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Influence of air dust on anatomo-morphological and biochemical parameters of Plantago Major L

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Abstract: Pollution has a great impact on the environment. Plants being the representatives of autotrophic organisms are the first to face it. The photosynthesis suppression, water exchange violation, transpiration reduction, growth general oppression and plants' development are exposed to pollutants. This causes changes in leaf coloration, necroses, premature leaf fall, changes in growth form. The effect of air dust on anatomo-morphological parameters of plantain and the effect of dust pollution on plantain's (Plantago major L.) production processes have been studied, the dust-holding capacity of plantain leaves has been estimated. The correlation between the dust pollution level and the stomata density in the leaves' epidermis of model species has been found out. Mass of aboveground organs (g) and leaf lamina area (cm2), the number of stomata on the leaf surface (pcs./mm2), the dust accumulation level on the leaf surface (g) have been analyzed in model species. Weighing was carried out with an accuracy of 0.001 g on electronic scales. According to the performed analysis, we have come to the conclusions: species of the plantain have 10 to 50 mg of dust particles deposited on the leaf surface, the size of leaf plates and the mass of plantain's terrestrial organs decrease as the level of air pollution increases. It should be underlined that air pollution causes an increase in the density of stomata in plantain associated with a reduction in the area of the assimilating apparatus and it can be viewed as one of the compensatory mechanisms.

Keywords: *Anatomo- morphological parameters, Compensatory mechanisms, Environmental pollution, Plantago major L., air dust.*

1. Introduction

The current stage of civilization development industrial production has a great impact on nature on a global scale. Pollution of any scale passes from one environment to another through numerous chains of natural links. Plants as autotrophic organisms face the problem at initial stage. Different gases and dust containing various components easily penetrate into plant tissues through the stomata and can directly affect the metabolism in cells, causing chemical interactions at the level of cell walls and membranes.

Dust settling on the surface of leaves impedes light absorption and disturbs water metabolism. Photosynthesis is suppressed, water exchange and many biochemical processes are disturbed, transpiration is reduced, and plant growth and development are generally depressed under the action of pollutants. This directly leads to changes in leaf coloration, necrosis, leaf fall, changes in growth form, etc [1].

The purpose of this work is to study the effect of air dust on anatomo-morphological and biochemical parameters of *Plantago major* L.

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To accomplish this goal, the following tasks should be solved:

1. To evaluate the dust-holding capacity of leaves of *Plantago major* L.
2. To study the effect of dust pollution on the production processes of *Plantago major* L.
3. To find out the dependence between the level of dust pollution and the density of stomata in the epidermis of plantain leaves.
4. To estimate the content of phenolic compounds in leaves of the model species depending on growing conditions.

A first comprehensive study of atmospheric pollution influence by insoluble particles on morpho-anatomical and biochemical features of plantain has been carried out. Accumulation of phenolic compounds and changes in morphometric parameters of leaves in plants can serve as an indicative criterion in assessing the degree of atmospheric air pollution.

2. Literature Review

One of the main indicators of industrial emissions pollution on the environment is vegetation. Being very sensitive to anthropogenic impact the vegetation suffers from the impact of anthropogenic process at a large scale. Dust particles clog the stomatal apparatus of plants, they lead to deterioration of their vital state, thus reflecting in the rate of growth and development of plants [2, 3, 4].

