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ORIGINAL ARTICLE

Fungal pathogens of shrubs in industrial cities

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Abstract Industrial human activities have an extremely negative impact on the ecological situation. In particular, they are harmful for ecosystems in close proximity to industrial centers. Fungi are saturated with these emissions and infect plants while colonization. In this connection, the purpose of this article is to clarify the species composition and phytosanitary assessment of fungi, which are carriers of plant diseases. The samples of infected plants were collected (about 700) to achieve the goal in the period from 2013 to 2015. To study the pathogenic fungi, we used the I. I. Zhuravlev's method, microscope MBR-3, and binocular in the position of microscope MBS-1. In the samples were found several species of fungi's from different orders. All found and identified species of fungi affecting trees and shrubs are the cause of various diseases. *Phyllosticta rosarum* causes spot anthracnose, and *Phragmidium disciflora* causes rose rust. *Trichocladia caraganae* is a powdery mildew pathogen, and *Phyllactinia suffulta* affects a lot of trees—lindens, oaks, birches. *Microsphaera* is a genus of powdery mildew. These fungi cause serious damage to trees and may be the cause of reducing their life expectancy. Thus, in the course of the study, we identified the harmful fungi and the nature of their impact on shrubs. In our opinion, it is necessary to create more effective methods of prevention of these diseases.

Keywords Fungi poisoning · Phytosanitary assessment of fungi · Plant infestation · Spore distribution · Urban greenery

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Introduction

The Astana Region, Karaganda Region, and Pavlodar Region are located in central and northeastern Kazakhstan. In recent years, several big factories have been operating within Pavlodar city (52°18′N 76°57′E) (Nurlankyzy et al. 2016). These include factories that manufacture non-ferrous metal, oil processing plants, and chemical plants (Lu and Jia 2012; Ponomarenko et al. 2016). On the outskirts of Ekibastuz, coal is mined in quarries; in addition, three thermal power plants that burn this coal are located in the same area. The ecological situation in Aksu (52°02′0″N 76°55′0″E) city is similar (Samerkhanova et al. 2016; Fisher et al. 2012).

Urban green spaces are constantly under the strong influence of external factors such as exhaust fumes of cars, air pollution as a result of the work of enterprises. Moreover, the list of air pollutants is quite wide and the negative effects of the impact felt by not only plants, but also the inhabitants of cities (Masiol et al. 2014). Another factor affecting the plants has microorganisms such as bacteria and fungi. They can have a positive impact as well as negative. Positive is manifested in the formation of symbiosis between fungi and trees, allowing the latter to increase the area of absorption of nutrients, and do not forget about the nitrogen-fixing bacteria that help plants get

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nitrogen from the external environment (McGuire et al. 2015). But also, they can be harmful for him to carry out the processes of decay important parts of the body, disrupt reproduction, and photosynthetic function (Bernadovičová and Ivanová 2008; Stravinskienė et al. 2015).

Landscaping is an important issue for many cities, since such an array of vegetation creates a favorable environment for the construction of housing tracts and children's playgrounds. They are a city filter for accumulating a harmful substances, thus reducing their concentration in the environment and reduces the risk of diseases among the population (Wolf 2003; Wells 2009). This is why the state of urban arrays is so important and why it is so important to protect them from the negative impact of the environment.

All the above necessitates the specification of the species composition and phytopathological assessment of fungi that cause plant diseases in these areas. The pathogens of fungal diseases reduce the rate of growth of plants and their longevity, deteriorate their external esthetic characteristics, and may even cause emergencies (Lo Presti et al. 2015; Nikolaidis et al. 2014). Therefore, one of the main environmental measures is the protection of plants in settlements from hazardous impacts and timely handling.

Materials and methods

The materials of this study included parasitic shrub fungi, herbaria with their affected parts, as well as sporocarps and spores of fungi, which the author collected in Astana, Karaganda, and Pavlodar in 2013, 2014, and 2015. Collection of herbarium and storage was carried out in accordance with the collection of herbarium specimens and plant regulations (Smith and Chinnappa 2015). They were collected during their vegetative period. These herbaria were collected from about 700 shrubs and stored at the laboratory of the S. Toraighyrov Pavlodar State University Biology and Ecology Department.

