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Morphological variability and fertility of *Syringa josikaea* pollen under industrial pollution of the Arctic city

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Abstract. The article presents the results of study of the morphology and embryology of *Syringa josikaea* pollen in the conditions of a cold climate and industrial pollution in the city of Murmansk. Four test sites were laid in the city from the North to the South. During the period of blossoming of lilac, flowers with mature pollen were collected. After staining by acetocarmine, palynological studies and fertility tests were carried out. The shape, size, number of apertures and furrows of pollen, developmental disorders, fertility were studied. High morphological variability and large proportion of sterile pollen were revealed in the North and Central districts of the city of Murmansk, where industrial enterprises are located.

1 Introduction

Monitoring of plants pollen of urban areas is of great interest for the ecological studies and environmental health. Many plant species are used as biomonitors and bioindicators of air pollution due to the accumulation of pollutants. The impact of pollutants leads to disruption of the size and shape of pollen grains, formation of the sterile pollen [1, 2]. In the Euro-Arctic region of Russia the studies of morphological variability and embryological state of pollen of woody plant species (*Pinus sylvestris, Larix sibirica, Sorbus gorodkovii*) were carried out in the cities of Murmansk, Severomorsk, Monchegorsk, Zapolyarny and Apatity [3–5].
The purpose of the study is to research the morphological variability and fertility of *Syringa josikaea* pollen under environmental pollution and extreme climate of the city of Murmansk.

2 Material and methods

Syringa josikaea J. Jacq ex Rchb. (*Oleaceae* Juss.) is an endemic shrub of the West Carpathians with a narrow range, is endangered [6]. Hungarian lilac is ornamental, fast-growing, highly drought- and frost-resistant species, its ecological plasticity determined its successful introduction in the North of the European part of Russia [7]. The seedlings of Hungarian lilac for the purpose of introduction in the regions of the Far North were brought

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to the Polar-Alpine Botanical Garden in 1936 from the Botanical Garden of Leningrad [7]. In 1940 *S. josikaea* was planted in the cities of Murmansk and Monchegorsk.

The city of Murmansk is largest ice-free port of the Russian Arctic, located in the Atlantic-Arctic temperate climate zone. The climate is formed under the influence of the warm North Atlantic Current. Average temperature of January–February is –10–11°C, average temperature of July is +12−13 °C. The average annual precipitation is 500 mm. Snow cover continue for 210 days and melts in May. Growing season at the latitude of Murmansk is 80–90 days. Polar night is from December 2 to January 11, polar day – from May 22 to July 22. In summer 24-hour lighting causes intensive growth of introduced species. The main sources of pollution of the city are Murmansk boiler houses, Murmansk Sea Commercial Port, incinerator, auto transport. In recent years the quality of the environment is deteriorated due to increasing of the volumes of open-pit coal transshipment and its crushing by the Murmansk Sea Commercial Port, using of low-quality fuel oil by local thermal power plants, increasing of traffic load. Main pollutants are soot, formaldehyde, volatile organic compounds, saturated hydrocarbons, heavy metals [8].

The experimental sites were laid from the North to the South of the city:

P1 – the square near the Mir shopping center (figure 1) in the vicinity of industrial zone of Murmansk (Leninsky district).

P2 – the public garden on the Leningradskaya Street close to the railway station and the Murmansk Sea Commercial Port (Oktyabrsky district).

P3 – planting of Hungarian lilacs near the bus stop "Autopark" near the Kola Avenue – main highway of the city (Pervomaisky district).

P4 – the public garden near the bus stop "Shevchenko Street" in the vicinity of Kola Avenue (Pervomaisky district).

As the control site were chosen the plantings of lilac in the settlement of Safonovo (19 km North- East of Murmansk), located on the shore of the Kola Bay of the Barents Sea, far from roads and industrial enterprises.

The city of Murmansk was built in 1916 on the shore of the Barents Sea (68°58′ N; 33°05′ E.). Public gardens in Murmansk were created in the 40–80 years of XX century. The garden on the Leningradskaya Street (P2) is the oldest botanical object of the city, in 1940 the first seedlings of Hungarian lilac were planted there. Plantings in the park near the "Mir" shopping center (P1) date back to 1968 (figure 1). The public garden near the Pervomaysky District Administration was laid in 1979 (P 4 – Schevchenko Street). In the settlement of Safonovo (control site), Hungarian lilac was planting in the square after the creation of the Northern Fleet Museum in 1976. At all test sites, *S. josikaea* is one of the dominant species. It is represented mainly by old (41–60 years or more) and middle-aged (up to 40 years) shrubs. At all sample sites, plants with spreading crowns of 3–4 m high are predominate.