The atmospheric pollution impact on plants is a complex phenomenon affecting first of all biochemical and physiological processes and destroying the ultrastructure of leaf cells. As intracellular structures are destroyed, external, visually observable damage to assimilatory organs and other plant parts begins to appear [5, 6]. Dust particles suspended in the air are deposited on aboveground plant organs by gravitational and electrical forces or by adhesion. The ability of different plant species to trap dust is directly related to the arrangement of leaf plates. In each case, depending on the specific species composition, structure and territorial location, the plant community has a different ability to bioaccumulate [7]. Dust particles have a variety of effects on plants both physical and chemical ones. Chemical influence is caused by the content of water-soluble substances in dust entering the plant they influence metabolism. Dust particles of soot plants are not highly reactive and are considered to be pH neutral. Thus, they have mainly physical effects. Physical impact is associated with the formation of a sheath that prevents normal heat and moisture exchange of the leaf with the atmosphere and reduces the access of light to the plant causing an increase in the temperature of dusty leaves by 1-1.50 ^{0}C. The denser the dust layer, the higher the temperature gradient of the leaf, and despite the increase in resistance to gas exchange, higher transpiration rate occurs. Increased transpiration of dusty plants causes their increased consumption of available moisture from the root-inhabited soil volume and under limited water availability, earlier water deficit happens [8]. Dust reduces air transparency and by decreasing illumination limits carbon nutrition of plants. Dust particles deposited on leaf surfaces act as a screen that reduces PAR "photosynthetic active radiation" access and enhances heat uptake. They can also lead to the clogging of stomatal slits as a result bad conditions of photosynthesis and water exchange appear. Cement dust being extremely harmful forms a dense crust on leaves in a humid environment. At high concentrations of poisonous impurities in the air, plants can get extensive burns and die, and prolonged exposure to low concentrations of gaseous toxins leads to the accumulation of chronic disorders. At the same time, affected plants are less resistant to drought, cold, and pests [9, 10, 11]. At high concentrations of gaseous toxins cells are deformed, cell sap is acidified, chlorophyll and chloroplasts are damaged, cytoplasm movement and enzyme systems malfunction, leading to the destruction of important organic compounds and subsequent cell death [12, 13]. Phytotoxicants entering the leaf are unevenly distributed within the leaf lamina and throughout the plant. Most of them are transported along the xylem to the apex or margins of the leaf plate. Toxic compounds penetrating the cytoplasm are concentrated mainly in vacuoles [14].

Higher plants being physiologically damaged by atmospheric toxicants are often accompanied by burns, necrotic spots, browning of leaves and dying of their edges, formation of ugly forms (wrinkled, twisted, etc.) [15, 16].

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3. Experimental Setup

This section mainly discusses the data processing, selected models, experimental area and evaluation metrics used in the study.

3.1. Materials and Data Processing

The research was conducted in the period of June-July 2024 in the territory of the town Yoshkar-Ola (Remzavodskoy microdistrict). To find out the influence of dust particles on the anatomo-morphometric parameters of *Plantago major L.* leaves, the following districts were selected:

1) control – village of Kadam, Sovetsky district, Republic of Mari El;
2) Karl Libknekht St., garage cooperative "Lada";
3) Heroes of the Stalingrad Battle St, 29;
4) Danilov Boulevard, 2;
5) Kirpichnaya St, 6.

The object of the study was generative specimens of *Plantago major L.*

Ecological and biological peculiarities of Plantago major L.

Kingdom: Plants - *Plantae*
Division: Flowering plants - *Angiosperms*
Class: Magnoliopsida, dicotyledons – *Magnoliopsida*
Order of plants: Mint family - *Lamiales*
Family: Plantain - Plantaginacea
Genus: Plantain – *Plantago*
Species: *Plantago major* L.

The plantain family Plantaginaceae is a small family with 270 species belonging to 3 genera. In CIS "Commonwealth of Independent States" countries 54 species from 2 genera are found.

The genus scientific name is derived from Latin words meaning "foot" and "move" as the pressed plantain leaves resemble the footprint of a foot. According to another version, the name is "propped up by the sole".

Figure 1 shows morphological description of *Plantago major* L.

Figure 1.
Plantain major (*Plantago major* L.).

