

Comparative Analysis of Foliar Diseases of Some Native and Non-Native Tree Species in Belarus and Siberia

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Abstract—Urban green spaces are known to be subjected to additional anthropogenic stress. Using native plants in monoculture, i.e., planting trees of the same species, may favour disease outbreaks and plant death. Non-native plants to be used in large cities for creating sustainable plantations are being searched for world-wide. Meanwhile, it is necessary to control plant pathogens in the variable conditions of the region and natural habitat. In Siberian cities, non-native European trees are used, and non-native Siberian plants are introduced in Belarus. This article reports long-term observations of foliar fungal pathogens attacking 21 woody plants (19 European, 2 Siberian) in Siberian and Belarusian cities. In both regions, 48 leaf fungal pathogens were detected, with powdery mildew fungi predominating in Belarus and leaf spotting fungi prevailing in Siberia. In both research regions, the greatest number of fungal species was found on *Syringa vulgaris* L. In Siberia, many pathogens were found on the non-native European plant *Berberis vulgaris* (9 species) and native plant *Caragana arborescens* Lam. (8 species). We have not detected the pathogens on European plants: *Acer campestre* L., *Acer platanoides* L., *Euonymus europaeus* L., *Lonicera caprifolium* L. in urban green areas in Siberia, while we have identified one to four foliar fungal pathogens on these plants in Belarus. To sum up: more pathogens were found on native plants in Siberia and Belarus; some leaf pathogen species (*Sawadaea tulasnei* (Fuckel) Homma, *Erysiphe alphitoides* (Griffon & Maubl.) U. Braun & S. Takam., *Cladosporium syringae* (Oudem.) Montem., *Erysiphe syringae* Schwein., *Erysiphe palczewskii* (Jacz.) U. Braun & S. Takam.) followed their host plants (*Acer tataricum* L., *Syringa vulgaris* L., *Caragana arborescens* Lam.) when introduced into new areas; and some local pathogens were also observed to spread to the non-native plants of closely related species.

Keywords: fungi, plant-host, alien species, native species, geographic distribution, damage, frequency

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Woody plants are of particular importance for urban green spaces since they form the structure of gardens and parks, create a long-term shape of landscape objects, have a significant artistic impact, and considerably affect the microclimate and sanitary conditions of urban areas. The state of woody plants in urbanized areas largely determines the quality of the environment, the aesthetics of the urban landscape, and the physical and psycho-emotional health of urban residents. However, species sustainability and the extent of the impact of urban environmental factors on vegetation are known to influence the physiological state of plants, their ornamental features, longevity in gardens and parks (Sucharzewska, 2010; Timofeeva, 2014; Kumar, 2018; Desprez-Loustau et al., 2019; Faticov et al., 2020). The range of plants used in urban green areas tends to include native woody plants. More than 50% of native plants in plantings contribute to the development of more pathogens (Tomoshevich,

2019). Using plant monocultures favour disease outbreaks and the consequent mortality of trees in urban green areas (Heiniger and Rigling, 1994; Brasier and Buck, 2001; Brasier and Kirk, 2010; Buiteveld et al., 2015; Jurisoo et al., 2019; Selikhovkin et al., 2020).

Non-native trees are planted in urban greeneries in both Europe and Asia. The global practice of introducing non-native species, varieties, and forms of trees and shrubs in the landscaping of large cities has shown the need for multi-species plantations (various species of native and non-native woody plants) that are more resistant to pathogenic complexes (Koropachinskii et al., 2011). Non-native plants have been reported to be more resistant, at least at the first stages of introduction, due to differences in phases of ontogenesis of plants and local harmful species, the absence of syngenetic pathogens at the new site, and some other factors (Tomoshevich, 2009; Tomoshevich and Banaev, 2013).

However, research indicates the possibility for new variants of pathogen complexes to emerge and their infectious potential to increase *ex situ* (Lebeda et al., 2008; Takamatsu et al., 2016; Jakuschkin et al., 2016; Yin et al., 2020).

Studies conducted in Siberian cities found that among non-native species, the highest resistance was in plants of Far Eastern and North American origin (Tomoshevich, 2019; Tomoshevich and Banaev, 2013). European non-native plants in Siberia proved to have variable resistance to leaf pathogens. It is unclear whether the plant resistance to pathogens is due to the specific characteristics of the plant species or to the climate impact. In this regard, it is worth investigating and comparing the species composition of pathogens, taking into account their damage, on European plants in their homeland (Europe) and in the new climatic conditions, in Siberia. In European conditions, urban green areas of Belarusian cities feature the key factor for comparing the species composition of leaf pathogens, i.e., the similar principles in urban planting and the maximum contrasting climatic conditions. Of particular interest are European plants *Quercus robur* L. and *Syringa vulgaris* L., widely introduced into urban green spaces in Siberian cities in recent years, and Siberian plants *Caragana arborescens* Lam. and *Rhamnus cathartica* L., becoming increasingly common in Belarusian cities.

At the first stages, it is essential to identify the species composition of leaf pathogens of woody plants, the damage caused, and the frequency of occurrence. It is known that some pathogens that follow their host plant may fail to adapt to local climatic conditions or manifest themselves in some years under specific weather conditions and cause damage (Tomoshevich, 2019).

In this article, we summarize observations of leaf pathogens that attack European and Siberian woody plant species in urban green spaces in Siberia and Belarus (Europe), taking into account that European woody plants are non-native to Siberia and Siberian woody plants are non-native to Belarus (Europe). We also discuss how the species composition of pathogens on European non-native plants in Siberian cities will differ compared to the same plants in urban plantations in Belarus, where European plants are native. Moreover, we consider how non-native plants without close relatives in the local flora are affected by leaf pathogens and discuss the potential for new pathogens to be found that may pose a threat to native and non-native woody plants, both in Siberian and in Belarusian (European) conditions.

MATERIALS AND METHODS

Collecting Samples in Urban Green Areas

In 5 Siberian cities, 19 European plants were used in urban plantations, while only two Siberian woody plants were found in urban green spaces in Belarus; all

these species were taken as model plants for research (Table 1).