Fig. 1. Hungarian lilac in the public garden near the “Mir” shopping center (The author of photo – Darya Morozova)

On each of the test sites 10 bushes of Hungarian lilac were marked. Picking of flowers of *S. josikaea* with mature pollen was carried out in early July. All material was placed in paper bags and stored at room temperature. Palynological study was carried out using light microscope "Microlife" at magnifications of 160 and 640 times. Pollen was stained by acetocarmine. Fertile pollen stained by acetocarmine become a crimson or dark crimson color, sterile – colorless. The morphological features of pollen grains of *Syringa josikaea* were research: the shape, sculpture of exine, number of apertures and grooves, symmetry, color. 500–900 pollen grains from each site were studied. Pollen with developmental disorders, if there was one difference from normal, was considered as anomalous (teratomorphic). The size of pollen was measured using an eyepiece micrometer, the length of polar axis and equatorial diameter was determined.

3 Results and discussion

Normal pollen grains of *Syringa josikaea* are tricolpate, spheroidal or ellipsoidal; in projection from the pole are three-lobed, from the equator are round or elliptical (figure 2). The sculpture is mesh. The exine is two-layered, thick is 3.0–4.1 μm [9]. Number of apertures – 3; the state of aggregation more often is monadic.

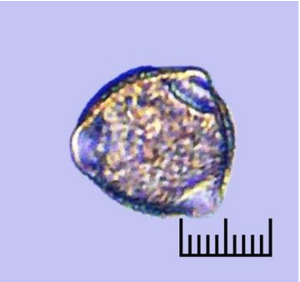

Fig. 2. Normal pollen grain of *Syringa josikaea.* The scale line in the micrographs corresponds to 17 μm. (The author of photo – Darya Morozova)

The study show, that in the city of Murmansk pollen grains of *S. josikaea* have significantly smaller sizes than in other regions of Russia, and Europe. Size of Hungarian lilac pollen in Murmansk: polar axis 30.1–31.7 µm, equatorial diameter 27.2–28.2 µm. In Sankt Petersburg the size of polar axis is 37.1 µm, equatorial diameter 34.7 µm [1]. In the Eastern Europe: polar axis 32.0–40.1 µm, equatorial diameter 36.0–44.8 µm [9].

In all tested samples in the city of Murmansk, normal and teratomorphic pollen grains were identified. The content of normal pollen varies in the range from 63.9 to 91.5%, in the control – 74.5% (figure 3). Teratomorphic pollen of *S. josikaea* differ from normal by size, shape, number of apertures, grooves, changes of exine. The ratio of teratomorphic pollen in the samples varies from 8.5 to 36.1% (figure 3). High content of anomalous pollen was found in the samples of experimental sites of the "Mir" shopping center – 36.1% and the Leningradskaya Street –31.6%. “Mir” shopping center is located in the north of the city, in the vicinity of industrial zone. Public garden on the Leningradskaya Street is in the center of the city, close to the Murmansk Commercial Sea Port and railway station, where various mineral raw materials (coal – 93,5%, apatite, manganese ore, iron pellets) are transheeped. O. F. Dzyuba [1] note, that natural polymorphism of pollen of *S. josikaea* varies between 1–10 %, in polluted environment this indicator can increase up to 100%.

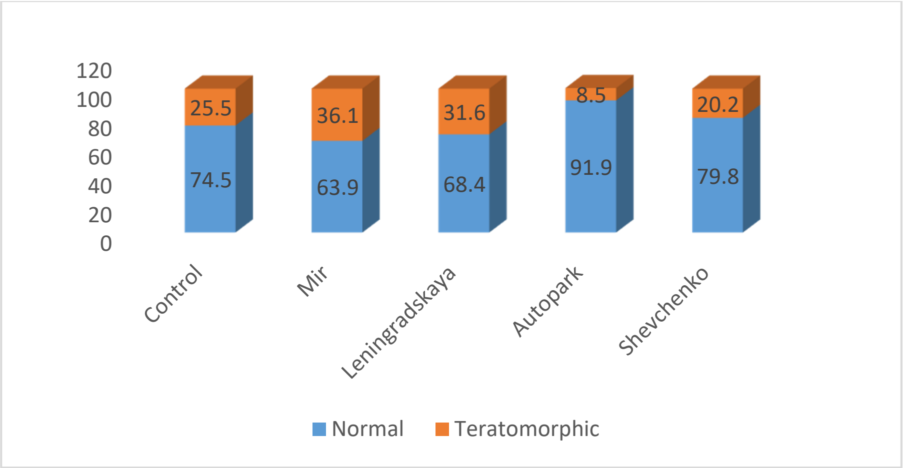

Fig. 3. The ratio of normal and teratomorphic pollen of *Syringa josikaea* in the city of Murmansk (%)

Palynological analysis revealed high morphological variability of Hungarian lilac pollen, a total of 14 tetramorphs were identified. Most often were the pollen grains with gap or thickening of the exine, without apertures, asymmetrical, dwarf. Hypertrophied pollen without apertures, with the ruptures (0.7–1.0%) (figure 4 A) or thickeners of exine (figure 4 B) were found in the samples from the experimental sites of the Mir shopping center and the Leningradskaya Street. Also, in this tested samples were identified dwarf, spherical pollen without apertures, with a triradiate fissure in the exine (1.5–2.0%) (figure 4 C). Such pollen grains indicate high levels of environmental pollution [10].

