Ecological Questions 32 (2021) 3: 101–109 http://dx.doi.org/10.12775/EQ.2021.28

Fungal diseases of trees and shrubs growing in Siberian Square in Warsaw

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Received: 21 October 2020 / Accepted: 5 May 2021

Abstract. A good condition of trees and shrubs growing in urban green areas is one of the key aspects of management. Plant monitoring, including recognition of symptoms of diseases caused by pathogenic fungi and prevention of their spread, is one of the ways of supporting the process of maintenance of green areas. The aim of the study was to conduct preliminary investigations of plants growing in Siberian Square in Warsaw infected by phytopathogenic fungi. The research carried out in 2017–2019 in Siberian Square in Warsaw revealed that the most common diseases observed on the trees and shrubs were caused by powdery mildew fungi infecting maples, poplars, apple trees, and barberry shrubs. *Sawadaea tulasnei, Erysiphe adunca, Erysiphe berberidis*, and *Podosphaera leucotricha* (*Erysiphales*) were identified as the causal agents of powdery mildew. Pathogens causing leaf spots and leaf lesions were identified as *Venturia inaequalis* on *Malus* x *purpurea* 'Ola' and *Rhytisma acerinum* on *Acer platanoides*. Rust caused by *Melampsora laricis-populina* (*Pucciniales*) and basidiomata of *Pleurotus ostreatus* were detected on infected *Populus nigra* 'Italica' trees.

Keywords: urban greenery, woody plant diseases, powdery mildew, maintenance of green areas.

1. Introduction

Green areas, which include parks, green squares, promenades, boulevards and many other types of gardens (Ustawa z dnia 16 kwietnia 2004 r. o ochronie przyrody (Dz. U. 2004 Nr 92 poz. 880, z późn. zm.)) have been recognized as one of the important elements organizing the structure of the city (Benevolo, 1995; Kimic, 2000b; Majdecki, 2009) and a way to counteract the negative effects of industrialization progressing since the 19th century (Clark, 1973; Kimic, 2004, 2005). Their role in providing contact with nature and rest for city dwellers has been very highly valued (Kimic, 2000a). Even small areas like green squares play an important role in many cities to the present day. Their compositional functions and contribution to shaping the urban landscape (Benevolo, 1995; Giedion, 2009; Sutkowska, 2006) as well as aesthetic aspects are invaluable (Łukasiewicz & Łukasiewicz, 2006; Majdecki, 2009; Niemirski, 1973; Tomalak, 2006). The natural values of public greenery are related to providing space for plants and habitats for animals, supporting the sustainable development of cities by improving their microclimate, increasing rainwater retention, and purification of air (Łukasiewicz & Łukasiewicz, 2006; Zimny, 2005), which enhances the health of city dwellers (Lee et al., 2015). The social values of the urban greenery include the provision of places for rest and different forms of interactions between people (Kimic, 2000a; Łukasiewicz & Łukasiewicz, 2006; Niemirski, 1973).

Trees and shrubs are the basic natural elements of urban green areas. They are represented by many decorative species and cultivars, including fruit trees (Kimic, 2019; Lisandru et al., 2016), which increase biodiversity. The management of urban greenery focuses on many activities related to planning, designing, maintenance, and protection. However, currently it is essential not only to create new green areas but also mainly to maintain the already existing ones, including plants growing therein. A good condition of trees and shrubs is important for the safety of public greenery users (Suchocka & Kimic, 2019), providing them with comfort and rest (Łukasiewicz & Łukasiewicz, 2006). It is also essential for limitation of the negative effects of climate change by co-creation of a system of green infrastructure improving the living conditions in the city (Benedict & McMahon, 2006; Karade et al., 2017; Shi & Woolley, 2014; Szulczewska, 2018).

A deteriorating state of the urban environment, including increasing air, soil, and water pollution, thermal stress, water deficit, mechanical damage of roots, trunks and branches, etc., negatively affects the condition of many trees and shrubs. Weakened plants become more susceptible to infection by various pathogens, including fungi. Their reproduction and spread may cause infections and further weakness of plants, reduce their decorative and utility values, and even cause their death (Suchocka et al., 2014). Therefore, monitoring of trees and shrubs in public green areas may be used as a key management task to eliminate many potential threats caused by fungi. Both existing and new plantings will need careful maintenance in the years to come given the climate changes enhancing the risk of pathogen infection (Tubby & Webber, 2010). The aim of this study was to conduct preliminary investigations of plants growing in Siberian Square in Warsaw infected by phytopathogenic fungi.