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(Botanical illustration from O.W. Thome's book "Flora von Deutschland, Österreich und der Schweiz", 1885)

Morphological description. *Plantago major* L. is a perennial herbaceous plant, 15 to 30 cm high, with a rosette of large root leaves on long spines. The stems of the plantain are furrowed. The rhizome is short, vertically arranged, and a bundle of numerous thin roots branches off from it. Flowering shoots (arrows) are glabrous, ascending, up to 30 cm high, furrowed, non-branched. Leaves are glabrous, broadly ovate, with pronounced arc-shaped veining, entire-edged, sharply tapered into a flat broad petiole, collected in a root rosette. Thanks to these veins, plantain leaves do not break and successfully resist trampling. Flowers are small, unsightly, collected in a dense, long cylindrical spike at the top of the stem. The corolla is filmy, light brownish; stamens with dark purple anthers and white filaments, far protruding from the corolla. Fruit is an ovoid boll with 8-16 (34) small angular, brown seeds. It blooms from late May to September, fruits ripen in August - September. One plant produces up to 60 thousand of seeds. It is propagated by seeds.

Places of growth. The homeland of plantain is Europe. The first settlers brought plantain seeds to America. North American Indians called this plant "the footprint of the white man".

Plantago major L. is widespread throughout Russia, except for the northern and northeastern territories, deserts. It grows on wastelands, weedy places, near dwellings, along roads and paths, in vegetable gardens, in meadows, on the banks of rivers and lakes.

3.2. Methods

The following morphometric parameters were analyzed in species of the *Plantago major* L.: mass of above-ground organs (g), leaf lamina area (cm^2). The number of stomata on the leaf surface was estimated as well (pcs/mm^2).

In addition, the level of dust accumulation on the leaf surface was determined (g). Weighing was carried out with an accuracy of 0.001 g on electronic scales HL - 100. The content of phenolic compounds in plantain leaves was determined by titration method in the presence of indigo carmine. Arithmetic mean, arithmetic mean error were used in statistical analysis.

4. Results and their Discussion

Green plants are known to play an important role as an air purifier, depositing up to 60% of dust on their surface in the urban environment.

We have carried out quantitative determination of dust deposited on the surface of leaves of plantain plantains. Figure 2 shows the control group has an insignificant amount of dust deposited on the surface of leaf plates.

In plants growing on Kirpichnaya St. and Heroes of the Stalingrad Battle St., the values of this index increased by 37.5-50.4% compared to the control. The greatest mass of dust particles was recorded on the surface of leaf plates of plants growing on Danilova Boulevard and K. Libknecht St. (43.7-55.1% more than in the control.

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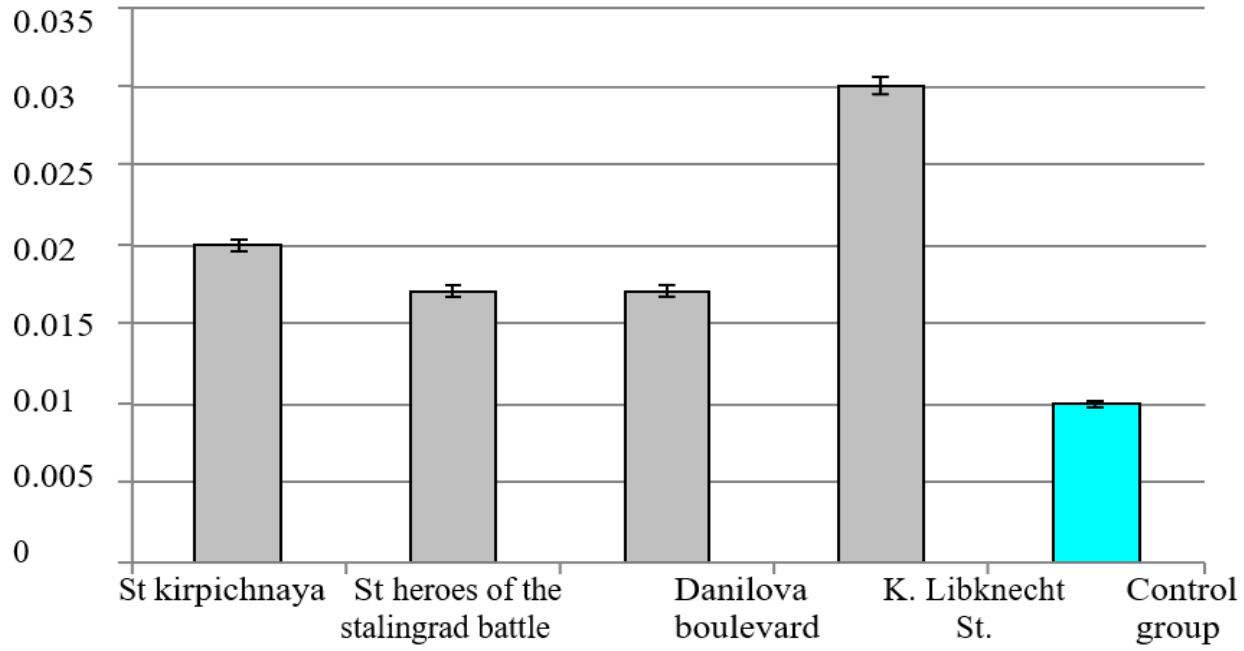

