Formation of pollen of different quality in some fruit trees under the influence of technogenic pollution

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Abstract. This article focuses on investigating the impact of anthropogenic factors on fruit-bearing trees - specifically, apple, cherry, apricot, walnut, and quince - in urban environments. The study delves into the influence of technogenic pollution on these plant species, conducting an ecological comparison of heavy metal accumulation in plants situated in both polluted and relatively dusty environments. Through a comprehensive analysis of scientific data, the article provides valuable insights for biomonitoring and environmental protection. The findings contribute to a deeper understanding of the intricate interactions between urbanization-induced pollution and plant life, offering crucial information that can inform measures for safeguarding the environment. The work represents a significant advancement in the realm of environmental science, shedding light on the ecological implications of human activities on the plant kingdom within urban landscapes.

1 Introduction

The implementation of the Presidential Decree in Uzbekistan involves a series of concerted efforts to enhance environmental conditions across regions. Biologists and ecologists are actively engaged in research to understand the ramifications of both global and local environmental changes on plant biodiversity. In recent years, a significant emphasis has been placed on comprehensive environmental monitoring to assess the state of the environment accurately. To achieve this, it is crucial to ascertain the natural concentration of various pollutants not only in soil and water but also in plant organs across different systematic groups. This knowledge forms the natural baseline against which anthropogenic pollution levels can be measured. Utilizing an array of indicator signs, encompassing ecological, morphological, biological, and structural parameters at the local level, enables not only ecological zoning of the country but also systematic monitoring of these indicators. This ongoing monitoring facilitates the tracking of environmental dynamics and

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informs the formulation of specific measures to stabilize environmental conditions in industrial areas, enabling more in-depth studies with additional environmental indicators.

Biological monitoring assumes a pivotal role in this context, offering a more efficient means compared to labor-intensive physical and chemical measurements of environmental pollution. Bioindication methods directly assess the impact of pollutants on individual ecosystems. The integration of biological monitoring methods significantly enhances the precision of forecasting the state and trends of environmental crises primarily driven by human activities.

An important element of biological monitoring is the assessment of the state of vegetation, which is highly sensitive to various types of environmental pollution. According to Yu.A.Izrael [8], V.I.Artamonov [1], Meagher et. el., plants should be considered as reliable indicators of pollution of the atmosphere, hydrosphere and other components of the biosphere.

The annual increase in construction and municipal waste from population activities contributes to the contamination of soil, vegetation, surface water, and groundwater with pesticides and heavy metals. Addressing the challenge of environmental cleanliness in cities and major industrial centers of the republic underscores the importance of biological and chemical monitoring. These monitoring approaches, through a comprehensive analysis within the "environment-soil-plant-cellular structures" system, are pivotal in assessing the state of natural ecosystems. This assessment is crucial for the development of a strategic set of measures aimed at preventing the consequences of both technogenic and anthropogenic activities.

The advancement of elements within biological monitoring systems for environmental assessments in Uzbekistan holds significance. It serves as a foundation for evidence-based measures in environmental protection, the judicious use of natural resources, and the implementation of environmentally friendly technologies. The integration of these monitoring methods plays a vital role in informed decision-making, contributing to sustainable environmental practices and fostering a scientific approach to mitigating the impacts of human-induced environmental challenges. The investigation into the role of woody and other vegetation types as phytoindicators of polluted biotopes and the optimization of the environment is of significant scientific and practical interest. Recent research indicates that the widespread use of plants capable of thriving in biotopes polluted with heavy metals, organic compounds, and other toxic substances can serve as effective and economical means of cleansing technogenic and highly saline biotopes. Notably, substantial progress in this field stems from the accelerated development of transgenic engineering and the production of synthetic plants employed as phytoindicators for various types of environmental pollution. Literature reports highlight that numerous woody plant species, including varieties of fruit trees, exhibit a high adsorption capacity for absorbing various ions of toxic substances. Remarkably, these plants maintain the potential for growth, normal reproduction, and fruiting in conditions of increased pollution. In the context of a modern city, particularly an industrial center with its specific production activities, individuals are exposed to a diverse range of natural, social, and biological factors that significantly influence adverse changes in their health. A highly informative indicator of technogenic pollution in the city of Tashkent is the condition of the soil cover, where metals tend to accumulate. Atmospheric fallout is the primary source of metal introduction into the soil, and concentrations of toxic elements in soils serve as key determinants of environmental distress levels in areas and pose risks to public health. The work of P.K. Zakirov, E.I. Girshevich and others is devoted to the question of how plants behave in an urban environment [16]. It examines the environmental significance of green spaces in an industrial city.

