covering tissues of the leaf blade of *F. suspensa*. The epidermis of plants performs a barrier and protective function, and changes in its structure reflect the effects of environmental conditions on the plant in general (Esau, 1969; Nikolayevskiy, 1979; Ilyas et al., 2021). Thus, in conditions of high traffic intensity and proximity to the highway (sites 1, 2, and 4), plants formed 1.2 times thicker cuticle, which is important for their peripheral protection from the influence of adverse environmental factors, in particular the ingredients of vehicles emissions (Table 1). The thickness of the adaxial epidermis was 1.5

times greater than the size of the abaxial one in all studied options, except for the samples from the site 3, where epidermises were almost the same. However, the thickness of the abaxial epidermis of *F. suspensa* leaves at all pollution levels did not differ significantly. Hence, the ingredients of vehicles' emissions have stronger effect on the thickness of the adaxial epidermis than the abaxial one.

The indicators of the stomatal apparatus also changed under pollution since most gases enter the leaf through the stomata (Nikolayevskiy, 1979; Beerling & Chaloner, 1993; Brownlee, 2001). Thus, the length and width of the closing cells of the stomata in *F. suspensa* leaves under increased pollution decreased (sites 1, 2, and 4) compared to plants grown in a less polluted area (site 3). The size of stomata in polluted areas was smaller, while their number per 1 mm² of the leaf area increased by 1.5–1.9 times (Table 2). Similarly, Jun-Ho & Suk-Pyo (2013) noted that the size of *F. suspensa* stomata in the urban environment is significantly smaller (1.2–1.5 times) than

in natural conditions, which is probably an adaptive plant's response to pollution.

The highest density of stomata per leaf area (numerous stomata according to Vasiliev's (1988) scale) was observed in plants growing under excessive exposure to vehicles' emissions (site 1). Instead, the smallest density of stomata (mediate stomata number) was characteristic of the plants growing at a considerable distance from the highway under conditions of an average level of pollution (site 3). The difference in the openness of leaf stomata was also noted; it increased as the intensity of vehicle traffic decreased. The largest size of the stomatal gap (7.3 μm) was recorded in plants from the site 3 with a moderate pollution level (Table 2). It is also worth noting that in *F. suspensa* plants, under very high exposure to exhaust gases and approaching the highway (sites 1 and 2), single stomata appeared near the central vein on the adaxial surface of the leaf. In our opinion, such changes in the stomatal apparatus of *F. suspensa* leaves are an adaptive reaction of plants to the constant influence of the ingredients of vehicle emissions.

With the increase in the load of highways, an increase in the number of cells of both the upper and lower epidermis in *F. suspensa* leaves, and, accordingly, the stomatal index and the xeromorphism index were recorded (Table 2). In the sites 1 and 2, the stomatal index was high (from 16 to 21%). With a lower intensity of traffic load and a greater distance from the highway (sites 3 and 4), the stomatal index was average (from 11 to 16%). The lowest xeromorphism index was recorded in the plants growing under the weakest exposure to toxic substances (site 3), while the highest values were observed in the plants growing under increased exposure to vehicles' exhaust (sites 1, 2, and 4).

The dependence of the microstructural characteristics of *F. suspensa* leaves on the vehicles' pollution intensity was tested using the Pearson correlation coefficient (r). Very strong positive correlation (r ranged from 0.8 to 0.9) between the degree of vehicles air pollution and the thickness of the cuticle, the adaxial epidermis, the density of stomata, the value of the stomatal index, the number of cells of the adaxial and abaxial epidermis per unit of the leaf surface and the xeromorphism index was revealed. A very strong negative

correlation was found between the parameters of the stomatal apparatus and the traffic intensity (r ranged from -0.8 to -0.9); as the concentration of vehicles emission increases, the parameters of the stomata decrease. There was also a strong correlation between the degree of car exhaust pollution and the thickness of the abaxial epidermis, mesophyll, and spongy parenchyma ($r=0.6$). A weak correlation ($r=0.3$) was revealed between the concentration of pollutants and the thickness of the leaf lamina and palisade mesophyll.