Figure 2.
Mass of dust deposited on the surface of leaves in common plantain in different growing areas.

Thus, the main sources of air pollution in the areas of *Plantago major* L. growth were motor transport emissions and JSC "Joint Stock Company" "Stroikeramika".

In the course of our studies, it was found out that as pollution increased, the leaf plate area decreased in *Plantago major* L. and it is shown in Figure 3.

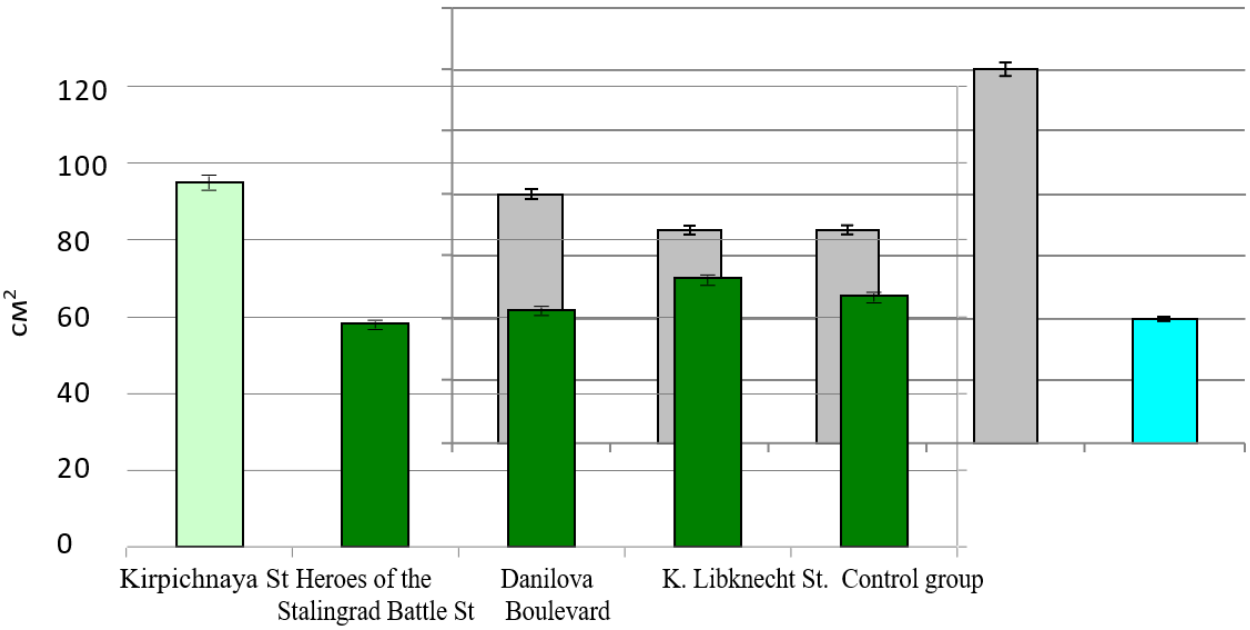

Figure 3.
Leaf lamina area of *Plantago major* L. in different growing areas.