Intense automobile traffic in cities located in areas with a high potential for air pollution leads to constant and high pollution of highway areas with carbon monoxide, high temperatures and levels of solar radiation during the hot period, causing overheating of the body, and the consumption of large amounts of water, carbohydrates and fiber, reduces the body's resistance. In summer, under the influence of UV radiation and air pollution with nitrogen oxide, hydrocarbons, sulfur dioxide (vehicle exhaust), photochemical reactions may occur, during which substances are formed that are more toxic than the original impurities entering the air basin.

Various pollutants have been found to slow down the growth and development of plants. After their action ceases, biological processes in plants normalize.

The degree of damage to plants by pollutants is also influenced by various meteorological factors: temperature, air and soil humidity, illumination, as well as the chemical properties, concentration and time of action of the pollutant. In addition, the degree of damage depends on the sensitivity of the species, time of day and growing season [12-13].

In the studies of M.V. Bulgakov [4], pollution is identified with the ability of plants to survive in unfavorable factory conditions (survival). Indicators such as a decrease in seed germination, growth energy and plant productivity, a method of biological tests and some physiological and biochemical indicators can also be used.

Damage to leaves and oppression of plants can be caused by soil salinity, drought, high and low temperatures, and infections. Therefore, many scientists point to the need to study the nature of air pollution or determine the presence of toxic substances in leaves.

Emissions of harmful compounds (fluoride, chlorine sulfur, hydrogen chloride, ammonia, arsenic oxides and other substances) disrupt the normal rhythm of plant life. There is information that mobile forms of pollutants disrupt the normal regime of physiological processes (photosynthesis, respiration), causing damage and death of plants. Damaged plants are less resistant to unfavorable conditions (drought, salinity, etc.). Under the influence of pollutants, including heavy metals, enzyme activity decreases, chloroplasts are destroyed, plasmolysis and dehydration of damaged cells occurs. The degree of plant resistance to gases depends on the nature of the plant itself, the phase of development, gas concentration, weather conditions, etc. [2]. Plants that are more tolerant of unfavorable conditions (drought, salinity) are also more resistant to gas influences [1].

In this regard, it is very important to correctly select the range of plants that are resistant to pollution, including industrial and urban pollution. The problem of plant resistance to various types of pollution has been of interest to many scientists in the CIS countries and abroad over the past two or three decades. Numerous works summarize experimental materials on the mechanism of action of sulfur dioxide and other toxicants on plants and show the role of biological, anatomical-morphological, physiological-biochemical and biophysical characteristics of plants in resistance to pollutants. The effects of gas on woody plant species of different resistance have been studied. It has been established that atmospheric pollution by phytotoxic industrial emissions causes disruption of water metabolism in the same direction as drought. In this regard, some authors V.S. Nikolaevsky, V.V. Firger [12-13] came to the conclusion that plants with an ordered structure of intracellular water, increased water-holding capacity, high heat resistance of tissues or the ability to actively regulate the temperature of a place, turn out to be more resistant to atmospheric drought and industrial pollution.

Toxic substances enter plant tissue through the aerial part (open stomata, damaged leaf cells, lentils, young shoots), as well as through the root system [5]. Next comes their integration into cellular systems or partial disruption of the physiological processes of the plant, the use of methods for determining the content of pigments, ascorbic acid, chlorophyll fluorescence, measurement of relative dry mass, determination of peroxidase activity in sensitive species (sycamore, ash, poplar, walnut) allow for bioindication studies anthropogenic pollution on plant objects, as well as assess the level of pollution of the natural environment. Many authors distinguish sensitivity to the action of chemical and physical factors, the processes of microspore formation and pollen germination. The work of V.P. Bessonova examines the influence of heavy metals on the condition and formation of pollen of a number of tree and shrub plants [3].