Phytopathological surveys of 21 species of woody plants (19 European and 2 Siberian) were conducted annually in Siberian cities (Novosibirsk, Krasnoyarsk, Barnaul, Tomsk, Kemerovo) and Belarusian cities (Baranovichi, Braslav, Brest, Vitebsk, Gomel, Grodno, Dzerzhinsk, Minsk, Orsha, Polotsk, Soligorsk) (Fig. 1).

Inspection and sampling was continuously conducted for 19 years (2000–2018) throughout the summer periods in all cities. The following categories of urban green spaces were considered: parks, squares, gardens, highways, boulevards, territories adjacent to the house, intra-quarter territories, street plantings, etc. Trees and shrubs in all urban green areas (more than 100 plantation objects), including arboreta, were studied. In different parks, one woody plant species was found to be represented by a different number of specimens (from 3 to 50). At each plantation object, all plants of the same species were examined from four cardinal directions, large trees up to 2 m from the ground. The leaves with symptoms of the disease were incorporated into the herbarium. When examining woody plants, we made the records of disease damage. The plant damage area was evaluated according to a special scale: 1 point, 1–10% damage; 2 points, 11–25%; 3 points, 26–50%; and 4 points, >50% (Dudka et al., 1982).

Given the heterogeneous occurrence of woody plants in different categories of urban green spaces in Belarus and Siberia, we provide a general profile of the occurrence of plants in the study area in Table 1.

Microscopy and Identification of Pathogens

Sections of fruit bodies were made with a blade and examined under an Olympus SZ51 binocular microscope. Preparations of dry samples for further microscopy were prepared in a mixture of glycerol and alcohol, in a 3% KOH solution, and in distilled water. Erythrosine was used to increase the contrast of a number of preparations. Pathogens were identified using Zeiss Discovery V4, Olympus CX31, and Nikon Eclipse E200 microscopes. More than 1500 samples were examined during the study. When possible, the nomenclature corresponds to Index Fungorum, 2021 (www.indexfungorum.org). Siberian samples of foliar fungal pathogen species that were collected in this study are stored in the Central Siberian Botanical Garden of the Siberian Branch of the Russian Academy of Sciences (Herbarium of the Laboratory of Dendrology, NSC Collection). Belarusian samples are stored at V.F. Kuprevich Institute of Experimental Botany of the National Academy of Science of Belarus (Herbarium of the MSC-F mycology laboratory).

Table 1. Frequency of woody plant occurrence in urban green areas of Siberia and Belarus

Woody plant species	Plant occurrence in urban green areas ¹	
	Siberia	Belarus
<i>Acer campestre</i> L.	Very rare non-native plant	Rare
<i>Acer platanoides</i> L.	Very rare non-native plant	Widely spread native plant
<i>Acer tataricum</i> L.	Frequent non-native plant	Frequent native plant
<i>Alnus glutinosa</i> (L.) Gaertn.	Very rare non-native plant	Frequent native plant
<i>Alnus incana</i> (L.) Moench	Very rare non-native plant	Frequent native plant
<i>Berberis vulgaris</i> L.	Widely spread non-native plant	Frequent native plant
<i>Chamaecytisus austriacus</i> (L.) Link	Very rare non-native plant	Rare
<i>Chamaecytisus ruthenicus</i> (Fisch. x Woloszcz.) Klaskova	Rare non-native plant	Frequent
<i>Crataegus nigra</i> Waldst. & Kit.	Very rare non-native plant	Rare
<i>Euonymus europaeus</i> L.	Very rare non-native plant	Frequent native plant
<i>Lonicera caprifolium</i> L.	Very rare non-native plant	Frequent
<i>Lonicera nigra</i> L.	Very rare non-native plant	Rare
<i>Quercus robur</i> L.	Widely spread non-native plant	Frequent native plant
<i>Rosa glauca</i> Pourr.	Rare non-native plant	Rare
<i>Salix acutifolia</i> Willd.	Very rare non-native plant	Frequent native plant
<i>Salix daphnoides</i> Vill.	Very rare non-native plant	Rare
<i>Syringa josikaea</i> J. Jacq. ex Rchb.	Widely spread non-native plant	Very rare
<i>Syringa vulgaris</i> L.	Widely spread non-native plant	Widely spread
<i>Viburnum lantana</i> L.	Rare non-native plant	Rare
<i>Caragana arborescens</i> Lam.	Widely spread native plant	Frequent non-native plant
<i>Rhamnus cathartica</i> L.	Widely spread native plant	Frequent non-native plant

¹ Widely spread, 81–100%; frequent, 41–80%; rare, 11–40%; very rare, 1–10%.

Interpretation and Analysis of Results

The following parameters were applied to assess the damage and occurrence of each pathogen on European and Siberian species of woody plants in green areas of Siberia and Belarus cities: A: pathogen

is detected irregularly, i.e., not every year or not in every place where the plant is found; B: detected annually and in all places where the plant grows. A Mann–Whitney *U*-test was used to compare the series of data on the number of pathogens on leaves of woody plants.



Fig. 1. Map of the locations in Belarus and Siberia (Russia) where the samples of infection on trees and shrubs were collected, and boundaries of neighboring countries.

RESULTS

Foliar fungal pathogens were found on 21 (19 European and 2 Siberian species) woody plant species inspected (Table 2). A total of 48 fungal species were detected, with 18 causing leaf spot; 17 species being powdery mildews, 7 species—saprotrophic fungal, 5 species—rusts, and one—fungal species, *Taphrina acerina* A.G. Eliasson, which caused leaf deformation.

At the same, in green plantings of Siberian cities, no pathogens were found on five European woody plants: *Acer campestre*, *A. platanoides*, *Euonymus europaeus*, *Lonicera caprifolium*, *L. nigra*. In cities and parks of Belarus, from one to four pathogens were registered on these species (Fig. 2). *Syringa vulgaris* was found to be the most affected species in both regions of the study. In Siberia, *Berberis vulgaris* (European woody plants) were infected by nine pathogens, and *Caragana arborescens* (native Siberian woody plants) by eight pathogens. While, in Belarus, *Berberis vulgaris* were infected by six pathogens and *Caragana arborescens* by two pathogens.

Significant differences have been revealed in the number of pathogens on native and non-native plants. Non-native plants showed a lower number of pathogens, averaging 1.89 ± 0.57 , whereas native plants showed 2.31 ± 0.43 (Mann–Whitney test $Z = 2.01$, $p = 0.04$).

