Teratomorphism of pollen of *Larix sibirica* Ledeb. (*Pinaceae* Lindl.) in the Arctic urbanized territory

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Abstract

This article presents data of palynological research of *Larix sibirica* Ledeb. (*Pinaceae* Lindl) in the Arctic climate of Murmansk city, located in the Far North of Russia. The purpose of this study is to research the teratogenesis of the *Larix sibirica* pollen in the conditions of the Arctic climate and technogenic pollution of the city of Murmansk and holding the palynoindication of the environment. In the tested samples of pollen of *L. sibirica*, five morphological anomalies of the development were defined: pollen without protoplast, with plasmolysed protoplast, with damaged exine, giant pollen grains and dwarfed. The proportion of teratomorphs in the samples varies from 76 to 81%, which is above the control values of 2.5 – 3 times. Most of the abnormal grains are represented by pollen with plasmolysed protoplast (58 – 64%) and without protoplast (11 – 18%). Giant, dwarf pollen grains and pollen with exine damage are much less common. High level of teratogenesis of *L. sibirica* allows us to draw a conclusion about the critical level of pollution of the city environment.

Key words: palynomorphology, teratomorphism, *Larix sibirica,* pollution, Arctic

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Introduction

Ecological palynology is one of the youngest directions in palynological science. Pollen can provide valuable information on plant phenology, ecophysiology, population dynamics and gene flow (Savolainen et al. 2007). One of the main directions, leading in ecological palynology, is the study of the effect of pollutants of an urbanized environment on the allergenic properties of pollen (Grundstrom et al. 2017, Sedghy et al. 2018). At the present time, also various methodological approaches are being developed to assess structural and functional changes in the male generative system of plants for the indication of environmental pollution. It is known, that in conditions of ecological stress, the processes of teratogenesis are intensified and the number of pathologies of pollen grains increases significantly.

Palynoindication of the environment on the basis of detection of teratomorphic pollen is actively developing in Russia (Dzyuba 2006). Studies are conducted on plants of different life forms – woody and herbaceous, mainly in the boreal zone. Among

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woody plants, teratomorphism of pollen is studied mostly in the following species: *Pinus sylvestris* (Elkina et Markovskaya 2007, Erokhina et al. 2011, Vasilevskaya et Petrova 2014), *Tilia cordata*, *Quercus robur, Acer tataricum, Ulmus glabra, U. laevis* (Dzyuba 2006), *Syringa josikae* (Morozova et Vasilevskaya 2017). Among herbaceous plants: *Triticum sp*. (Kozlova et Zlotnikova 2014), *Alopecurus pratensis, Dactylis glomerata, Plantago major, Chenopodium albium* (Dzyuba 2006) are used for the same studies. Of the great interest are researches of the processes of microsporogenesis in various species of conifers, which are prone to industrial pollution (Kalashnik et al. 2008, Kalashnik 2011). All the northern taiga species (*Pinaceae*) annually stably produce a number of anomalous pollen grains due to disturbances in meiosis of microsporocytes and endogenous microgametophytogenesis (Surso 2013).

The genus *Larix* Hill is represented in the world flora by 10 species, which are widely distributed mainly in the mountainous, cold regions of the Northern Hemisphere (Shearer 2008). Changes, occurring in the reproductive sphere of larch under the influence of technogenic pollution have not been sufficiently studied. Many researchers note, that the processes of pollen formation in species of the genus *Larix* Hill are strongly dependent on weather – climatic conditions, therefore, it is difficult to detect the influence of technogenic factors on the pollen state (Kozubov 1974, Noskova et al. 2004, Tretyakova et al. 2006, Surso et al. 2012). According to Surso (2013), the number of anomalies in the development of pollen in larches can be significant in hereditary teratologies, as well as at unfavourable weather conditions during the process of microsporogenesis, with radiation exposure on meiocytes, and in a number of other cases.