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In the control group the leaf area of generative plants amounted to 95.8±0.07 cm². Plants growing in the area of Remzavod microdistrict showed a tendency of leaf lamina reduction by 26.7-29.3% (Kirpichnaya St., Heroes of the Stalingrad Battle), by 35.4% (Danilov Boulevard). In plants growing on K. Libknecht St., the value of this parameter was 38.0% lower than in the control group .

Uka N, et al., Wagoner, S., Tripathi, A.K, et al., Giri, S, et al., Ncube B, et al studied the assimilatory apparatus, including its morphometric parameters. They found out that under the action of pollution the intensity of assimilation is significantly reduced, symmetry changes and metric indices of photosynthetic organs are reduced, the passage of individual ontogenetic states is accelerated. Thus, the data obtained by us generally correspond to the previously established facts.

One of the indicators of the state of plants, both in natural and anthropogenically disturbed populations is their phytomass.

Plants growing in the control group habitat were characterized by the maximum values of this parameter. Under conditions of atmospheric dust pollution, the biomass of aboveground organs in individuals of the model species decreased, it is shown in Figure 4.

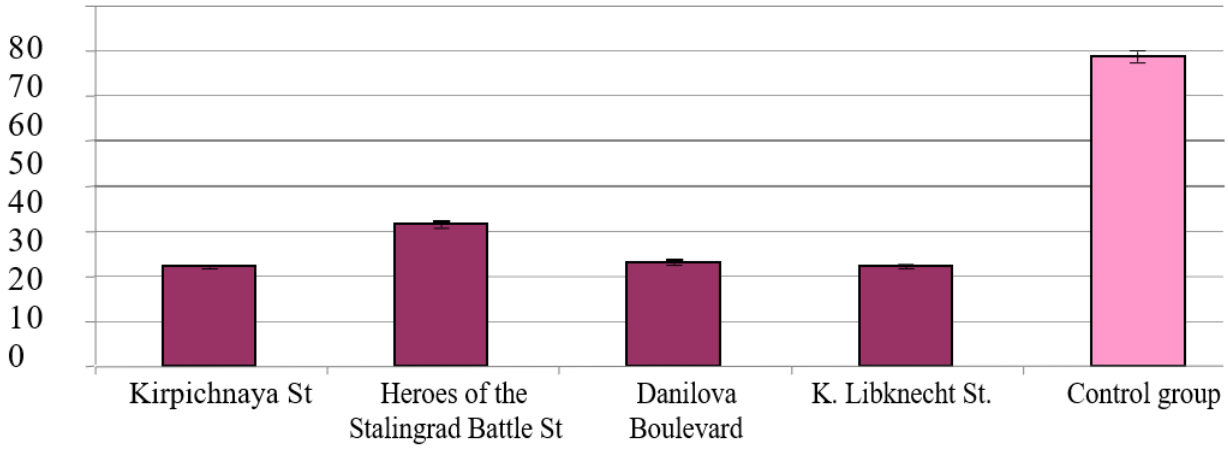

Figure 4.
Changes in aboveground biomass of *Plantago major* L.in different growing areas.

In the control group, the aboveground phytomass of generative plants amounted to 68.9±4.63 g. A decrease in the aboveground phytomass of plants is observed with increasing level of dust pollution.

Thus, the difference with the control amounted to 54.9-64.1% (Kirpichnaya St., Heroes of the Stalingrad Battle St.), 66.9% (Danilov Boulevard), 68.1% (K. Libknecht St.).

Thus, we observed inhibition of growth processes in plants, and, as a consequence, a decrease in the biomass of aboveground organs.

According to the data found by a number of authors [17,18,19.20] in conditions of increased pollution the stomatal chambers of herbaceous plants often contain foreign particles (dust); secretory cells are enlarged associated with a more active removal of toxic substances entering the leaf laminae through the stomata and accumulating in the cells of the folded parenchyma, from which they, in turn, enter the secretory cells.

We analyzed the number of stomata per 1 mm² of leaf surface in Plantago major and common chicory, it is shown in Figure 5.