The results of studying the effect of atmospheric pollution at the Tajik Aluminum Plant (TajAZ) on the physiological and biochemical processes of agricultural crops are discussed in the work of N.N. Norbaev [14], where it is shown that the metabolism of plants is disrupted, leading to a decrease in their productivity. Under the influence of atmospheric pollution of the TajAZ, as noted by N.N. Norbaev, the germination of seeds decreases and their germination is delayed due to the suppression of peroxidase activity, as happens with gamma irradiation. The results of the study by R.M. Talipov et al. showed the negative impact of emissions from industrial enterprises, as well as ore deposits, on living organisms. In this regard, it is necessary to carry out measures to clean up the environment both to reduce the content of toxic elements and to reduce the negative impact of dumps and cinders on the surrounding areas.

However, the work carried out on individual types of natural environments, including fruit trees, is fragmentary; they are not linked together along the entire ecological chain and do not provide a complete picture, even for individual areas of research. In addition, an important problem is establishing the threshold of toxicological effects and determining the relationship between the dose of the toxicant and the response rate of the plant organism, in particular fruit trees, which make up the daily diet of the local population.

The purpose of our research was a comparative study of the degree of sensitivity of some varieties of fruit trees to pollution of urban ecosystems with heavy metals based on a comprehensive system analysis of biological, morphological and physiological indicators. To complete this work, we identified the following tasks:

- Conduct observations of some varieties of fruit trees growing in conditions of urban biotopes of varying degrees of pollution.
- Study biological indicators of pollen.
- Highlight the most representative parameters as phytoindicators of the state of the environment in polluted urban ecosystems.

2 Materials and methods

As research material, we selected 5 species of widespread fruit trees growing in urban biotopes of varying degrees of pollution: Common apricot (Armeniaca vulgaris Lam., Rosaceae family, Sukhani variety); Quince (Cydonia oblonga Mill., family Rosaceae, variety Canning); Common cherry (Cerasus vulgaris Mill., family Rosaceae, Samarkand variety); Walnut (Juglans regia L, family Juglandaceae, thin-shell variety); Domestic apple tree (Malus domestica Borkh., family Rosaceae, variety Renet Simirenko).

The preparation of plant samples for research was carried out according to generally accepted cytoembryological methods [15].

The collection of material for studying pollen was carried out during the period of mass flowering of plants. The buds were collected on the eve of the flowering day from the branches of the middle tier. Anthers for cytological analysis were fixed according to Carnoy, and crushed acetocarmine preparations were prepared using the acetocarmine smear method. Pollen measurements were carried out under an MBI-3 microscope using an eyepiece micrometer. The dust grains were sketched using a drawing apparatus, then measurements and mathematical processing of the obtained data were carried out.

A method for extracting heavy metals (lead, copper) from soil, from fruits, from roots in the form of nitric acid salts and determining them by atomic absorption method. When measuring the content of mobile forms of heavy metals from soil, fruits, and roots, the following measuring instruments were used:

- Atomic absorption spectrophotometer with flame atomization type AAS-3, AAS-5 (Germany), Hitachi (Japan); with laser-induced plasma Hewlett-Packard and others;
- Analytical scales VLKT-500, 2nd accuracy class according to GOST 24104.

Statistical processing of the factual material was carried out using generally accepted criteria [6, 9, 10]. When calculating and analyzing data, appropriate statistical data processing software (Microsoft Excel) was used.

3 Results and Discussion

One of the methods for assessing the impact of industrial emissions and exhaust gases on terrestrial vegetation is anatomical and cytological.

The internal structure of the generative organs of a plant organism is one of the most conservative, since the generative organs are much less variable compared to the vegetative ones. The exceptions are the processes of microsporogenesis, gametogenesis and pollen germination. These developmental stages are sensitive to changes in environmental conditions. Indicators of adverse effects are disruption of the correct course of meiosis in anthers, an increase in the amount of sterile pollen, changes in the size of pollen grains, and pollen viability. The processes of microspore formation and pollen germination are very sensitive to the action of chemical and physical factors. However, the influence of industrial emissions on the formation of pollen, its condition and the possibility of using it to assess environmental pollution, in particular with heavy metals, has not been sufficiently studied. Studying this issue will allow us to come closer to understanding the processes of generative development and seed productivity of woody and cultivated plants under conditions of environmental pollution.