The features of microsporogenesis and anomalies in the development of pollen of larch, which are growing on the territory of Russia in conditions of urbanized territories and industrial pollution are investigated by a number of researchers: Noskova et al. 2004, Romanova et Tretyakova 2005, Tretyakova et al. 2006, Dzyuba et al. 2008, Surso et al. 2012, Kalashnik et al. 2008, Kalashnik 2011, Tupitsyn et al. 2012, Noskova et Romanova 2013.

The research was conducted in Murmansk, the world's largest non-freezing port beyond the Arctic Circle (68° 58' N, 33° 4' E). Murmansk is situated on a relatively narrow, slightly hilly valley, stretching from the north to the south along the Kola Bay of the Barents Sea. The city is located on four terraces and stretched for 25 km, with separate districts, divided by hills and areas of natural vegetation. Murmansk is in the Atlantic–Arctic zone of temperate climate (Yakovlev 1972), which is formed under the influence of the Barents Sea and by the warm North Atlantic Current. The average temperature in January – February is -10°C. Summer is cold, the average temperature in July is +12°C. Most of the precipitation in Murmansk, approximately 500 mm per year, falls from June to September. The snow cover keeps in the city average 210 days and snow is melting in May. The wind is monsoonal – in the winter, the southern winds prevail, in the summer – the northern winds. The polar night begins on 29 of November and ends on 13 of January (44 days), the polar day – from 22 of May to 22 of July (62 days) (Yakovlev 1972). The duration of vegetative period is approximately 120 – 130 days. In Murmansk, there is only one weather station, so there is no data on climatic differences in the city's districts.

The main sources of pollution of atmosphere are the Murmansk boiler houses, operating on fuel oil, the Murmansk seaport, plant for the incineration of solid domestic waste and automobile transport. Characteristic pollutants are soot, formaldehyde, volatile organic matters, hydrocarbons ([2]). Since 2012, a significant increase in dust pollution has been recorded in Murmansk. A study, conducted by the All-Russian Scientific Research Institute for Nature Conservation (formerly the Atmosphere Research Institute) revealed two main sources of atmospheric pollution in the city of Murmansk: emissions of boiler houses and transshipment of coal by the opened method in the Murmansk seaport. The main emissions of boiler houses are abrasive dust, soot, ash, hydrocarbons, formaldehyde, sulfur dioxide, carbon monoxide and vanadium compounds ([1]). In 2014, about 14,373 tons of pollutants were thrown into the atmosphere of the city of Murmansk from boiler houses ([2]). Coal dust includes combustible volatile elements, silicon dioxide, pyrite, ash and slag, which consist of oxides of silicon, aluminum, iron (III), calcium, potassium, rare and dispersed elements (Ge, V, W, Ti, *etc*.). The most dangerous emissions of factories for the incineration of solid household waste are super toxicants: dioxins and furans (Demina 2011), as well as heavy metals. Studies of soils around the Murmansk plant for the incineration of solid household waste showed, that the content of heavy metals (Cu, Zn, Ni, Cd, Fe) exceeds the maximum permissible concentrations for "soils of populated areas" many times (Yakovlev 2007).

The purpose of the study – is to research the teratogenesis of *Larix sibirica* pollen in the conditions of the Arctic climate and technogenic pollution of the city of Murmansk and holding the palynoindication of the environment.

Material and Methods

Larix sibirica Ledeb.

The object of the study is *Larix sibirica* Ledb. (Siberian larch), a representative of the genus *Larix* Hill., family *Pinaceae* Lindl. – Boreal, East European-Siberian species (Dylis 1981). Siberian larch has a huge range, it grows in the North-West of the European part of Russia, in the Urals, in Western Siberia, in the Altai, Sayans, China, in the north-west of Mongolia (Dylis 1981, Karaseva 2003). According to many authors, *L. sibirica* can be viewed as one of the species of plants, the racial composition of which was formed from the gene pools of different ancestral populations, geographically separated and being at different stages of evolution (Dylis 1981, Milyutin 2003, Iroshnikov 2004, Wei et Wang 2004).