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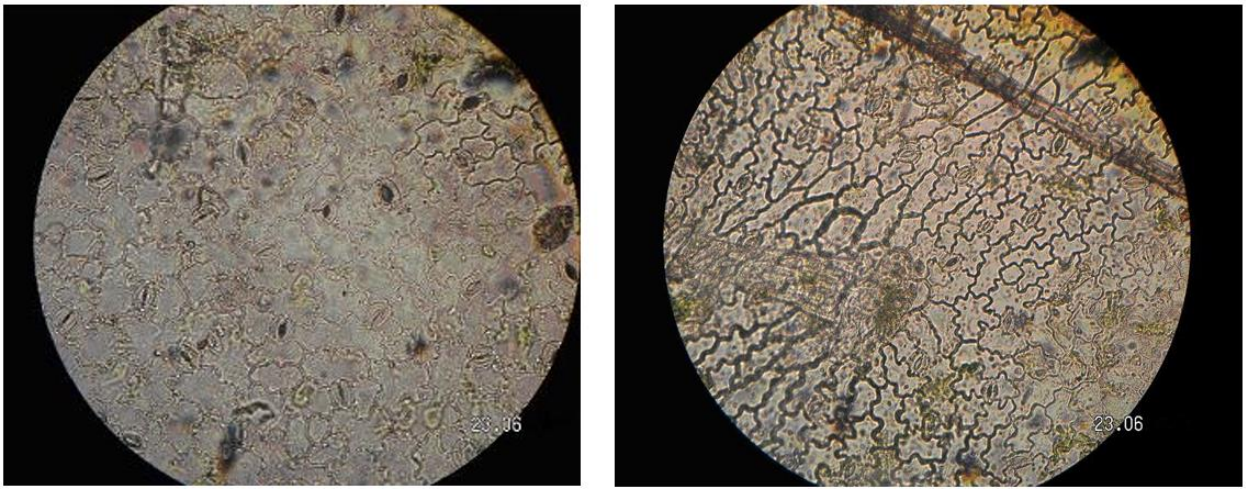

Figure 5.
Stomata of Plantago major growing in the control (a) and on K. Liebknecht St.

In the control group the number of stomata of young generative plants was 16.3±0.09 pcs/mm². Under conditions of dust pollution, an increase in the number of stomata was observed: by 15.3%-21.6% (Kirpichnaya St., Heroes of the Battle of Stalingrad St); by 32.9% (Danilov Boulevard); by 36.3% (K. Libknecht St.) more than in the control group and is shown in Figure 6.

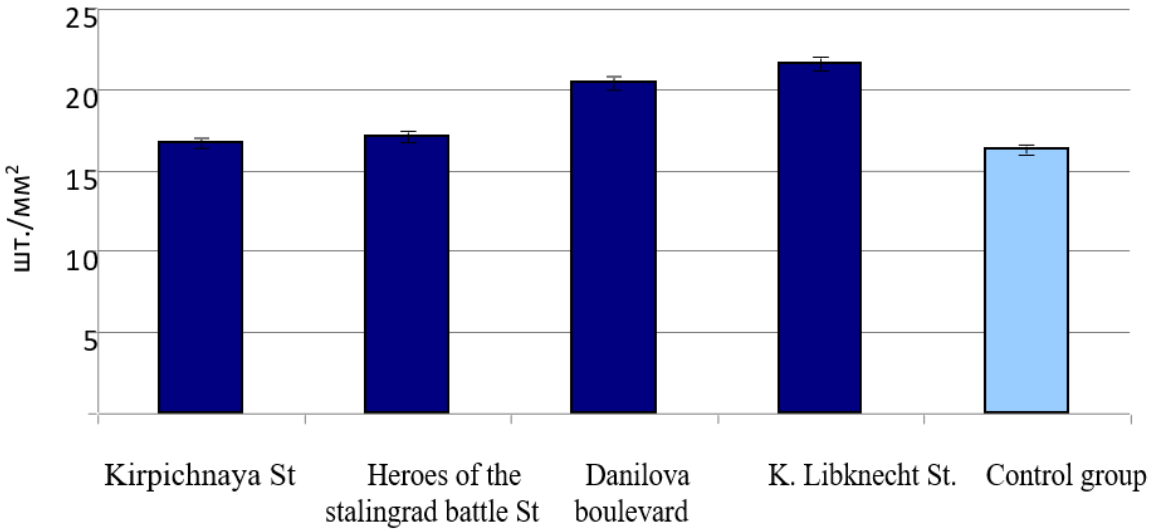

Figure 6.
Number of stomata per 1 mm² of leaf plates of Plantago major in different growing areas.