The work of V.P. Bessonova [3] examines the influence of heavy metals on the condition and formation of pollen of a number of tree and shrub plants. It was found that significantly more metals accumulate in the flower buds of experimental plants than in the control, especially iron, manganese, lead and chromium. A decrease in the size of pollen grains was observed; only in white willow they increased. The change in pollen size is associated with a disruption in the process of growth and cell division during the formation of primary archesporium cells and during the formation of microspore tetrads. Morphological differences in the quality of pollen and the formation of wrinkled, destroyed, and giant grains were observed.

A study of microsporogenesis in common apricot and common lilac indicates the negative effect of environmental pollution on this process. In anaphases and telophases of the first and second divisions of meiosis, single and multiple bridges and chromosome lag are observed, which is probably associated with a disruption of the spindle. This leads to genetic variation in the quality of pollen. The presence of heavy metals in the pollen germination environment inhibits its germination and the growth of pollen tubes. The processes of pollen formation in common lilac, common apricot, large-leaved linden, and silver birch are most sensitive to environmental pollution, as evidenced by the highest percentage of pollen sterility and the degree of change in its size. V.P. Bessonova [3] recommends pollen of these species for bioindication of environmental pollution with heavy metals.

Our work presents the results of studying the impact of environmental pollution with heavy metals (copper and lead) on the morphology of pollen of a number of fruit trees.

We have established that under normal external conditions for a given plant, almost all the pollen formed in the anthers is completely normal and fertile, that is, capable of fertilization. Morphologically it looks more or less homogeneous. Under the influence of unfavorable external conditions, in particular pollution, the normal development and structure of pollen can be disrupted to varying degrees. This leads to the appearance of sterile pollen, characterized by deformation and degeneration of nuclei, cells and cytoplasm. In the presence of significant sterility of pollen, the fertility of the plant is reduced to a greater or lesser extent, since an insufficient amount of normal pollen cannot fully ensure fertilization in all ovules and contribute to the development of all ovules into seeds.

Environmental pollution with heavy metals is an unfavorable external environment for plants, which affects pollen fertility (Table 1).

Table 1. Pollen fertility (in%) (n=20).

Type	Control	Experimental site
Armeniaca vulgaris (apricot)	94.02 ±0.5	88.10±0.7
Cydonia oblonga (quince)	84.00±0.6	82.05±0.3
Cerasus vulgaris (common cherry)	88.88±0.5	76.19±0.2
Malus domestica (homemade apple tree)	89.18±0.4	83.33±0.5

Note: p>0.05

As can be seen from Table 1 and Figure 1, pollen fertility decreases under polluted conditions. In the common cherry, the percentage of sterile pollen increased by 12%, and in the oblong quince - only by 2%, which indicates the greater resistance of quince to adverse environmental conditions, including pollution.

In case of disruption of normal development, pollen looks morphologically heterogeneous and is of different quality. On micropreparations prepared from the anthers of tree buds grown in conditions with a high content of lead and copper, along with very small pollen grains, giant dust grains and all sorts of transitions between these extreme limits are found. Both dwarf and giant pollen are usually sterile and degenerate early in development. The dust grain shrinks, the nuclei and cytoplasm are destroyed, the pollen becomes empty, and therefore sterile.

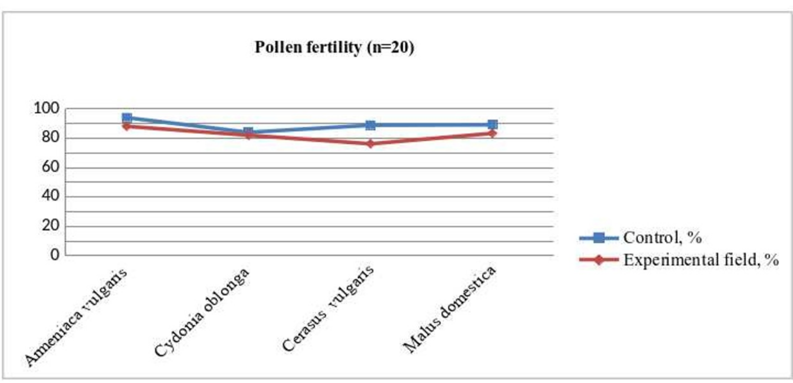

Fig. 1. Pollen fertility.