2. Material and methods

The investigations were carried out in 2017–2019 in the Section of Plant Pathology at Warsaw University of Life Sciences – SGGW and involved trees and shrubs growing in Siberian Square, which is located between Chłodna and Krochmalna Streets in Warsaw. The trees and shrubs were inventoried in 2017. 162 trees and 63 shrubs were identified in the square (including 8 groups of shrubs composed of 52 plants and 11 solitary specimens). In total, there were 225 plants in the square.

The plants were inspected for the presence of symptoms of diseases and etiological signs of pathogens. Several pieces of stems, shoots, fruits and 15 leaves with visible disease symptoms were taken from each tree or shrub. The inspections were carried out in four terms: in autumn (October), winter (February), spring (May), and summer (July). The collected plant material was stored for maximum 3 days in the refrigerator and investigated in the fresh state.

Pathogens were identified based on their morphology assessed under an SZ11 stereoscopic light microscope and a BX50 simple light microscope (Olympus) as well as literature data (Braun & Cook, 2012; Majewski, 1977; Marcinkowska, 2012; Suchocka et al., 2014). Photographic documentation was prepared using a DP71 camera integrated with the simple light microscope mentioned above. Measurements of individual fungal structures (approx. 30) were made using the CellF program. Additionally, individual objects in the square were photographed.

3. Results

Among the 225 trees and shrubs growing in Siberian Square in Warsaw, disease symptoms were observed on 68 individual plants (Table 1). The etiological symptoms of powdery mildews were most visible on the leaves of maples, poplars, apple trees, and barberry shrubs.

The powdery mildew was recognized on 4 plants of *Acer platanoides* (Fig. 1a, b). They were also infected by the fungus *Rhytisma acerinum* (Pers.) Fr. (Rhytismatales) causing the tar spot disease. In summer, oval black spots (1–2 cm diameter) surrounded by a yellowish ring were observed on the upper leaf surface.

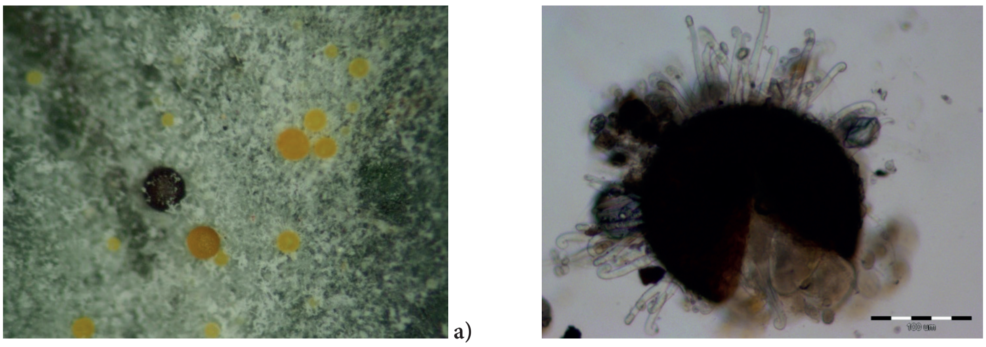
All 5 *Populus nigra* 'Italica' plants were infected by the powdery mildew fungus *Erysiphe adunca* (Wallr.) Fr. (Erysiphales). The mycelium covered the entire leaf surface. Chasmothecia with appendages were stiff to flexuous, straight to somewhat curved with hooked tips. Symptoms of poplar rust caused by *Melampsora laricis-populina* Kleb. (Pucciniales) were observed on 100% of black poplar trees as well. Uredinia that produced urediniospores were clearly visible on the infected leaves. They were yellow, cylindrical, broadly ellipsoidal or obovoid, and echinulate except for apices, which had a smooth surface (Fig. 2a, b).

Conks of *Pleurotus ostreatus* (Jacq.) P. Kumm. (Agaricales) were observed on one Black poplar tree. The upper surface of the conk was smooth, creamy to grayish with gills extending onto the stalk. The *Pleurotus ostreatus* basidiomata were located at the base of the poplar trunk (Fig. 3a, b).