The systematics of the genus *Larix* Hill are very complex and are still the subject of discussions, first of all the status of species of larch that grow in Eurasia is discussed. Difficulties with the identification of taxa are due to the deficiency of data on the history of genus formation, active introgressive hybridization at the boundaries of range (Rysin 2010). Actively discussed is the question whether *Larix sibirica* can be allocated as a separate species. Recently, many molecular genetic studies of *L. sibirica* populations have appeared (Hewitt 1996, Timerjanov 1997, Bashalkhanov et al. 2003, Semerikov et al. 1999, 2003, 2007, Wei et Wang 2004, Araki et al. 2008). Some authors consider these populations as one species – *Larix sibirica* Ledeb. (Semerikov et al. 1999, Wei et Wang 2004). From the point of view of others, the populations, located west of the rivers Irtysh and the Ob are an independent species of *Larix sukaczeii* Dylis (Bashalkhanov et al. 2003). Studies of the genetic variability of Siberian larch (Timerjanov 1997, Semerikov et al. 1999, 2003, 2007) confirmed the conclusion of Dylis (1947), that these species consist of two genetically different races: the eastern race *L. sibirica* and the western race *L. sukaczeii* Dylis. We consider the larch, which we study, as *Larix si-*

birica Ledeb.

Currently, on the urbanized areas of the Murmansk region, grows artificially created populations of Siberian larch, introduced in the 1930s on the Kola Peninsula (Goncharova et Poloskova 2014). Winter hardiness, tolerance to the soil quality, ability to grow in a short growing season and survive under high anthropogenic loads due to annual needle change, made *L. sibirica* a promising decorative coniferous species in conditions of the Far North (Goncharova et Poloskova 2014). In urban green plantations there are larch specimens of more than 70 years of age, in Murmansk the share of *L. sibirica* is 4 – 5% of the total number of green plantations (Gontar et al. 2013).

Pollen of the genus *Larix* Hill. differs from the pollen grains of other representatives of *Pinaceae* Lindl. by the absence of pollen sacs, by spheroidal shape, with one recess (Surso 2013). A characteristic feature of larch pollen is a thick shell – exine, which protects the pollen grain from the adverse effects of the environment and prevents its germination (Tretyakova et al. 2006). The surface of the exine is finely granulated, with weakly expressed trihedral traces, which remain after the decay of tetrads. Besides starch granules, in the mature pollen grains of larch there are numerous, sometimes quite large, protein globules (Surso 2013). Larch pollen has no air sacs, so it has weak aerodynamic properties and cannot spread over long distances (Owens et al. 1998). According to Trenin (1988), the diameter of the pollen grains of Siberian larch in South Karelia and the Murmansk region (station Khibiny) varies from 69 to 83 μm, the average diameter is 82.1 ± 0.07 μm.

The formation of *L. sibirica* pollen has its own peculiarities: meiosis begins in the autumn, the development of microsporocytes continues to the stage of diplotene (Prophase I) (Noskova et al. 2004). End of meiosis occurs in the spring of next year. With unfavorable dynamics of air temperatures (warming before the beginning of dusting process and after it a sharp cooling) meiotic divisions come with numerous violations. As a result, a large number of abnormal pollen is formed, both in clean and in contaminated areas (Romanova et Tretyakova 2005). Rain, low relative humidity and low air temperatures have the negative impact influence on larch pollen formation. The pollen of Siberian larch ripens in the Murmansk region at the end of May.

Experimental sites

For research, we selected larch trees, age of which are 50 years or older, planted in the territory of Murmansk in the 1960s and 1970s years. On the green plantations of the Lenin and Oktyabrsky districts of the city in the spring of 2014, there are 5 experimental sites laid down: P_1 – Geroev Severomortsev Street, P_2 – square near the Murmansk Clinical Hospital named after N. I. Pirogov (Pavlik Morozov Street), P_3 – square on Leningradskaya Street, P_4 – square near the Drama Theater (Lenina Street), P_5 – planting on Knipovich Street (Fig. 1). All experimental sites are laid in areas with increased anthropogenic load: P_1 and P_2 are located near the industrial zone and the plant for the heat treatment of solid domestic waste, P_3 is situated near the Murmansk seaport, where coal is transshipped by open method, P_4 and P_3 – along Lenin Street, which is the main highway of the city. As a control, is chosen a garden near the Church of the Annunciation of the Blessed Virgin Mary in a small city of Kola (68° 52' 59 " N, 33° 01' 19" E), located 12 km from Murmansk, where the level of anthropogenic pollution is much lower ([2]).