An MBR-3 microscope (LOMO, Russia) and an MBS-1 binocular microscope (LZOS, Russia) were used to study the sporocarps of phytopathogenic fungi, their mycelium, spores, and affected plant parts.

I. I. Zhuravlev's method was used to analyze and identify the sporocarps, asci, and spores of phytopathogenic fungi (Blanchar and Tattar 2013; Zhuravlev 1979). The family, genus, and species of phytopathogenic fungi were determined according to the system offered in the book Cryptogam Flora of Kazakhstan (1981), study materials processing using the identification guides Bisby (1933), Schwarzman (1950), Cryptogam Flora of Kazakhstan (1981).

Results

The study of five species of shrubs identified six species of phytopathogenic fungi, belonging to five genera. The affected plants included two species, belonging to one genus, which were new host plants. The species composition of phytopathogenic shrub fungi that grow in Astana, Karaganda, and Pavlodar is as follows.

The *Erysiphales* order includes three species: (*Microsphaera vanbruntiana* Ger., host plant—*Sambucus racemosa* L.; *M. syringae—japonicae* Brau., host plant—*Syringa* sp.; *Phyllactinia suffulta* Sacc. *f. syringae* Jacz.–*Syringa vulgaris* L.).

The *Uredinales* order includes one species: (*Phragmidium disciflorum* (Tode.) J. James, host plant—*Rosa* sp.

The *Uredinales* order includes one species: (*Phyllosticta rosarum* Pass., host plant—*Rosa oxyacantha* M.B.) (Table 1).

The comparison of the species composition of phytopathogenic fungi identified in shrubs that grow in these three cities found the *Erysiphales* order (one species in Astana, one species in Karaganda, and two species in Pavlodar), the *Uredinales* order (one species in Astana and one species in Karaganda), and the *Sphaeropsidales* order (one species in Karaganda). This means that in the Pavlodar *Erysiphales* dominate.

Species compendium

The compendium includes three orders and five genera of phytopathogenic fungi, which comprise of six species. Two species, belonging to one genus, were identified in new host plants in Astana, Karaganda, and Pavlodar. The study also provides the characteristics of species, data on their location, collection period, host plants, and names of collectors. The species compendia feature photographs.

Erysiphales order
Microsphaera genus
Microsphaera vanbruntiana Ger., Bull

Located on both sides of the leaf in the form of black spots. Cleistothecia are scattered, 70 µm in size. Appendage count—4. Spore count—6–8, size—14.4–16.2 0 × 10.6–12 µm.

Host plant—*Sambucus racemosa* L, found on leaves.

Finding location in Kazakhstan. Pavlodar, Satpayeva Str. (52°18′N 76°57′E), September 24, 2014, A.K. Ospanova. This species complements both the mycoflora of the Pavlodar Region and that of Kazakhstan (Fig. 1a, b).

Microsphaera syringae—japonicae Brau

Table 1 Taxonomic species composition of phytopathogenic fungi

Order	Family	Number of species		
		Astana	Karaganda	Pavlodar
1	2	3	4	5
1. *Erysiphales*	1. *Microsphaera*	1	–	1
	2. *Phyllactinia*	–	1	–
	3. *Trichocladia*	–	–	1
2. *Uredinales*	1. *Phragmidium*	1	1	–
3. *Sphaeropsidales*	1. *Phyllosticta*	–	1	–