The damage to the leaves and fruits of *Berberis vulgaris* 'Atropurpurea' plants growing as a group of shrubs was mainly related to infection by a powdery mildew fungus identified as *Erysiphe berberidis* DC., (Erysiphales) (Braun & Cook, 2012). All the 20 European barberry plants had severely infected buds, leaves, growing tips, fruits, etc., which were covered by a grayish white mycelium of the powdery fungus with conidiophores producing conidia in chains (oidia). Late in the season, chasmothecia with several-fold dichotomously branched appendages (stiff to flexuous) were formed (Fig. 4a, b, c, d).

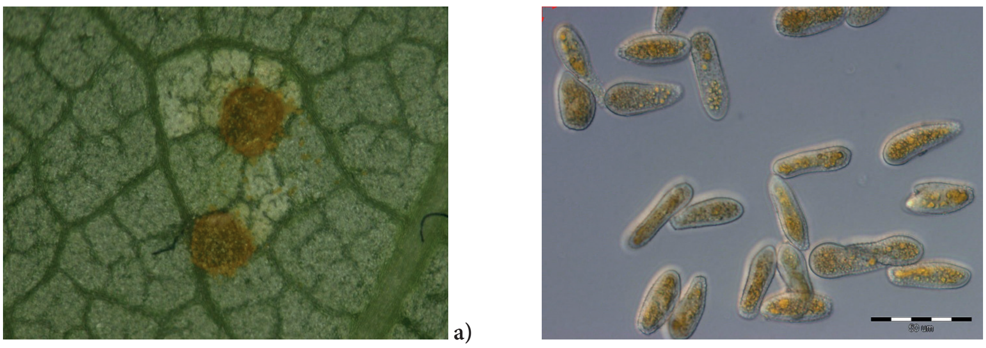
Table 1. Pathogens and diseases on trees and shrubs growing in Siberian Square in Warsaw

Plant Latin name	Plant common name	Pathogen	Disease	Number of infected plants /Total number of plants
Acer platanoides L.	Norway maple	*Rhytisma acerinum*	Tar Spot	4/4
Acer platanoides L.	Norway maple	*Sawadaea tulasnei*	Maple Powdery Mildew	4/4
Berberis vulgaris 'Atropurpurea'	European barberry	*Erysiphe berberidis*	Barberry Powdery Mildew	20/20
Malus x *purpurea* 'Ola'	Apple-tree	*Venturia inaequalis*	Apple Scab	39/40
Malus x *purpurea* 'Ola'	Apple-tree	*Podosphaera leucotricha*	Apple Powdery Mildew	25/40
Populus nigra 'Italica'	Black poplar	*Erysiphe adunca*	Poplar Powdery Mildew	5/5
Populus nigra 'Italica'	Black poplar	*Melampsora laricis-populina*	Poplar Rust	5/5
Populus nigra 'Italica'	Black poplar	*Pleurotus ostreatus*	White Flacy Sapwood Rot	1/5
Acer negundo L.	Ash-leaved maple	–	–	0/2
Acer pseudoplatanus L.	Sycamore maple	–	–	0/10
Acer saccharinum L.	Silver maple	–	–	0/37
Cotoneaster lucidus Schltdl.	Hedge cotoneaster,	–	–	0/22
Crataegus rhipidophylla Gand.	Midland hawthorn	–	–	0/2
Forsythia x *intermedia*	Weeping Forsythia	–	–	0/18
Fraxinus pennsylvanica Marsh.	Green ash	–	–	0/3
Ribes aureum Pursh	Golden currant	–	–	0/2
Robinia pseudoacacia L.	Black locust	–	–	0/6
Sambucus nigra L.	Elder	–	–	0/1
Sorbus aucuparia L.	Rowan	–	–	0/6
Tilia cordata Mill.	Small-leaved linden	–	–	0/7
Tilia platyphyllos Scop.	Large-leaved linden	–	–	0/40



a) b)

Figure 1. Chasmothecia of *Sawadaea tulasnei:* a) on leaf, b) magnification



a) b)