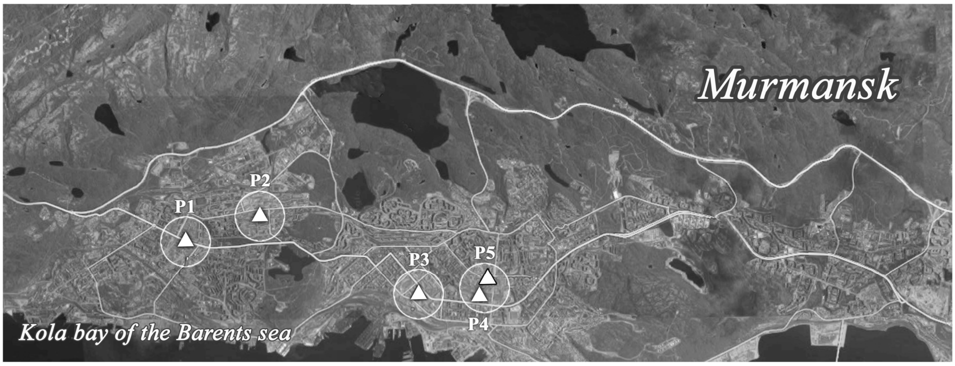

Fig. 1. Experimental sites of Siberian larch in Murmansk. *Symbols*: P_1 – Geroev Severomortsev Street, P_2 – square near the Murmansk Clinical Hospital named after Pirogov (Pavlik Morozov Street), P_3 – square on Leningradskaya Street, P_4 – square near the Drama Theater (Lenina Street), P_5 – planting on Knipovicha Street.

Palynological analysis

Samples of *L. sibirica* pollen were collected on May 29 and 30, 2014. Abundant pollen was observed in trees at all experimental sites. On each of them, 5 microstrobils with mature pollen from six *L. sibirica* trees were collected. Male cones were dried and fixed in a 50% solution of alcohol. For analysis microsporophylls were used from the middle part of the microstrobil, the pollen was stained in a 1% solution of acetocarmine (Dzyuba 2006). Pollen studies were carried out using a light microscope Arechlab 104/600, at a 160-fold magnification. Microphotographs were made with the help of a digital camera DEM 35. On the basis of disturbances in the development of *L. sibirica* pollen, described in the literature (Dzyuba 2006, Kalashnik et al. 2008, Kalashnik 2011), morphological anomalies in the development of pollen grains have been identified. The amount of normal and teratomorphic pollen with various developmental disorders was calculated. More than 300 pollen grains have been studied in each sample. Micromorphometry of the pollen was carried out on temporary preparations; the diameters of the pollen grains were measured with an ocular micrometer (N = 50). The statistical processing of the experimental material was carried out according to a generally accepted methodology using the Microsoft Excel software package.

Results

The results of palynological studies of Siberian larch from different cenopopulations of the city of Murmansk have shown that all samples contain teratomorphes of pollen grains (Table 1, Fig. 2, Fig. 3). In all the tested samples, the content of normal *L. sibirica* pollen without visible developmental disorders are low and varies from 19.2% to 23.8% at the experimental sites of the city (Table 1, Fig. 2 A, Fig. 3), which is three times less than in the control (71.7%). At the same time, the number of abnormal pollen grains in the samples is very high and varies from 76 to