In Siberian cities, the fungal-caused leaf spot, scab, and similar diseases are dominant (52%), while in Belarusian cities, powdery mildews were found to prevail (48%) (Fig. 3).

In Belarus, 35 pathogens were registered, with 15 not reported in Siberian cities (Table 2). In Siberia, a total of 29 species of fungi were detected, with 13 of them found only in Siberian cities. Twenty species of micromycetes were found on woody plants in both study regions, with 43% of them being powdery mildew fungi distributed on species: *Acer tataricum*, *Berberis vulgaris*, *Chamaecytisus austriacus*, *Chamaecytisus ruthenicus*, *Quercus robur*, *Salix acutifolia*, *Salix daphnoides*, *Syringa josikaea*, *Syringa vulgaris*, *Caragana arborescens* (Table 2). Four pathogens (*Erysiphe lonicerae*, *Erysiphe penicillata*, *Podosphaera pannosa*, *Sawadaea bicornis*) were also found in both study regions, but they do not occur on European woody plants in Siberia.

DISCUSSION

Leaf Pathogens Affecting Non-Native and Native Plants

We found that both in Siberia and Belarus, a greater number of pathogens were found on native plants. Siberian woody plant species in green spaces of Belarusian cities were found to be attacked by 1–2 pathogens, whereas in Siberia, 4–9 pathogens were registered on them. In Siberia, European woody plants were also infected with fewer fungal species (more often, 1–2 fungus species) than in Belarusian cities. The most significant differences were identified for *Acer platanoides* that was not affected in Siberia but was infested by four pathogens in Belarus and for *Caragana arborescens* that was in contrast affected in Siberia by eight pathogens and in Belarus by two patho-

Table 2. Foliar fungal pathogens found on European and Siberian woody plant

Pathogen species recorded on woody plants	Urban green areas with presence of pathogens	
	Siberia	Belarus
<i>Acer campestre</i>		
<i>Sawadaea bicornis</i> (Wallr.) Homma	—†	Minsk
<i>Acer platanoides</i>		
<i>Rhytisma acerinum</i> (Pers.) Fr.	—	Widespread
<i>Sawadaea bicornis</i> (Wallr.) Homma	—	Widespread
<i>Sawadaea tulasnei</i> (Fuckel) Homma	—	Widespread
<i>Taphrina acerina</i> A.G. Eliasson	—	Minsk
<i>Acer tataricum</i>		
<i>Sawadaea bicornis</i> (Wallr.) Homma	—	Minsk
<i>Sawadaea tulasnei</i> (Fuckel) Homma	Widespread	Minsk‡
<i>Alnus glutinosa</i>		
<i>Cladosporium cladosporioides</i> (Fresen.) G.A. de Vries	—	Soligorsk
<i>Erysiphe penicillata</i> (Wallr.) Link	—	Widespread
<i>Melampsorium hiratsukanum</i> S. Ito ex Hirats.	—	Minsk
<i>Mycopappus alni</i> (Dearn. & Barthol.) Redhead & G.P. White	Novosibirsk	—
<i>Phyllactinia alni</i> Y.N. Yu & S.J. Han	—	Minsk
<i>Alnus incana</i>		
<i>Erysiphe penicillata</i> (Wallr.) Link	—	Widespread
<i>Melampsorium hiratsukanum</i> S. Ito ex Hirats.	—	Minsk
<i>Mycopappus alni</i> (Dearn. & Barthol.) Redhead & G.P. White	Novosibirsk	—
<i>Phyllactinia alni</i> Y.N. Yu & S.J. Han	—	Orsha‡
<i>Berberis vulgaris</i>		
<i>Alternaria alternata</i> (Fr.) Keissl.	Widespread	Minsk
<i>Cladosporium herbarum</i> (Pers.) Link	Novosibirsk	Minsk
<i>Erysiphe berberidis</i> DC.	Widespread	Widespread
<i>Kabatiella berberidis</i> (Cooke) C.G. Shaw & Arx = [<i>Gloeosporium berberidis</i> Cooke]	Novosibirsk, Krasnoyarsk	—
<i>Fumago vagans</i> Pers. = [<i>Leptoxylum fumago</i> (Woron.) R.C. Srivast.]	Novosibirsk, Krasnoyarsk, Kemerovo	—
<i>Phyllosticta westendorpii</i> Thum.	Novosibirsk	—
<i>Puccinia graminis</i> Pers.	Widespread	Widespread
<i>Sphaerulina berberidis</i> (Niessl) Quaedvl., Verkley & Crous = [<i>Septoria berberidis</i> Niessl]	Novosibirsk	Minsk
<i>Ascochyta berberidina</i> Sacc	Novosibirsk	Minsk, Brest
<i>Chamaecytisus austriacus</i>		
<i>Erysiphe trifoliorum</i> (Wallr.) U. Braun	Novosibirsk	Minsk
<i>Pleiochaeta setosa</i> (Kirchn.) S. Hughes	Novosibirsk	—
<i>Chamaecytisus ruthenicus</i>		
<i>Erysiphe trifoliorum</i> (Wallr.) U. Braun	Widespread	Gomel, Dzerzhinsk
<i>Fumago vagans</i> Pers. = [<i>Leptoxylum fumago</i> (Woron.) R.C. Srivast.]	Novosibirsk	—
<i>Ascochyta borjomi</i> Bondartsev	Novosibirsk	—
<i>Phyllosticta caraganae</i> P. Syd.	Novosibirsk	—
<i>Pleiochaeta setosa</i> (Kirchn.) S. Hughes	Novosibirsk	—
<i>Crataegus nigra</i>		
<i>Coryneum foliicola</i> Fuckel	Krasnoyarsk	—
<i>Euonymus europaeus</i>		
<i>Erysiphe euonymi</i> DC.	—	Vitebsk‡
<i>Lonicera caprifolium</i>		
<i>Erysiphe lonicerae</i> DC.	—	Minsk
<i>Lonicera nigra</i>		
<i>Erysiphe lonicerae</i> DC.	—	Minsk
<i>Quercus robur</i>		
<i>Alternaria alternata</i> (Fr.) Keissl.	Widespread	Minsk
<i>Cladosporium macrocarpum</i> Preuss.	Novosibirsk	Minsk, Brest Gomel
<i>Dendrostoma leiphaemia</i> (Fr.) Senan. & K.D. Hyde = [<i>Gloeosporium quercinum</i> Westend.]	—	Brest
<i>Erysiphe alphitoides</i> (Griffon & Maubl.) U. Braun & S. Takam.	Widespread	Widespread

Table 2. (Contd.)