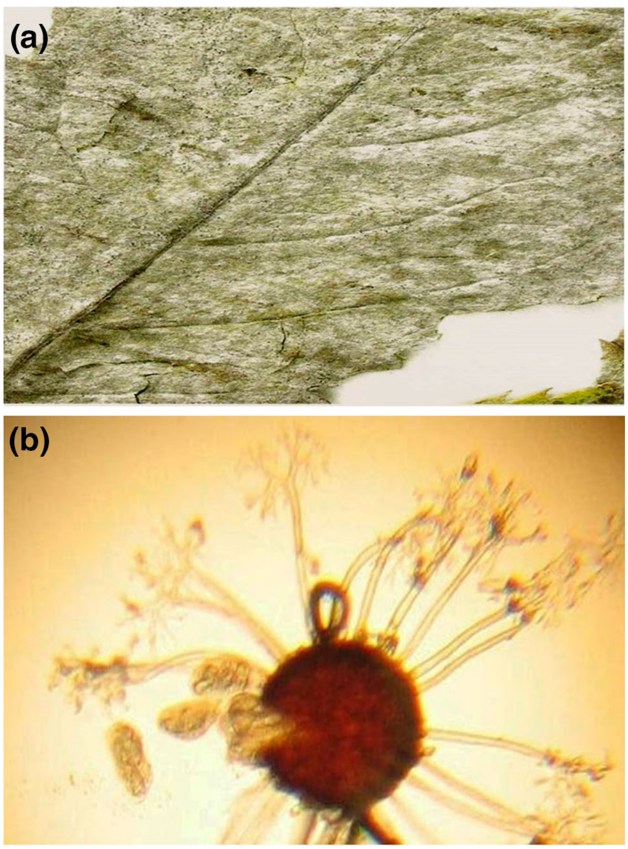

Fig. 1 **a** *Microsphaera vanbruntiana Ger*; **b** appendages, cleistothecia, asci, and spores of the *Microsphaera vanbruntiana Ger. fungus*

Located on both sides of Syringa laminas in the form of black spots. Cleistothecia are spherical. Propagules are located on all sides. The tips of propagules resemble elk horns. Ascus count—4. Spore count—6–8, 12.3–15.5 × 10.2–11.2 µm in size.

Host plant—*Syringa* sp, found on leaves of all plants in this genus.

Finding location in Kazakhstan. Astana, "Culture Center"; Pavlodar, park, September 28, 2014 (52°18′N 76°57′E), A.K. Ospanova. New host plant for Kazakhstan (Fig. 2).

Phyllactinia genus

Phyllactinia suffulta Sacc. *f. syringae* Jacz.

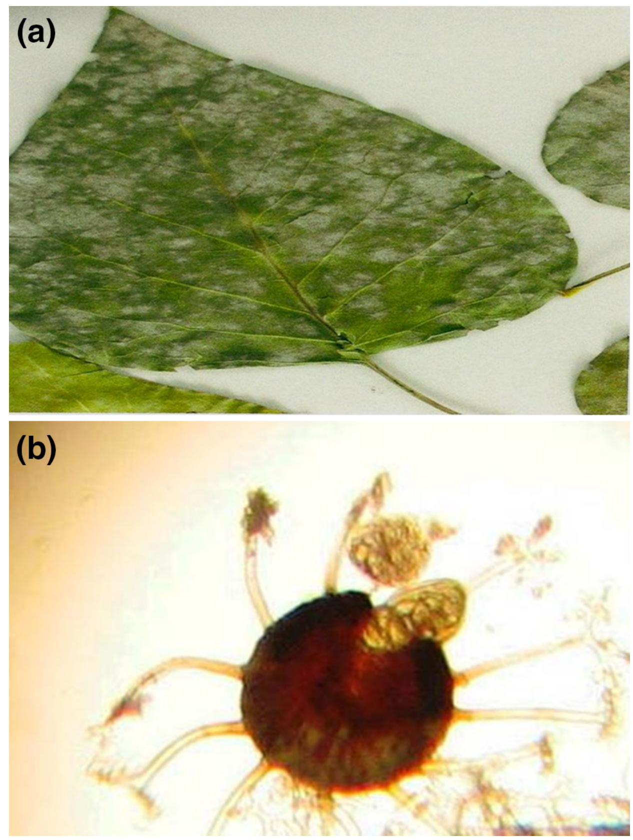

Fig. 2 **a** Leaves of *Syringa* sp. genus plants; **b** appendages, cleistothecia, asci, and spores of the *Microsphaera syringae—japonicae Brau. fungus*

Brown cleistothecia, 180–230 µm in size. Propagules are scattered, 160–240 µm in size. Multiple asci. Spores are oval; spore count—2–3; colorless, 20–31 × 12–14 µm in size.

Host plant—*Syringa vulgaris* L., found on leaves.