The increase in the density of stomata per 1 mm² of leaf lamina with increasing pollution is an adaptive restructuring aimed at increasing carbon dioxide diffusion at the "stomata-intercellular" site. This is due to the fact that under conditions of increased dust and gases, the stomatal chambers may contain foreign particles sharply reducing the efficiency of photosynthesis. Thus, an increase in the number of stomata is a compensatory mechanism to increase the efficiency of photosynthesis under polluted conditions.

Our data obtained are in agreement with the studies of the scientists [Mishra, L.C.[21], Nandy, A. at al.[22]; Abu Ziada, M.E.A. at al.[23], Wagoner, S.[24].

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The authors found that the number of stomata increased in herbaceous plants in polluted areas compared to the clean zone.

Phenolic compounds play an important role in the healing of mechanical injuries, in the protection of cells from penetrating radiation, free radicals, oxidants, mutagens.

During our study, we have found out that the lowest concentration of phenolic compounds was in the leaves of the studied species growing on Heroes of the Battle of Stalingrad St. - 0.62±0.046 mg/g dry weight. The concentration of phenols in leaves of plantain big increased 1.3 times on Brick Street and 1.4 times on Danilov Boulevard. The highest amount of phenolic compounds was found in plants of the studied species growing on K. Libknecht St. - 1.35±0.090 mg/g dry weight, i.e. 2.2 times more than in plants growing in control conditions presented in Table 1.

Table 1.
Influence of growing conditions on phenols content in assimilating organs of common plantain.

Research area	Concentration of phenolic compounds, mg/g dry mass
Karl Libknekht St., garage cooperative "Lada";	1.35±0.090
Danilov Boulevard, 2;	0.96±0.048
Kirpichnaya St, 6.	0.80±0.051
Heroes of the Stalingrad Battle St, 29	0.62±0.046
Village of Kadam, Sovetsky district, Republic of Mari El	0.58±0.036

Apparently, under conditions of atmospheric pollution, free radicals begin to accumulate in the leaves of common plantain, mutagens, oxidizing agents, as a result of which the content of phenolic compounds increases. According to analyzed literature Arnon DI., [25], Bénard C., at al. [26], Swami, A. [27] summerzed that the accumulation of phenolic substances under the influence of unfavorable and stressful environmental conditions are known to provide an increase in the stability of the species.

Jochner, S. at al. [20] stated that when the amount of phenolic compounds increases, a protective cover is formed to protect dividing cells from all kinds of damage, preventing their penetration deep into tissues.

5. Conclusion

In species of *Plantago major* L. 10 to 50 mg of dust particles were deposited on the leaf surface. The amount of dust on the leaf surface increased in the following sequence: control → Kirpichnaya St., Heroes of the Stalingrad Battle st. → Danilov Boulevard → K. Libknecht St., which is due to the peculiarities of dust particles deposition at the level of the herbaceous layer. When the level of atmospheric air pollution increased, the size of leaf plates and the mass of ground organs of plantain large decreased, which is explained by the inhibition of growth processes in plants. The effect of pollution on stomata density in *Plantago major* L. was expressed as an increase in their number in the following order: control → Kirpichnaya St., Heroes of the Battle of Stalingrad St. → Danilov Boulevard → K. Libknecht St., which is associated with a reduction in the area of the assimilating apparatus and partial dysfunction of stomata under pollution conditions. The greatest amount of phenolic compounds is accumulated in the leaves of plants growing under anthropogenic stress. At a distance from the source of atmospheric air pollution the concentration of phenols in leaves decreases by 1.3-2.2 times.

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