Pathogen species recorded on woody plants	Urban green areas with presence of pathogens	
	Siberia	Belarus
<i>Fumago vagans</i> Pers. = [<i>Leptoxylum fumago</i> (Woron.) R.C. Srivast.]	Widespread	—
<i>Septoria quercina</i> Desm.	—	Brest
<i>Rosa glauca</i>		
<i>Botrytis cinerea</i> Pers.	—	Minsk
<i>Passalora rosae</i> (Fuckel) U. Braun	Krasnoyarsk	—
<i>Phragmidium mucronatum</i> (Pers.) Schltld.	—	Minsk
<i>Podosphaera pannosa</i> (Wallr.) de Bary	—	Minsk
<i>Salix acutifolia</i>		
<i>Erysiphe adunca</i> (Wallr.) Fr.	Novosibirsk	Minsk
<i>Salix daphnoides</i>		
<i>Erysiphe adunca</i> (Wallr.) Fr.	Novosibirsk	Minsk
<i>Syringa josikaea</i>		
<i>Erysiphe syringae</i> Schwein.	Widespread	Minsk
<i>Erysiphe syringae-japonicae</i> (U. Braun) U. Braun & S. Takam.	—	Minsk [‡]
<i>Cladosporium syringae</i> (Oudem.) Montem.	Novosibirsk	—
<i>Syringa vulgaris</i>		
<i>Ascochyta syringae</i> (Westend.) Bres.	Novosibirsk	Minsk
<i>Capnodium citri</i> Berk. & Desm.	—	Minsk
<i>Cladosporium herbarum</i> (Pers.) Link	Novosibirsk	Minsk
<i>Cladosporium syringae</i> (Oudem.) Montem.	Novosibirsk	—
<i>Erysiphe syringae</i> Schwein.	Widespread	Widespread
<i>Fumago vagans</i> Pers. = [<i>Leptoxylum fumago</i> (Woron.) R.C. Srivast.]	Krasnoyarsk, Tomsk	Brest
<i>Septoria syringae</i> Westend.	Novosibirsk	Brest
	Novosibirsk	
	Krasnoyarsk, Barnaul	
<i>Viburnum lantana</i>		
<i>Cladosporium herbarum</i> (Pers.) Link	Novosibirsk	—
<i>Erysiphe hedwigii</i> (Lév.) U. Braun & S. Takam.	—	Minsk, Brest, Grodno [‡]
<i>Caragana arborescens</i>		
<i>Erysiphe palczewskii</i> (Jacq.) U. Braun & S. Takam.	Widespread	Minsk, Brest
<i>Erysiphe robiniae</i> Grev.	—	Minsk [‡]
<i>Alternaria alternata</i> (Fr.) Keissl.	Novosibirsk	—
<i>Ascochyta borjomi</i> Bondartsev	Novosibirsk, Krasnoyarsk	—
<i>Cladosporium herbarum</i> (Pers.) Link	Novosibirsk	—
<i>Mycosphaerella jaczewskii</i> Potebnia [= <i>Septoria caraganae</i> (Jacq.) Died.]	Novosibirsk	—
<i>Fumago vagans</i> Pers. = [<i>Leptoxylum fumago</i> (Woron.) R.C. Srivast.]	Widespread	—
<i>Phyllosticta caraganae</i> P. Syd.	Novosibirsk	—
<i>Uromyces cytisi</i> J. Schröt.	Novosibirsk, Krasnoyarsk, Tomsk	—
<i>Rhamnus cathartica</i>		
<i>Erysiphe friesii</i> (Lév.) U. Braun & S. Takam.	—	Baranovichi, Gomel [‡]
<i>Phyllosticta cathartici</i> Sacc.	Novosibirsk	—
<i>Puccinia coronata</i> Corda	Novosibirsk	—

[†] Pathogen not found; [‡] species identified by I.S. Girilovich (2018).

gens. This fact was confirmed by other researchers who found fewer plant pathogens on non-native plants than on native plants (Mitchell and Power, 2003; Kleunen and Fischer, 2009).

Analysis of the Species Composition of Pathogens Found on European Plants in Siberia and Belarus (Europe)

At the same, in green plantings of Siberian cities, no pathogens were found on five European woody

plants: *Acer campestre*, *A. platanoides*, *Euonymus europaeus*, *Lonicera caprifolium*, *L. nigra*. In cities and parks of Belarus, from one to four pathogens were registered on these species (Table 2). Pathogens were not found only on one species *Crataegus nigra* in urban green areas in Belarus.

More surprisingly, four European woody plants (non-native) in green plantings in Siberia had 4–9 pathogens: *Berberis vulgaris*, *Chamaecytisus ruthenicus*, *Quercus robur*, *Syringa vulgaris* (Table 2). It