Morphotypes of pollen grains	Experimental sites					
	Control	P_1 Geroev Severomortsev street	P_2 Murmansk Clinical Hospital	P_3 Leningradskaya street	P_4 Drama Theater (Lenina street)	P_5 Knipovicha street
With plasmolysed protoplast	22.8%	63.7%	57.6%	62.5%	57.1%	59.8%
Without protoplast	3.5%	11.4%	18.2%	13.6%	13.4%	14.5%
Giant	0.8%	0.9%	0.9%	0.9%	1.3%	1.5%
Dwarf	0.5%	1.5%	1.5%	1.1%	2.3%	2.1%
With damaged exine	0.5%	0.9%	1.5%	2.6%	2.0%	3.0%
Abnormal pollen grains	28.3%	78.4%	79.7%	80.7%	76.2%	80.8%
Normal pollen grains	71.7%	21.6%	20.3%	19.3%	23.8%	19.2%
Total pollen sum	368	333	330	352	303	338

Table 1. Normal and teratomorphic pollen grains of *Larix sibirica* in the city of Murmansk (share).

81% for different cenopopulations, in control 28.3 %.

In total, five morphological anomalies in the development of *L. sibirica* pollen have been identified: without protoplast (with signs of complete degradation of the nucleus and cytoplasm, not colored), with plasmolysed protoplast (unevenly stained), with damaged exine, giant pollen grains and dwarfed (normal or deformed) (Fig. 2). In Murmansk, the high content of teratomorphic pollen are found in all samples (*see* Table 1, Fig. 3). In the center of the city the share of teratogenic pollen of larches, planted along the Knipovich Street and in the park on Leningradskaya Street is near 81% (Fig. 3). These experimental sites are located near the main highways of the city and the Murmansk seaport, where the coal is transshipped by open method. Similar values are obtained in the study of *L. sibirica* pollen of the green plantations near the Murmansk Clinical Hospital, named after Pirogov (79.7%) and Geroev Severomortsev Street (78.4%), located in close proximity to the industrial zone and the plant for the thermal treatment of solid domestic waste.

Most of the anomalous grains in all samples from the cenopopulations of *L. sibirica* in Murmansk are pollen with plasmolysed protoplast, unevenly colored (*see* Fig. 2 C, Fig. 4). The content of such pollen grains is very high in the samples of all experimental sites and varies in the range of 57.1– 63.7% (Fig. 4), in the control – 22.8%.

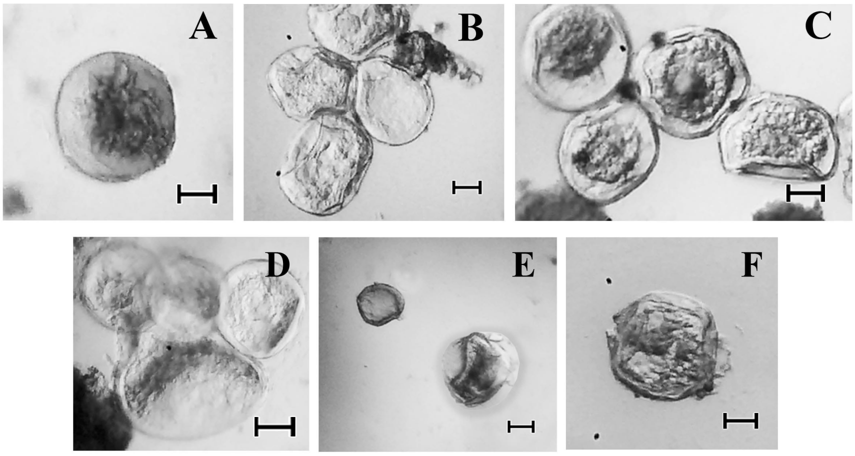

Fig. 2. Normal and teratomorphic pollen of *Larix sibirica* in Murmansk: A – normal, D – without protoplast (steril), C – with plasmolysed protoplast, D – giant, T – dwarfed, F – with exine damage. *Note:* the scale line in micrographs corresponds to 20 µm.

Also in the samples are detected a significant amount of *L. sibirica* pollen without protoplasts, unpainted, with complete degradation of the nucleus and cytoplasm (*see* Fig. 2 B, Fig. 4), their content in the samples varies in the range 11.4–18.2%, in control – 3.5%. The greatest amounts of such teratomorphs are found in samples of larches in the experimental site of the Murmansk Clinical Hospital after Pirogov (18.2%), Knipovich Street (14.5%), the park on the Leningradskaya Street and near the Drama Theater.