Therefore, the detected changes in the anatomical structure of the leaf of the studied species towards xeromorphism can be considered an adaptive reaction of plants to the negative effect of the ingredients of vehicles' emissions. This, in turn, indicates the plasticity of *F. suspensa* in the urban environment. Adaptation of plants to changing environmental conditions is associated with changes in the functional characteristics of the leaf, which is a manifestation of the adaptive response of plants to the influence of stressful conditions (Grodzinskiy, 2013; Ilyas et al., 2021). Most species tend to increase the xeromorphism signs in the leaf microstructure. Many authors (Dineva, 2004; Rashidi et al., 2012; Dzhigan, 2014) reported that plants in the urban environment are adapted to stress by increasing the thickness of the leaf blade, cuticle, epidermis, palisade mesophyll, etc. There is also information that plants under the influence of toxins change the anatomical structures of their leaves in a downward direction (Dineva, 2004; Ilyas et al., 2021). For example, in *Platanus orientalis* L., *Tilia cordata* L., and *Tagetes patula* L. under conditions of vehicles' emission pollution, an increase in the thickness of the leaf blade, cuticle, palisade parenchyma, epidermis, and an increase in the ratio of columnar mesophyll to spongy height were observed (Kapelyush & Bessonova, 2005; Ponomaryova, 2013; Dzhigan, 2014). Instead, *Tanacetum vulgare* L., *Ficus bengalensis* L., *Guaiacum officinale* L., and some representatives of *Hemerocallis* L. under the influence of vehicles' emissions decreased their leaf parameters (Jahan & Iqbal, 1992; Chipilyak & Grishko, 2008; Stevovi et al., 2010).

Stomata play an important role in the plant organism's functionality. It was found that reducing the size of the stomata and the degree of their opening, and increasing their

number per area unit help to limit the entry of harmful substances into the plant organism, improve the regulation of gas exchange and transpiration, and increase the gas resistance of plants in urban conditions (Nikolayevskiy, 1979; Beerling & Chaloner, 1993; Brownlee, 2001). Many researchers showed that stomatal characteristics are effective bioindicators for assessing urban habitat quality (Nikolayevskiy, 1979; Balasooriya et al., 2009; Ilyas et al., 2021; Leshcheniuk & Mazura, 2021).

Conclusions

The peculiarities of the anatomical and morphological structure of *F. suspensa* leaves in the conditions of the Kyiv metropolis were established. It was found that in the variants where the plants were exposed to the increased effect of the ingredients of vehicle emissions, there were changes in the leaf histological structure toward xeromorphism. In particular, the cuticle (1.2 times) and the adaxial epidermis (1.4–1.5 times) became thickened; the size of the stomata decreased; the degree of their opening decreased; their density increased (1.4–1.7 times); the stomatal index (1.2–1.3 times) and the xeromorphism index (1.4 times) increased; single stomata appeared on the adaxial surface of the leaves. The changes in *F. suspensa* leaf structure increased the resistance of plants to environmental pollution with toxic gases, which indicates the plasticity of the species and a sufficient level of its adaptation to the urban environment. The variability of stomatal parameters of *F. suspensa* leaves can be applied as test indicators for biomonitoring of urban pollution. Consequently, *F. suspensa* can be recommended for creating stable culturphytocenosis in conditions with a strong technogenic influence.

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Морфологічні й анатомічні показники листків *Forsythia suspensa* (Thunb.) Vahl в умовах міського середовища

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Досліджено анатомо-морфологічні параметри листової пластинки рослин *Forsythia suspensa* з метою визначення стійкості виду в умовах Київського мегаполісу та моніторингу забруднення довкілля. Матеріалом дослідження слугували листки *F. suspensa* відібрані на чотирьох моніторингових ділянках Києва, які відрізнялися різною віддаленістю від автошляхів та інтенсивністю руху автотранспортних засобів. З’ясовано, що у варіантах, де рослини зазнавали посиленого впливу автотранспортних викидів, відбувалися зміни показників гістологічної структури листка у бік ксероморфності. Зокрема, зростала товщина кутикули та адаксіального епідермісу, зменшувалися розміри продихів, зменшувався ступінь їх відкриття, збільшувалася їх щільність, зростали показники продихового індексу та індексу ксероморфності. Такі зміни у структурі листків *F. suspensa* забезпечують підвищену стійкість рослин в умовах забруднення, що свідчить про пластичність виду та достатній рівень адаптації в урбосередовищі. Отже, параметри продихового апарату листової пластинки *F. suspensa* можна використовувати в якості тест-показників для біомоніторингу забруднення міського середовища. Цей вид можна рекомендувати для створення стійких культурфітоценозів в умовах високого рівня техногенного впливу.

Ключові слова: *Forsythia*, екологічні умови, ступінь забруднення, анатомія листка, пластичність, ксероморфізація