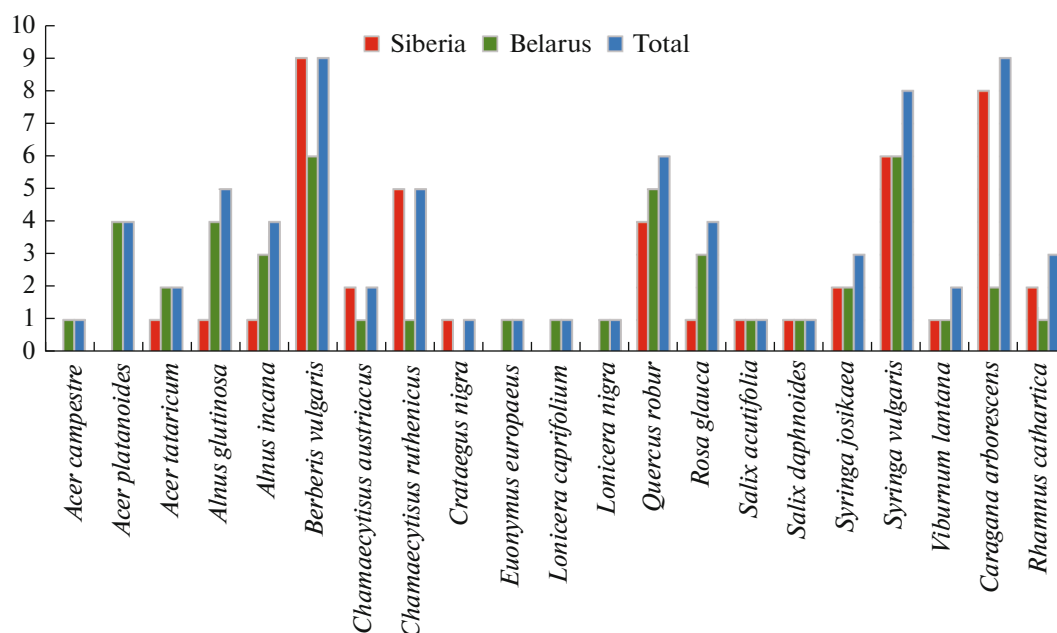


Fig. 2. Number of foliar pathogen species found on different plant species in urban green areas in Siberia and Belarus.

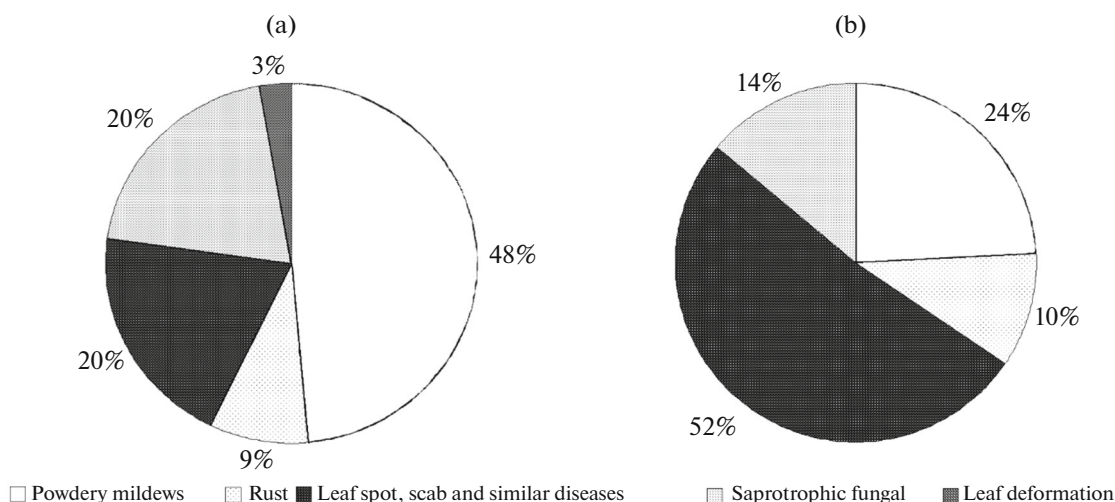


Fig. 3. Diagram of foliar fungal pathogens discovered in urban green areas: (a) Belarus; (b) Siberia.

may be due to the wide distribution of these woody plants in plantations in Siberia (Table 1). Two of them—*Berberis vulgaris*, *Chamaecytisus ruthenicus*—were attacked by a greater number of leaf pathogens than in green plantings in Belarus (Fig. 2).

Ascochyta borjomi and *Phyllosticta caraganae*, fungi widespread on the Siberian native woody plant *Caragana arborescens*, were found on *Chamaecytisus ruthenicus* (non-native woody plant).

Of particular interest is the species *Pleiochaeta setosa*, causing leaf spot and root rot on various herbaceous lupin species (*Lupinus* sp.). *Pleiochaeta setosa*, a dangerous pathogen infesting lupin worldwide (Paulitz, 1992; Yang and Sweetingham, 2002; Garibaldi et al., 2012; Gur and Om, 2015; Luckett et al., 2009),

was also registered in Belarus (*Mikobiota Belorussko-Valdajskogo poozer'ya*, 2013). Nevertheless, the pathogen was found in Siberian greenspaces on the woody plant *Chamaecytisus ruthenicus* in the medium degree of damage (Fig. 4). Earlier, *Pleiochaeta setosa* was detected on woody plants of the legume family: on *Genista tinctoria* in Oregon (USA) (Sahakian, 1996) and *Chamaecytisus supinus* (L.) Link. in Poland (Mułenko et al., 2008).

Analysis of the Species Composition of Pathogens Found on Siberian Plants in Siberia and Belarus (Europe)

In green spaces of Belarusian cities, Siberian species of woody plants *Caragana arborescens* and *Rham-*

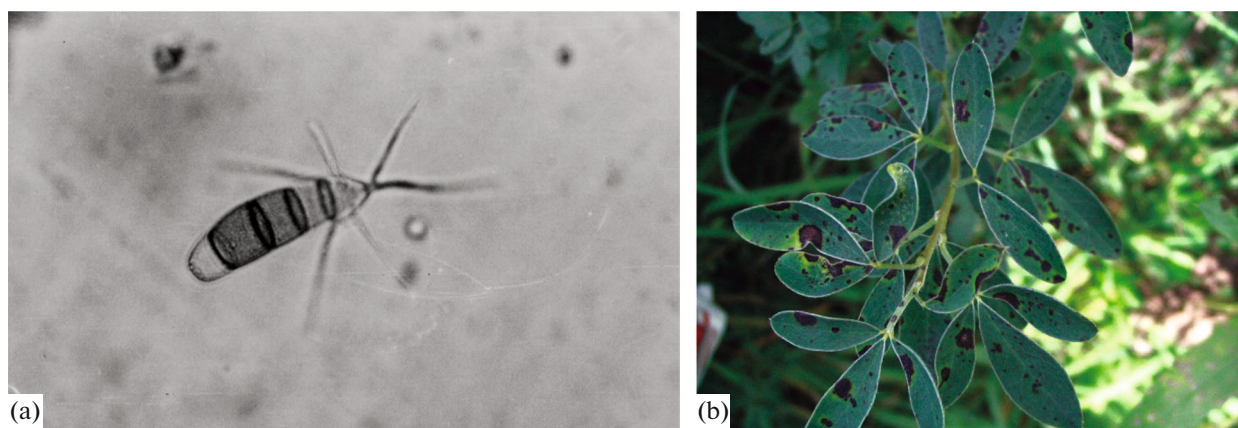


Fig. 4. Pathogen *Pleiochaeta setosa*: (a) fungal spore; (b) disease symptoms on leaves *Chamaecytisus ruthenicus*.