Significantly less in the samples occurs dwarfed (Fig. 2 E) and giant pollen (Fig. 2 D). In general, the size of *L. sibirica* pollen in cenopopulations of Murmansk varies from 25 µm to 175 µm. The average size of normal pollen is 82.18 ± 3.7 µm. Average diameter of dwarf pollen of a larch in Murmansk is 38.81 ± 6.55 µm. The content of such teratomorph in the samples varies in the range 1.1 – 2.3%, in control – 0.5% (Fig. 5). The maximum amount of small pollen is found in samples from Knipovich Street (2.1%) and the green plantations near the Drama Theater (2.3%). The average size of hypertrophied (giant) pollen of *L. sibirica* in the investigated samples in Murmansk is 120 ± 50.6 µm. The share of such pollen grains in different cenopopulations ranges from 0.9 to 1.5% (Fig. 5). The highest content is noted in the samples from Knipovich Street (1.5%) and in the park of the Drama Theater (1.3%), which is located near the Lenin Avenue – the main highway of the city.

Pollen with breaks of exine is a small fraction in the palynoterate complex of Siberian larch in Murmansk (*see* Fig. 2 F, Fig. 5). The proportion of such teratomorphs in samples varies from 0.9 to 3.0%, in control 0.5%. The highest content of such pollen is found in samples from Knipovich Street (3.0%) and Leningradskaya Street (2.6%), located in the city center. The ruptures of the exine of pollen in larches are usually quite rare – 0.02%, but in certain years, with unfavorable air temperature dynamics (warming before the beginning of dusting and after it a sharp cooling), the amount of pollen grains with damaged exine can be quite substantial (Surso 2013).

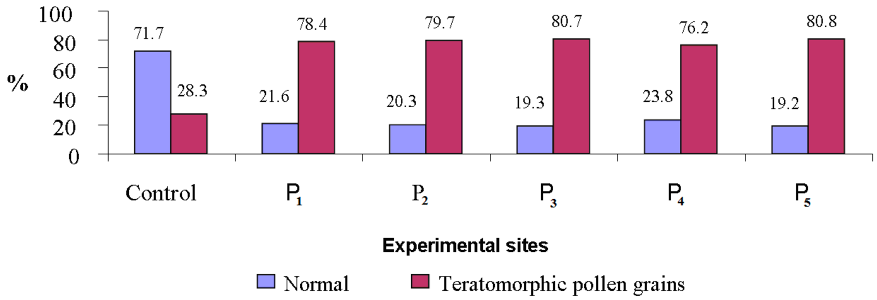

Fig. 3. The ratio of normal and teratomorphic pollen grains of *Larix sibirica* in the city of Murmansk (in %).

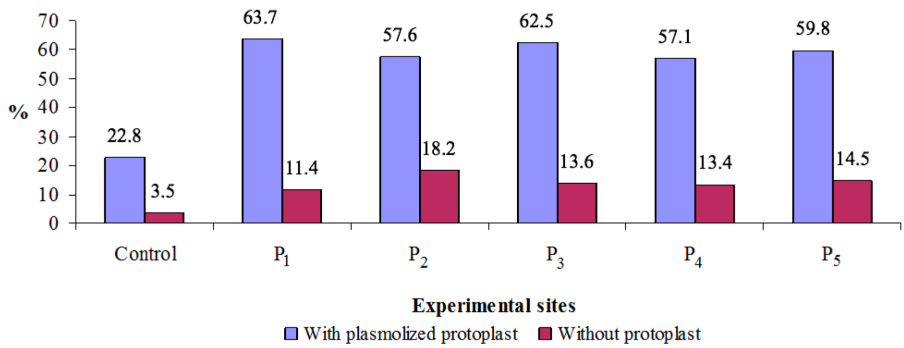

Fig. 4. The ratio of pollen of *Larix sibirica* with plasmolysed protoplast and without protoplast in the city of Murmansk (in %).