Figure 2. *Melampsora laricis-populina:* a) uredinia on the lower surface of poplar leaf, b) urediniospores

Figure 3. a) Basidiomata of *Pleurotus ostreatus* at the base of the *Populus nigra* 'Italica' trunk, b) close-up

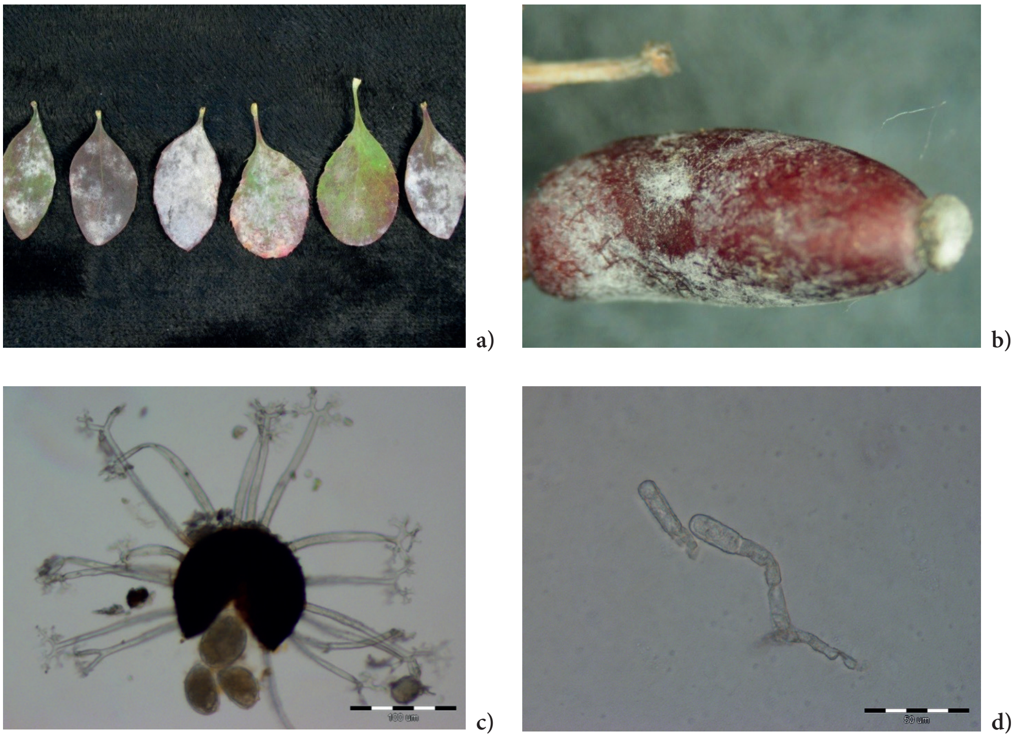
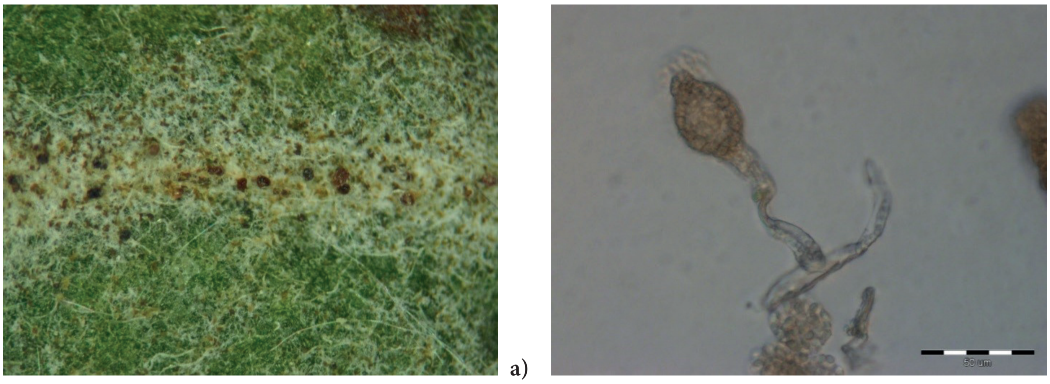


Figure 4. Powdery mildew on *Berberis vulgaris* caused by *Erysiphe berberidis*: a) on leaves, b) on fruits, c) magnification of chasmothecium, d) conidiophore