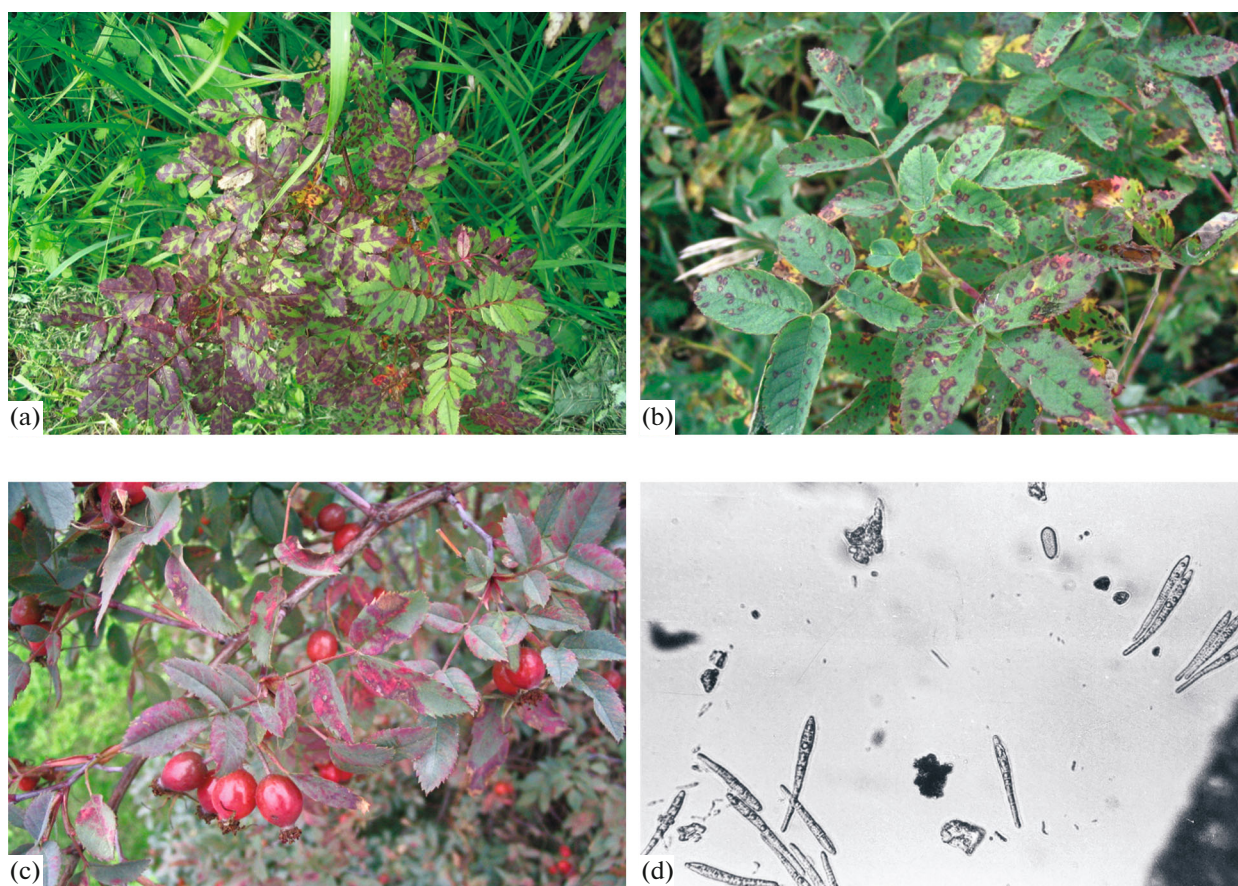


Fig. 5. Symptoms of leaf spot infection (*Passalora rosae*) on plant-hosts: (a) *Rosa spinosissima*; (b) *Rosa majalis*; (c) *Rosa glauca*; (d) fungal spore.

nus cathartica were attacked mainly by powdery mildew fungi: *Erysiphe palczewskii*, *Erysiphe robiniae*, *Erysiphe friesii*. In Siberia, they were also found to have rust and leaf spots (Table 2).

In the 1960s and 1970s, the leaf pathogen *Erysiphe palczewskii* was endemic to the Far East (Koval' and Nelen, 1970; Nelen, 1963, 1972). Extensive use of the

Siberian species *Caragana arborescens* as an ornamental plant in the landscaping of cities in the Far East allowed *E. palczewskii* to displace *Trichocladia caragana*. At the beginning of the 1980s, the occurrence of the fungus in the European part of the former USSR and the epiphytotic character of the disease development were reported (Gelyuta, 1981; Gelyuta and Gor-