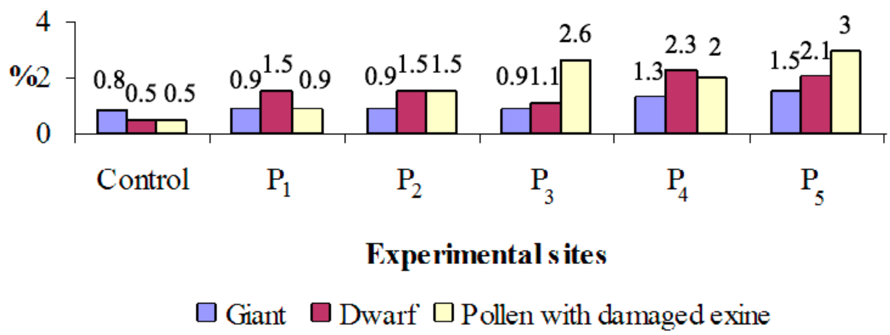

Fig. 5. The ratio of pollen of *Larix sibirica:* dwarf, giant, with damaged exine in the city of Murmansk (in %).

Experimental sites: P_1 – Geroev Severomortsev Street, P_2 – square near the Murmansk Clinical Hospital named after Pirogov (Pavlik Morozov Street), P_3 – square on Leningradskaya Street, P_4 – square near the Drama Theater (Lenina Street), P_5 – planting on Knipovicha Street.

Discussion

Palyno-ecological studies in Murmansk have shown, that in the reproductive sphere of Siberian larch, significant developmental disturbances are observed. A high level of teratogenesis of pollen, which reaches 76 – 80.7% in the investigated cenopopulations of *L. sibirica* are revealed. Usually the total number of anomalous pollen grains of larches under natural growth conditions is 2 – 5% (Surso 2013). According to Kalashnik (2011), the proportion of teratomorphic grains of *L. sibirica* in the samples from the city of Ufa (Bashkortostan) ranges from 22.3 to 25.6%, in control – 7.3%. The researches of Siberian larch pollen from radioactive, contaminated territories of different districts of St. Petersburg showed, that the level of teratomorphism of pollen of *L. sibirica* exceeds 87% (Dzyuba et al. 2008). The authors came to the conclusion, that this level of developmental disorders is evidence not of polymorphism, but of teratomorphosis of pollen grains, which affects almost all the morphological structures of pollen, and possibly the biochemical composition of their membranes.

In Murmansk, the proportion of pollen of *L. sibirica* with plasmolysed protoplast in all studied samples is extremely high and amounts to 57.1 – 63.7%. Surso (2013) notes, that plasmolysis of protoplast is a characteristic morphological defect of pollen grains of larch. Kalashnik (2011) indicates, that pollen grains with such an anomaly of development are most often encountered in conditions of strong technogenic pollution. Share of *L. sibirica* pollen without protoplast in the samples from Murmansk varies from 11 to 18%. The lack of protoplasts in pollen can be caused by being damaged at low temperatures, which results in autolysis of the cytoplasm (Kozubov 1974). The increased occurrence of pollen of the *Larix sukaczevii* with a reduced protoplast (plasmolysed) and without it, are noted by Kalashnik (2011) on the territory of Ufa. These developmental anomalies are more common in conditions of high anthropogenic pollution (8.9 – 10.2%), in samples from the territories of moderate pollution 2.2 – 7.7%, in control – 3.2% (Kalashnik 2011). As follows from the above data, the content of pollen with plasmolysed protoplasts in the samples of Murmansk are 57.1 – 63.7%, which is 5 – 6 times more, than in the experimental plots of Ufa with high level of pollution (Fig. 4).