Table 2 shows the results obtained from measuring pollen grains. According to average indicators, the sizes of dust particles in the experimental and control variants differ slightly (P>0.05). But under conditions of environmental pollution, pollen sizes vary much more than in plants in an unpolluted area. The greatest variation in the size of pollen grains among the studied species is observed in walnut and common cherry, the smallest in oblong quince and domestic apple.

Table 2. Effect of environmental pollution on the size of pollen grains (μm).

Type	Control		Experimental site	
	M±m	min - max	M±m	min - max
Armeniaca vulgaris (apricot)	36.58 ±3.02	30.13-40.88	34.85±3.20	21.88-54.69
Cydonia oblonga (quince)	28.90±2.65	23.00-30.95	25.61±2.21	19.23-35.90
Cerasus vulgaris (common cherry)	27.33±2.61	23.08-35.90	24.18±2.10	12.82-38.46
Malus domestica (homemade apple tree)	26.28 ± 2.51	23.07-30.78	22.32±2.01	15.38-38.46
Armeniaca vulgaris (apricot)	28.05±2.03	21.88-33.75	27.58±2.43	25.00-34.38

Note: $p>0.05$

Thus, in plants growing under conditions of environmental pollution with heavy metals, there is a disruption in the formation of pollen grains and the formation of morphologically different quality pollen. Of the species studied, common cherry, walnut and common apricot turned out to be more sensitive to pollution. In this regard, it is possible to recommend the pollen of these species as bioindicators of environmental pollution with heavy metals. In addition, such studies may be useful in selecting tree species for planting in contaminated environments.

Equations should be centred and should be numbered with the number on the right-hand side.

4 Conclusion

A comprehensive ecological-biological, structural-morphological and physiological approach to the study of fruit trees is a significant contribution to the development of a strategy for adaptation and conservation of the gene pool of valuable varieties of fruit trees to various types of pollution (industrial, technogenic, exhaust gases, dust, gas pollution, etc.) and anthropogenic -transformed urban ecosystems.

The study of the morpho-anatomical, physiological and chemical (concentration of various heavy metal ions in plant tissues) characteristics of various varieties of fruit trees made it possible to identify some mechanisms of adaptation and norms of plant reaction to the harsh conditions of integral pollution of urban ecosystems, which is an important link in the creation of new highly productive and tolerant to contamination of varieties and solving zoning issues, and also contributes to practical recommendations for increasing the efficiency of fruit growing development.

The results obtained will contribute to the development of scientific and theoretical foundations of metalhalophytism, with subsequent application in practical recommendations for zoning and the creation of orchards away from strong foci of pollution of urban ecosystems. The database on the components of biological and chemical monitoring of the state of the environment will serve as the basis for the adoption of scientifically based measures in the field of environmental protection, rational use of natural resources and the introduction of environmental technologies.

A modern highway is a complex system of technical structures designed to ensure high speeds, intensive and safe traffic. Toxic substances emitted by cars accumulate in growing crops and then enter the human body along with food. Due to the fact that one of the most important functions of green spaces in cities, along with recreational, structural-planning and decorative-artistic, is sanitary and hygienic, which consists in cleaning the environment from toxic substances. For urban landscaping, plants should be selected that are not only decorative, but also capable of actively absorbing harmful gases and adsorbing dust. For this reason, it is advisable to plant trees and shrubs along roads that have a pronounced ability to absorb harmful substances. An example of such plants are wide-crowned, durable: oak, chestnut, ash, maple, etc.

Taking into account the increased traffic load on the busiest highways, today it is better to plant fruit trees at least 300-500 meters from the road. But we must remember: different fruit trees accumulate harmful emissions in different ways. As mentioned above, in the city conditions, at present, when landscaping new highways created, it is necessary to use ornamental trees with sanitary and hygienic properties.

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