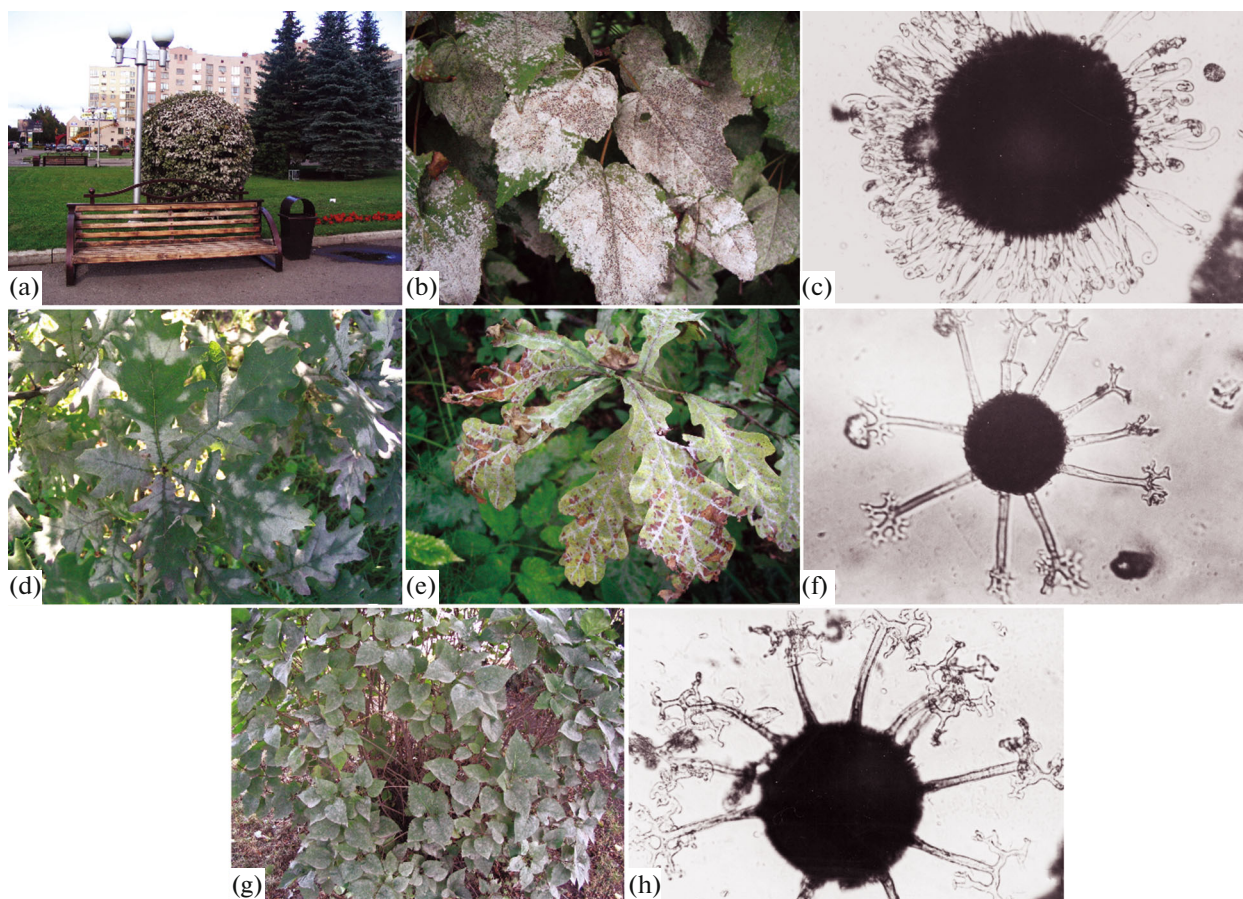


Fig. 6. Symptoms of powdery mildew infection on plant-hosts: (a) *Acer tataricum* in Kemerovo; (b) *Acer tataricum* in Novosibirsk; (c) chasmothecia *Sawadaea tulasnei*; symptoms of powdery mildew infection on plant-hosts: (d) *Quercus robur* in Novosibirsk; (e) *Quercus robur* in Krasnoyarsk; (f) chasmothecia *Erysiphe alphitoides*; (g) symptoms of powdery mildew infection on *Syringa vulgaris* in Barnaul; (h) chasmothecia *Erysiphe syringae*.

lenko, 1984). Recently, many researchers have been observing this fungus further advancing from the East to the West (Huhtinen et al., 2001; Vajna, 2006; Lebeda et al., 2008; Mieslerová et al., 2020). Most likely, *Erysiphe palczewskii* entered Belarusian cities together with the Siberian plant *Caragana arborescens*.

Leaf Pathogens of Non-native Plants with no Close Relatives in the Local Flora

Some pathogens have been found to affect both native and closely related European woody plants in Siberia. For example, *Coryneum foliicola* is widely found in Siberia on a native plant *Crataegus sanguinea* Pall. and has been found on *Crataegus nigra* (European woody plant). Similarly, *Passalora rosae* actively attacks native species *Rosa acicularis* Lindl., *R. majalis* Herrn, *R. spinosissima* L. and has been found on European species *Rosa glauca* (Fig. 5). These pathogens have a vast distribution area but were not registered on native European woody plants in Belarusian cities.

Meanwhile, some species of leaf pathogens (*Sawadaea tulasnei*, *Erysiphe alphitoides*, *Cladosporium syringae*, *Erysiphe syringae*) were possibly brought to Siberia with their plant hosts (*Acer tataricum*, *Quercus robur*, *Syringa vulgaris* (Fig. 6)), since there are no closely related species in this Region.

Also, non-native European plants *Acer campestre*, *A. platanoides*, *Euonymus europaeus*, *Alnus glutinosa*, *A. incana* have no closely related representatives in Siberia, but they have not brought pathogens from the European region. The fungus *Mycopappus alni* was registered on *Alnus glutinosa* and *A. incana* plants in Novosibirsk, while it remains to be determined how it appeared in Siberia. *M. alni* was first found in Canada and the United States on *Alnus rubra* and *A. sinuata* in the late 1980s (Redhead and White, 1985). Later, *M. alni* was detected in the Far East on leaves of *Alnus hirsuta*, as well as on hawthorn and chokeberry leaves in Korea and Turkey (Braun et al., 2000; Lee et al., 2013; Park et al., 2013). We detected this fungus for the first time in Russia in 2005 in the arboretum of the Siberian Branch of the Russian Academy of Sciences

Table 3. Fungus—host plant associations found in Siberia and Belarus and pathogen impact