Finding location in Kazakhstan. Almaty Region, Almaty (43°16′39″N 76°53′45″E), Gorky Park, September 14, 1955, B.K. Kalymbetov; Karaganda, Pushkina Str., October 02, 2013, A.K. Ospanova (Fig. 3).

Trichocladia genus

Trichocladia caraganae Neger.

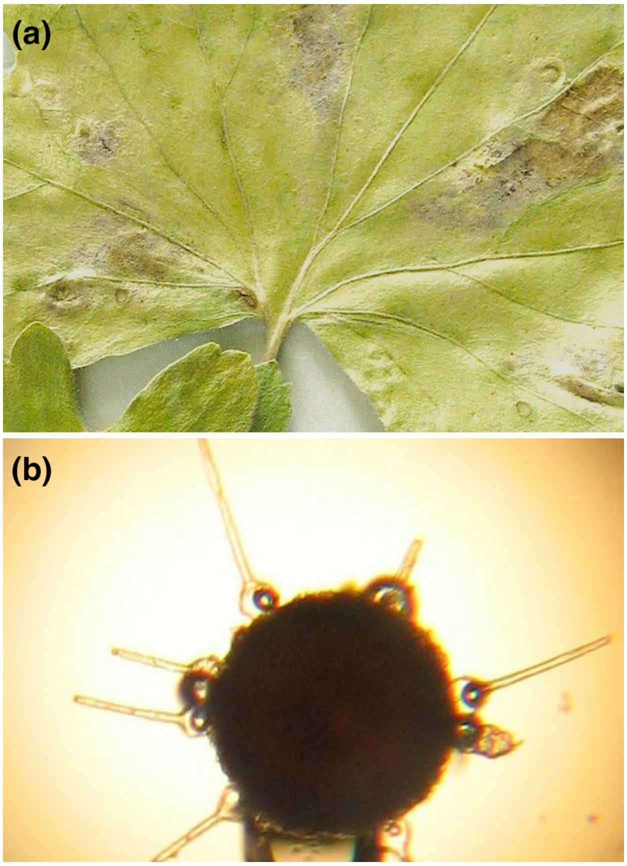

Fig. 3 **a** On *Ribes* sp. leaves, *Phyllactinia suffulta* Sacc. *f. ribesii* Jasz; **b**—appendages and cleistothecia of the *Phyllactinia suffulta* Sacc. *f. ribesii* Jasz. fungus

Sporocarps can be found on both sides of leaves and shoots. Conidia are cylindrical, 18–32.4 × 6.9–14.8 μm in size. Cleistothecia are scattered, spherical, 85–170 μm in size. Appendage count—12–15, located in groups at the top of cleistothecia, tips are dichotomously branched. Ascus count—5–12, oval, 44–78.8 × 27–50.2 μm in size. Spore count—4–6, elliptic form, 13.5–30 × 8.9–14 μm in size.

Host plant—*Caragana arborescens* Lam. found on leaves.

Finding location in Kazakhstan. Almaty (43°16′39″N 76°53′45″E), Ile Atalau, Small Almatinka, down the road to Medeo, October 19, 1934, September 17, 1937, M.N. Kuznetsov; same area, down the road to Lake Issyk (43.2531°N 77.4847°E), August 28–29, 1939, M.N. Kuznetsov; same area, L.D. Kazenas, 1953; Semipalatinsk Region, East Kazakhstan Region, 6 km from Lake Zaysan (48°00′N 84°00′E), June 14, 2013, G.S. Nevodovsky; Pavlodar (52°18′N 76°57′E), Victory Park, July 21, 2013, A.K. Ospanova (Fig. 4a, b).