Especially, significant variation in the size of larch pollen in the cenopopulations of Murmansk should be noted. In the opinion of Bessonova (1992), in conditions of environmental pollution, pollen grains of plants greatly vary in size, in contrast to plants of an uncontaminated zone. The proportion of *L. sibirica* small pollen in samples from Murmansk is 1.1 – 2.3%. In other regions of Russia, data has been obtained on the frequent occurrence of small larch pollen. The proportion of dwarfed pollen of *L. sibirica* in the north of the Arkhangelsk region is 1.7% (Noskova et al. 2004). In samples of pollen from *L. sukaczevii*, which grows in ecologically clean conditions of Bashkortostan, its content is 5.3%, and varies from 7.2 to 14% in conditions of pollution (Kalashnik 2011). In the territory of the Chelyabinsk region, the content of dwarf pollen of *L. sukaczevii* varies from 3.1% to 9.7% in areas with different degrees of pollution (Kalashnik et al. 2008). Some authors believe, that the formation of small pollen grains in the genus *Larix* Hill in high latitudes is associated with adaptation to low temperatures and excessive moistening (Tupitsyn et al. 2012). At the same time, Bessonova (1992) showed, that the appearance of small pollen grains is associated with meiotic disturbances, in which a part of the genetic material is lost as a result of damage to the fission spindle or chromosomal mutations.

The content of hypertrophied (giant) larch pollen in samples from the territory of Murmansk is not large (0.9 – 1.5%). The formation of giant pollen can be explained both by the influence of unfavorable climatic factors, and by the high level of pollutants. Surso (2013) showed, that dyads and triads of larches microspores sometimes develop into giant pollen, whose sizes exceed the average grain size by more than two times. In addition, polysporia is characteristic for larch, cases of which can be very numerous for individual trees. In the north of the Arkhangelsk region, the proportion of hypertrophied pollen of *L. sibirica* can be up to 0.2% (Surso et al. 2012). In the city of Ufa, the content of giant pollen of *L. sukaczevii* varies from 3.0 to 6.0%, in conditions of strong industrial pollution to 8.2%, in control 1.8% (Kalashnik 2011).

The increase in the proportion of teratomorphic pollen is due to the negative impact of various environmental factors on the meiosis processes. There are some researches of meiosis of *Pinaceae*, including *Larix* Hill (Yasovieva et Kalashnik 2000, Romanova et Tretyakova 2005, Kalashnik et al. 2008, Kalashnik 2011, Noskova et Romanova 2013). It is shown, that the total number of disturbances in the meiosis of microsporocytes of larches increases in connection with following environmental factors: a sharp decrease in air temperature, atmospheric pollution, increased radiation background and introduction (Trenin 1988, Romanova et Tretyakova 2005). A stably high number of disturbances in meiosis can be caused by both the individual features of the trees and by the biology of the species (Kozubov 1974). In the conditions of technogenic pollution there is an increase in chromosome aberrations in the process of reduction division of pollen of *L. sibirica* (Romanova et Tretyakova 2005). According to Surso (2013), *L. sibirica* is characterized by morphological defects such as the formation of undivided dyads of microspores due to the fallout of the second division of meiosis, plasmolysis and the rupture of the exine of microspores. Very often, with rare exceptions, it is impossible to determine exactly which disturbances in meiosis happened, and how it leads to various teratological changes in pollen grains and pollen sterility (Surso 2013).

Dzyuba (2006) considers, that *L. sibirica* is a rather complex object for ecological palynology, since this species is characterized by an increased level of pollen polymorphism under the conditions of introduction. However, the pollen of larch can be used to obtain additional regional and environmental information. Data on the high level of teratogenesis, obtained during the research of pollen of *L. sibirica* in the conditions of the Arctic climate and technogenic pollution of the city of Murmansk, allow us to draw a conclusion about the critical level of anthropogenic pollution of the city environment.

Summary

In the pollen samples of *L. sibirica* in Murmansk, five anomalies of development have been identified: pollen without protoplast, with plasmolysed protoplast, giant and dwarfed pollen grains, with damaged exine. The most common morphotypes in the palynoterated complex are pollen with plasmolysed protoplast and without protoplast (sterile). This is confirmed by the data of a number of Russian researchers (Romanova et Tretyakova 2005, Kalashnik et al. 2008, Kalashnik 2011), obtained in urbanized areas in Siberia and Bashkortostan, which showed that under conditions of high anthropogenic load, the number of such pathologies significantly increases in representatives of the genus *Larix* Hill.

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