Pathogen species	Plant species	Period of pathogen development		Plant tissues infected		Damage/frequency ¹	
		Belarus	Siberia	Belarus	Siberia	Belarus	Siberia
<i>Alternaria alternata</i>	<i>Berberis vulgaris</i>	Jul–Aug	Jul–Aug	Leaves, shoots	Leaves	2/B	2/A
	<i>Quercus robur</i>	Jul–Sept	Jul–Sept	Leaves, young shoots	Leaves	1-2/B	2/A
<i>Ascochyta syringae</i>	<i>Syringa vulgaris</i>	Jul–Sept	Aug–Sept	Leaves	Leaves	2/A	1/A
<i>Cladosporium herbarum</i>	<i>Berberis vulgaris</i>	Jul–Aug	Jul–Aug	Leaves, shoots	Leaves	1/B	1/A
	<i>Syringa vulgaris</i>	Jul–Sept	Jul–Sept	Leaves, young shoots	Leaves	1/B	1/A
<i>Cladosporium macrocarpum</i>	<i>Quercus robur</i>	Jul–Sept	Aug–Sept	Leaves, young shoots	Leaves	1/A	1/A
<i>Erysiphe adunca</i>	<i>Salix acutifolia</i>	Jun–Sept	Aug–Sept	Leaves	Leaves	2-3/B	2-3/B
	<i>Salix daphnoides</i>	Jun–Sept	Aug–Sept	Leaves	Leaves	2/B	2/B
<i>Erysiphe alphitoides</i>	<i>Quercus robur</i>	Jun–Sept	Jun–Sept	Leaves	Leaves, young shoots	4/B	3-4/B
<i>Erysiphe berberidis</i>	<i>Berberis vulgaris</i>	Jun–Sept	Jul–Sept	Leaves	Leaves, young shoots	4/B	4/B
<i>Erysiphe palczewskii</i>	<i>Caragana arborescens</i>	Jun–Sept	Jun–Sept	Leaves	Leaves, young shoots	3/B	4/B
<i>Erysiphe syringae</i>	<i>Syringa josikaea</i>	Jul–Aug	Jul–Sept	Leaves	Leaves	4/B	2/A
	<i>Syringa vulgaris</i>	Jul–Aug	Jul–Sept	Leaves	Leaves	3-4/B	3-4/B
<i>Erysiphe trifoliorum</i>	<i>Chamaecytisus austriacus</i>	Jun–Sept	Aug–Sept	Leaves	Leaves	2/B	2/A
	<i>Chamaecytisus ruthenicus</i>	Jun–Sept	Aug–Sept	Leaves	Leaves	2/B	3/A
<i>Puccinia graminis</i>	<i>Berberis vulgaris</i>	Jun–Aug	May–Jun	Leaves	Leaves	2-3/B	2/A
<i>Sawadaea tulasnei</i>	<i>Acer tataricum</i>	Jun–Oct	Jul–Sept	Leaves	Leaves, young shoots	3/B	3-4/B
<i>Septoria syringae</i>	<i>Syringa vulgaris</i>	Jul–Sept	Jun–Aug	Leaves	Leaves	1-2/B	3-4/B
<i>Sphaerulina berberidis</i>	<i>Berberis vulgaris</i>	Jul–Sept	Jul–Sept	Leaves	Leaves	2/B	1/A

¹ Relative levels of damage by pathogen (i.e. the percentage of damaged surface of leaf or other tissues): 1: 1–10%; 2: 11–25%; 3: 26–50%; 4: >50% of leaf/plant surface. Two numbers in the same row represent different situations in different cities. Frequency of attack: A: found irregularly, i.e. not every year or not at every location where the plant occurs; B: found every year and at all locations where the plant occurs.

on *Alnus glutinosa* and *A. incana* (Tomoshevich, 2008). The fungus is not found every year, but under favorable weather conditions, it causes serious damage (leaf damage up to 80–100%), resulting in curling and falling of leaves on lower branches by mid-August. Earlier, we noted that the fungus *Mycopappus alni* was likely to appear in Europe (Tomoshevich et al., 2013).

Pathogen Impact on Woody Plants in Siberia and Belarus

It should be noted that in green areas of Belarus, pathogens, excluding *Ascochyta syringae* and *Cladosporium macrocarpum*, are found every year and at all

locations (Flora of Belarus, 2015). However, in Siberia, only seven pathogens (*Erysiphe adunca*, *Erysiphe alphitoides*, *Erysiphe berberidis*, *Erysiphe palczewskii*, *Erysiphe syringae*, *Sawadaea tulasnei*, *Septoria syringae*) are found every year and at all locations where the plants grow (values A and B, Table 3).

In Belarus (Europe), seven pathogens (*Erysiphe adunca*, *Erysiphe alphitoides*, *Erysiphe berberidis*, *Erysiphe palczewskii*, *Erysiphe syringae*, *Sawadaea tulasnei*, *Puccinia graminis*) cause 26–50% or more damage, whereas in Siberia, only three pathogens (*Septoria syringae*, *Sawadaea tulasnei*, *Erysiphe trifoliorum*) are more aggressive (values 3–4, Table 3). This fact proves

native species to be affected to a greater extent in the region of origin.

Leaf pathogens *Alternaria alternata*, *Cladosporium herbarum*, *Erysiphe alphitoides*, *Erysiphe palczewskii*, *Sphaerulina berberidis* were found to develop during in the same months in Siberia and Belarus (Table 3). However, most fungi occur in green areas of Siberia a month later or have a longer period of development than in the Belarusian cities. The exception is *Puccinia graminis* recorded in Siberia in May–June. The later occurrence of leaf pathogens in Siberia is related to the delayed phenophases of European woody plants. For example, in the European part of Russia, the first oak shoots open in mid-April (Shimanyuk, 1964). In Siberia, the opening of buds and the growth of *Quercus robur* shoots were recorded more than a month later (late May–early June) (Vstovskaya and Koropachinskiy, 2005).

CONCLUSIONS

The research has shown that using native and non-native woody plants in parks and gardens enables creating more sustainable green spaces. However, continuous monitoring of European woody plants in Siberia and Siberian plants in Belarus should be carried out since the transmission of local pathogens to introduced plants and increased aggressiveness of pathogens that were brought to the region by their host plants are observed. It is particularly the case for powdery mildew fungi since these biotrophic pathogens can persist in twigs and seeds, such as oak acorns.

When adapting to environmental conditions, the non-native woody plants change their development rhythm and decrease the resistance, affecting the degree of pathogenic fungi development. For example, in the sharply continental conditions of Siberia, the delayed appearance of disease symptoms is observed due to the shift in the phenophases of plants, but the aggressiveness of pathogens increases compared to the regions of Belarus.

The new findings on the development of *Mycopappus alni* and *Pleiochaeta setosa* for Siberia suggest that they are likely to appear on woody plants in Europe and have a possible invasive status.

The first findings of pathogen analysis on non-native and native plants in Siberia and Belarus (Europe) show that using non-native plants in urban plantations can cause new associations between plants and pathogens and even more severe plant lesions. Future molecular studies are needed to understand the distribution of the fungus more accurately, especially in urban areas. In controversial cases, pathogen identification and replenishment of GenBank with parallel analyses of samples of Siberian and European fungus samples will be required.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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