Uredinales order
Phragmidium genus

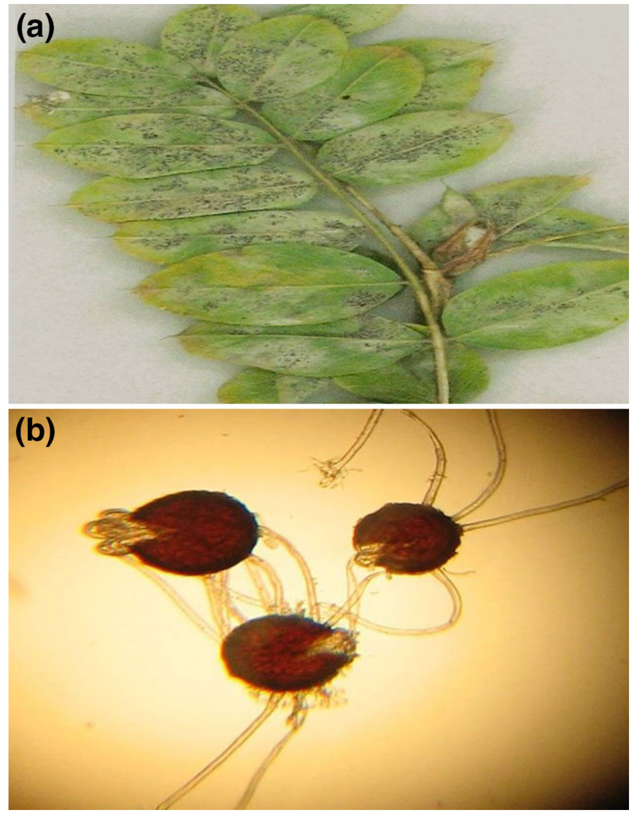

Fig. 4 **a** On *Caragana arborescens* Lam. leaves; **b**—appendages, cleistothecia, and asci of the *Trichocladia caraganae* Neger. fungus

Phragmidium disciflorum (Tode.) James.

Spermatogonia and ecidia are found on the upper surface of leaves. Urediniospores are elliptical, 21–28 × 14–21 μm in size, spiky, with a 1.5-μm-thick surface layer. Paraphyses are club shaped.

Host plant—found on *Rosa* sp. genus leaves.

Finding location in Kazakhstan. Ile Atalau, June 02, 1993 Ya.I. Korbonskaya; Astana (51°10′N 71°26′E), near the Auil café, October 15, 2013, Karaganda (49°50′0″N 73°10′0″E), Central Marketplace, September 27, 2014, A.K. Ospanova (Fig. 5a–c).

Sphaeropsidales order
Phyllosticta genus
Phyllosticta rosarum Pass

Pycnidia are spherical, 54–132 × 88–121 μm in size. Count—multiple. Dense wall comprising of small-celled tissue. Stylospores are unicellular, 2.2–5.5 × 1–1.5 μm in size.

Host plant.—*Rosa oxyacantha* M.B., found on leaves.

Finding location in Kazakhstan. Akmola Region (52°0′N 69°0′E), Sandykty forestry, July 12, 1963, N.M. Leonova; North Kazakhstan Region (54°53′N 69°10′E), Soviet forestry, July 28, 1953 N.M. Leonova; East