Leaves and fruits of 39 (97.5%) ornamental apple trees of *Malus* x *purpurea* 'Ola' showed the symptoms of apple scab caused by the fungus *Venturia inaequalis* (Cooke) G. Winter (Pleosporales). Initially, olive-colored irregular spots were observed on leaves. Later, they became olive-green to gray lesions with a velvety surface. Circular scabby lesions were observed on infected fruits. Misshapen and cracked fruits were visible (Fig. 5). In addition to scab, symptoms of powdery mildew on the leaves of 25 of *Malus* x *purpurea* 'Ola' trees were observed as well.

The pathogen was identified as *Podosphaera leucotricha* (Ellis & Everh.) E.S. Salmon (Braun & Cook, 2012). This fungus grew rather poorly because it was parasitized by a hyperparasite *Ampelomyces quisqualis* Ces. (Pleosporales) (Fig. 6a, b). *A. quisqualis* produces pycnidia with one-celled conidia.

Figure 5. Apple scab symptoms caused by *Venturia inaequalis*



a) b)

Figure 6. Hyperparasite *Ampelomyces quisqualis:* a) on mycelium of *Podosphaera leucotricha* b) pycnidium

4. Discussion

Disease symptoms were observed on 30.2% of all ornamental plants growing in Siberian Square in Warsaw. Failure to eliminate pathogens may significantly increase the number of infected plants in the following years, which at the same time deteriorates the health condition of many plants.

Laboratory identification confirmed that the fungus *Sawadaea tulasnei* (Fuckel) Homma (order Erysiphales) was the causal agent of powdery mildew on all plants of *Acer platanoides*. The morphology and sizes of fungus structures (conidia, chasmothecia, appendages, asci, and ascospores) were similar to those described by Braun and Cook (2012). In Poland, this pathogen was observed by Kochman e.g. in the vicinity of Warsaw on Norway maple in 1960. In the experiments carried out by this researcher, the pathogen was found to infect only the Norway maple (*A. platanoides*), but was not identified on either the sycamore (*A. pseudoplatanus*) or the ash-leaved maple (*A. negundo*). In a study carried out in Olsztyn (Sucharzewska, 2010), *S. tulasnei* developed abundantly on the Norway maple during a dry and warm summer, which was also noted in the present investigation. In the study conducted by Sucharzewska (2010), the highest infection rate was exhibited by maple trees growing along busy streets, which may explain the infection of 100% of *A. platanoides* trees in Siberian Square, which is located virtually in the center of Warsaw. Besides powdery mildew on all *A. platanoides* trees the occurrence of *R. acerinum* was noted. This pathogen was observed by Werner and Andrzejak (2008) in green areas in Poznan as well. As demonstrated by Łuszczyński (2002) and Kosiba (2007), this fungus can be used as an indicator of air pollution. Bevan (1978) (after Łuszczyński (2002)) found that *R. acerinum* is very susceptible to the sulfur dioxide (SO_2) content in the air, as its concentration at the level of 0.09 mg/m^3 is lethal to this pathogen. Since 100% of the *A. platanus* trees showed symptoms of this disease, we can suppose that the concentration of SO_2 in Siberian Square is not harmful to residents.

The fungus *Erysiphe adunca* (Wallr.) Fr. (Erysiphales) recognized on trees of *Populus nigra* 'Italica' species is commonly present on these plants in Poland (Mułenko et al., 2008). The morphological features of this fungus were in line with the description provided by Braun and Cook (2012).

Rust fungus *Melampsora laricis-populina* Kleb. (Pucciniales) noted on Black poplar trees for the first time was described on this species by Klebahn in 1902 as *M. larici-populina* Kleb. The morphology and average size of the urediniospores (38.32 x 14.47 μm) were characteristic for this species of rust (Klebahn, 1902; Pei & McCracken, 2005).

Pleurotus ostreatus (Jacq.) P. Kumm. (Agaricales) observed on Black poplar tree is an edible fungus with fleshy annual shelving conks, sessile or with a short eccentric stalk (Grzywacz & Staniszewski, 2003; Szczepkowski, 2012).