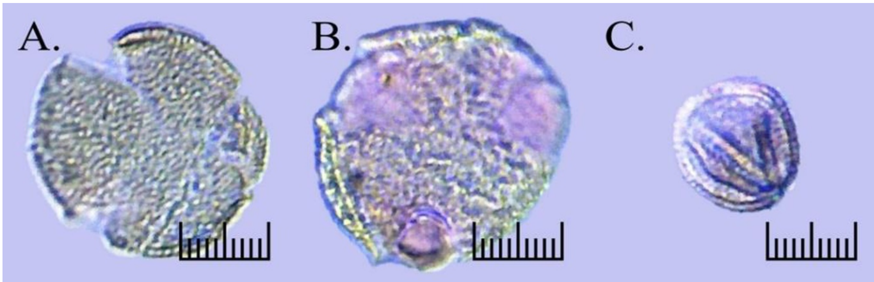

Fig. 4. Teratomorphic pollen grains of *Syringa josikaea* in the city of Murmansk. The scale line in the micrographs corresponds to 17 µm. (The author of photo – Darya Morozova)
A – hypertrophied, without apertures, with the ruptures of the exine. B – hypertrophied, without apertures, with a thickened exine. C – dwarf, spherical, without apertures, with a triradiate fissure in the exine.

Analysis of the embryological state of lilac pollen showed that all samples contained fertile (colored) and sterile (colorless) pollen grains. The proportion of fertile pollen varies among the experimental sites from 63 to 92%. The largest content of such pollen grains was detected in the Pervomaisky district, in the south of the city: bus stop "Autopark" (92%) and the Shevchenko Street (82%) (figure 5).

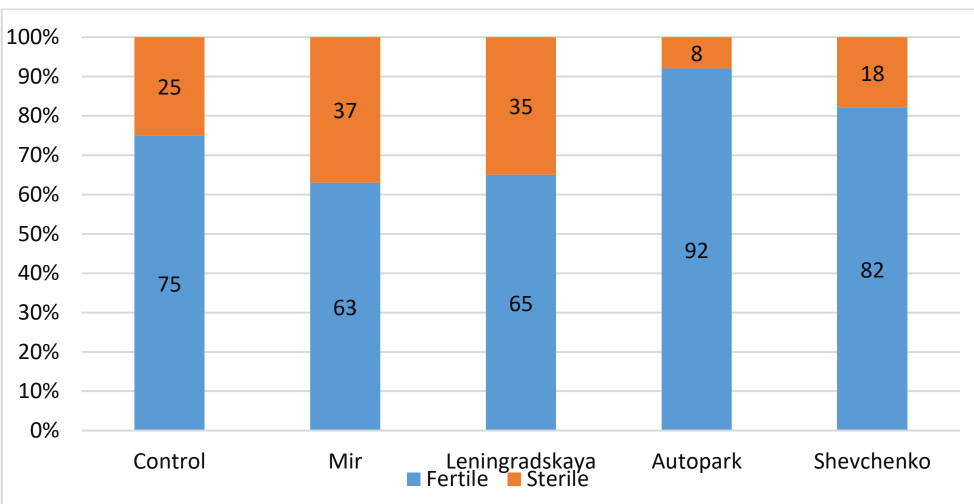

Fig. 5. Ratio of fertile and sterile pollen grains of *Syringa josikaea* in the city of Murmansk (%).

The proportion of sterile pollen changes from 8 to 37% (figure 5), its large content was identified in the samples of the Mir shopping center (37%) and the Leningradskaya Street (35%). Many authors note a high content of sterile pollen of various plant species in urbanized areas, especially in the vicinity of industrial enterprises [2, 4, 5]. A high content of sterile pollen is an indicator of environmental pollution and the presence of mutagens that cause genetic disorders. The study of microsporogenesis of *S. vulgaris* [11] under industrial pollution showed various disturbances during divisions in meiosis, the release of individual chromosomes and fragments outside the division spindle. Pollen fertility is under the control of both nuclear and cytoplasmic genes. Cytoplasmic male sterility occurs, as a result of mutation of the mitochondrial genome, which leads to degeneration of anthers or the formation of abortive (sterile) pollen [2].

4 Conclusion

Palynological analysis of *S. josikaea* in the city of Murmansk revealed a high morphological pollen variability. In tested samples were identified 14 teratomorphs. The most of them were found in the North and the Center of Arctic city. At the same sites, in the samples was revealed a high content of sterile lilac pollen. Pollen sterility caused by industrial pollution of the environment is a large environmental problem, connected with overall productivity of plant species. Palynological studies carried out in the city of Murmansk indicate that the Leninsky district on the North and Oktyabrsky district in the Center of the city are highly polluted and environmentally unfavorable.

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