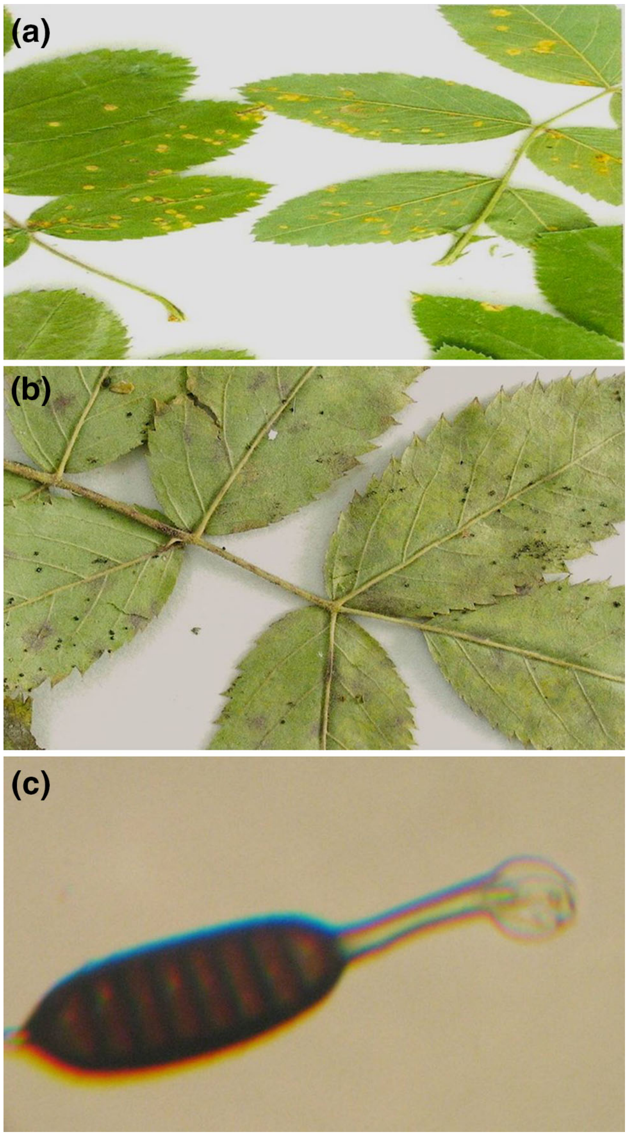

Fig. 5 **a** On *Rosa* sp. genus leaves,urediniospores of *Phragmidium disciflorum* (Tode.) James. fungus; **b** *Phragmidium disciflorum (*Tode.) James. fungus; **c** Teliospores of *Phragmidium disciflorum* (Tode.) James. fungus

Kazakhstan Region (49°57′N 82°37′E), Altai, Irtysh River (50°55′N 86°55′E) bank, August 07, 1958, M.P. Vasyagina; Pavlodar (52°18′N 76°57′E), Irtysh River bank, July 27, 2015, A.K. Ospanova (Fig. 6).

Discussion

The increase in land area occupied by cities leads to an increase in the number of artificial greenery. Studies have shown that there are differences between the same kinds of plants living in the city and away from the cities. Since the environment in urban areas may be contaminated with

Fig. 6 *Phyllosticta rosarum* Pass. fungus

various gases and metal, they can accumulate in the tissues of living beings. Mushrooms sprouting on the trees are in a close relationship with them. They can exchange nutrients, so that dangerous accumulation of toxic substances in one of them. It has been proven that mushrooms sprouting in urban areas accumulate more than manganese, lead, and zinc, which may be the result of human activity in the environment, but it should be noted that such an uncontrolled increase in heavy metals such as zinc, copper, and lead can have toxic effects on plant cells (Jumpponen and Jones 2010).

Previously, it was investigated the influence of environmental factors on the growth and development of urban trees. It was found that climate change, including an increase in mean annual temperature and moisture, leads to a reduction in their resistance to pathogens, competitors (fungi, bacteria). This can lead to destruction of some part of the greenery (Tubby and Webber 2010).

In 2011, the study of the relationship between trees and mycorrhizal podsazhenoy, they have found that with proper selection of the fungus is possible to increase the area covers the roots of the territory. This allows in trees more efficiently impregnated with the nutrients from the soil and grow better (Fini et al. 2011).

It should be noted that in addition to the positive effect on the trees, mushrooms mogun and cause damage. One of the most famous of fungal diseases has blight, particularly strong heavy losses from this fungus in the agricultural industry where it can easily destroy an entire crop of potatoes or tomatoes—important food for humans (Barber et al. 2013). This means that the mushrooms can be dangerous neighbors for urban trees that are already suffering from environmental pollution.

All found and identified species of fungi affecting trees and shrubs are the cause of various diseases. *Phyllosticta rosarum* causes spot anthracnose, and *Phragmidium disciflora* causes rose rust. *Trichocladia caraganae* is a powdery mildew pathogen, and *Phyllactinia suffulta* affects a lot of trees—lindens, oaks, birches. *Microsphaera* is a genus of powdery mildew. They cause enormous damage to trees, so it is necessary in the future to develop methods of dealing with these parasites and create methods of preventing such fungal infections.

Conclusion

Thus, due to complex ecological situation in industrial centers, fungi are saturated with harmful substances and infect plant by their colonization. Because of this situation, symbiosis is replaced with parasitism.

Due to described nature of plant infestation by fungi, the next stage of the research can be directed to the search for the most effective medicine, taking into account the nature of plant diseases.

We believe that one of the future directions in the study of fungal diseases must be the establishment of effective prevention methods. Measures should be taken to reduce the proliferation of fungi on healthy trees to preserve urban green spaces.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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