On *Berberis vulgaris* 'Atropurpurea' the symptoms of powdery mildew were noted on 100% of plants just like in research conducted in Poznan (Werner & Andrzejak, 2008). The causal agent of this disease was identified as *Erysiphe berberidis* DC., (Erysiphales) according to the description of Braun (2011) and Braun and Cook (2012). *E. berberidis* is known to infect various species of the Berberidaceae (Braun, 1987). In Poland this fungus was reported on *Mahonia aquifolium* (Pursh) Nutt as well (Sałata, 1985). Powdery mildews are probably the most common and widespread plant diseases. Therefore, the presence of mainly this disease on the plants inspected in the square was not surprising, as the summers in the investigated period were particularly dry and warm (Te Beest et al., 2008).

Apple scab caused by *Venturia inaequalis* (Cooke) G. Winter (Pleosporales) was identified on 97.5% of *Malus* x *purpurea* 'Ola' trees in Warsaw Siberian Square. It is one of the most dangerous disease of apple trees (Bowen et al., 2011; Marcinkowska, 2012). The highest disease severity on *Malus* x *purpurea* was observed in Poznan (Werner & Andrzejak, 2008) as well. This pathogen was found in almost all areas in which apples are grown commercially, and at the same time is more severe in temperate countries with cool, moist climates during early spring (MacHardy, 1996; Bowen et al., 2011).

Powdery mildew caused by *P. leucotricha* is the second most important apple tree disease after scab. The hyperparasite (*A. quisqualis*) parasitizing this pathogen can occur on many other species of powdery mildew (*Erysiphe alphi*toides, *E. hypophylla, E. palczewskii*, *Golovinomyces sordidus, Podosphaera fusca* and *Sawadaea tulasnei*) in urban areas (Sucharzewska et al., 2012).

5. Conclusions

There is very little information on the occurrence of fungal diseases on shrubs and trees growing in urban green areas, including Warsaw, due to the lack of research conducted in recent years in this field. This situation is worrying as these types of plant diseases are often impossible to eradicate once they have established themselves, and managing the problem is time-consuming and expensive. At the same time, the number of other typical factors reducing the health of trees and shrubs (e.g. urban heat islands, water deficit, summer drought, etc.) is constantly increasing in large urban agglomerations such as Warsaw. Plants weakened by urban stress are increasingly exposed to infection by a growing number of pathogens (Tomalak, 2003; Piętka & Ciurzycki, 2018). Prevention is therefore crucial to avoid the devastating impact of diseases and to maintain a high level of attractiveness and quality of urban green spaces. In this context, systematic monitoring and assessment of plant health in cities (Bach, 2012) may become a key tool of their management, including to counteract many negative effects of fungal infestation. Keeping trees and shrubs in good condition in urban green areas will reduce the costs of maintenance thereof in subsequent years, limit their felling, and, as a result, will allow the maintenance of a greater number of plants in cities (Krynicki & Witkoś-Gnach, 2016), bringing benefits to their inhabitants.

Counteracting various types of plant diseases, including fungal diseases, should be included in a wide range of activities related to the maintenance of trees and shrubs in cities. The implementation of this approach is crucial, especially at the level of the local management of urban greenery (Bergier & Kronenberg, 2018; Biejat, 2017), including the cooperation of local governments and scientists in the preparation of guidelines such as Standards for urban green spaces, which have increasingly been developed for many Polish cities in recent years. Trees and shrubs growing in green areas in Warsaw are monitored and cared for, but the prevention of fungal diseases is currently insufficient. The document of Warsaw Standards for urban green spaces (Standardy kształtowania zieleni Warszawy, 2016) indicates only the problem of the fungal diseases' risk as one of the factors which should be taken into account in the process of maintaining greenery in the city. Unfortunately, so far no investigation has been conducted on the occurrence of fungal diseases on trees and shrubs in city squares and parks. The results of preliminary studies presented in this paper and conducted on plants growing in Siberian Square in Warsaw show that fungal diseases can threaten various species of plants even under conditions less favourable for infections (e.g. warm and dry summers). The results validate the need to extend the research on fungal diseases on plants in other green areas in the city. The research extension will allow to compare and assess the degree of risk of fungal diseases to trees and shrubs, and then indicate the directions and methods of their prevention, as well as in the case of infection – counteracting their negative effects.

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