Powdery mildew fungi in objects of the landscape architecture: features of dissemination, harm and protection of plants

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Abstract. It was investigated that the majority of the deciduous trees and bushes applied in gardening of the city territories are in a varying degree struck by mildew fungi. The infected plants are weakened; lose decorative properties and ability to form an environment. Most often pathogens infect plants of Berberidaceae, Betulaceae, Fagaceae, Hippocastanaceae, Oleaceae, Rosaceae, Salicaceae, Sapindaceae, Ulmaceae families. The species relating of Adoxaceae, Caprifoliaceae, Fabaceae, Malvaceae and Pinaceae families show resistance to this pathology. Causative agents of mildew choose leaves of plants as a nutritious substratum; however, the disease has been noted on sprouts and buds of roses. Native species of trees and bushes are struck by mildew more often than introduced species. Moreover, it is noted the high extent of distribution of the disease on local plants, especially on an oak and a maple. The most struck exotic plants are barberries. The major ecological factors promoting distribution of powdery mildew fungi are insufficient aeration of plantings and low level of insolation. The major preventive action is using steady species of plants. The immunity of plants to this pathology can be increased by competent use of fertilizers - restriction of nitrogen and timely application of phosphorus and potassium.

1. Introduction

One of the most widespread and harmful pathologies of the majority of deciduous plants is the powdery mildew fungi, which strikes forest, fruit, decorative trees and bushes, lawn herbs and also the flower cultures of the outdoor and indoor soil [1]. Pathology develops on over ground parts of plants – leaves, herbaceous sprouts, buds, ovaries and fruits. As a result of powdery mildew infection the processes of assimilation break in a plant organism, plants are weakened and lag behind in growth, lose resistance to adverse factors, reduce winter hardiness. Even insignificant extent of an infection spread leads to loss of decorative effect. At mass infections the plant dies off [2].

Powdery mildew is caused by sac fungi of Erysiphaceae family. They are obligate parasites and have two stages in their development cycle – asexual (conidia form) and sexual (ascus form). At the beginning of summer there is a light raid representing a mycelium and conidia on the struck plant parts. By autumn fruiting bodies are formed on mycelium – they are dark spherical cleistothecium forms in which there are asci with ascospores, the fungi winter in such a state. In the spring ascospores carry the first infections on plants [3].
Insufficient aeration and insolation of plantings in the period of high humidity and temperature, which is optimum for development of fungi, are the factors promoting dissemination of mildew. Moreover, the strong cutting of tree crowns and excess of nitrogen prolonging vegetation of plants in the soil contribute to the development of the pathology.

The wide area and considerable injuriousness of mildew fungi have formed the basis for studying of their bio ecological features in various forest vegetation zones.

I. A. Bunkina, studying mildew fungi wide spread in Far East, established that the conjugate evolution of angiospermous plants and mildew fungi provides their coexistence, where plants are determinants, and fungi – consorts of the first order, biotroph. At the first stages of the development of the relation between consorts and a determinant are like symbiotic, and by autumn the influence of consorts amplifies, and the relations between them become parasitic [4]. A.W. Tobias, S.M. Fedorova (St. Petersburg) noted the greatest specific variety of mildew fungi on roses, bird cherries and oaks. At the same time the bird cherry has been most strongly struck [5]. M.B. Agabekyan in the conditions of the Ararat plain of Armenia established that in the protected soil the pathogen gives 20 to 22 generations, but in the field conditions during one vegetation period – 10 to 12 generations, and the loss from the disease is 30-50% of flower production [6].

The relevance of the present researches is defined by need of increase in biological stability and decorative effect of plantings of the city architecture in which the deciduous breeds, which are actively stricken by mildew, prevail.

The aim of the researches was studying of a specific structure of the powdery mildew fungi widespread in objects of the city architecture and development of actions for protection of plants. Research tasks included determination of a specific variety of park plantings, identification of fungi – causative agent of mildew, studying of their dissemination and injuriousness.

2. Materials and methods
The most significant objects of a city landscape architecture of Voronezh (Russian Federation) are the “Scarlet Sails” park and “Dynamo” park.

The territory of the “Dynamo” park is located in the lowland of a right bank of the Voronezh reservoir and represents well remained natural phytocenosis with the typical soil cover, wood and shrubby structure, which is typical for the Voronezh mountain oak grove [7]. Plantings are presented by such breeds as Acer campestre L., Acer negundo L., Acer platanoides L., Aesculus hippocastanum L., Alnus glutinosa (L.) Gaertn., Betula pendula Ehrh., Fraxinus excelsior L., Malus sylvestris P. Mill., Picea obovata Ldb., Picea pungens Engelm., Pirus communis L., Populus alba L., Populus tremula L., Pseudotsuga menziesii (Mirb.) Franco., Quercus robur L., Quercus rubra L., Robinia pseudoacacia L., Salix babylonica L., Salix fragilis L., Tilia cordata Mill., Ulmus parvifolia Jacq.

There are shrubby plants, such as Berberis thunbergii DC, Corylus avellana L., park roses of Rosa acicularis Lindl. ‘Crimson Meillanddecor’, soil integumentary roses of R. acicularis Lindl. ‘Fiona’ and R. acicularis Lindl. ‘Fleurette’, Spiraea vanhouttei (Briot.) Zab. and Symphoricarpos albus (L.) Blake.

The “Scarlet Sails” park is located on the left bank of the Voronezh reservoir. The main plant breed is Pinus sylvestris L. Among deciduous breeds are: Acer negundo L., Betula pendula L., Fraxinus excelsior L., Populus nigra L., P. suaveolens Fish, Quercus rubra L., Sorbus aucuparia L., Tilia cordata Mill., Ulmus parvifolia Jacq. There are single trees of Aesculus hippocastanum L., Alnus glutinosa (L.) Gaertn., Picea pungens Engelm., Robinia pseudoacacia L., Salix babylonica L., Sambucus nigra L. and Ulmus laevis Pall. There are some shrubby plants, such as Berberis thunbergii DC and B. vulgaris L., Cornus sanguinea L., Rosa acicularis Lindl. ‘Fiona’, R. canina L. ‘Meilland’, R. canina L. ‘Liane Foly’, R. rugosa Thunb. ‘Tegala’, Spiraea vanhouttei (Briot) Zabel., Symphoricarpos albus (L.) S. F. Blake., Syringa vulgaris L. and Viburnum opulus L. ‘Roseum’.

Researches were conducted during 2016-2017 with application of the standard techniques accepted in phytopathology and their author's modifications. Specific accessory of trees and bushes was determined by Chepik F. A. continuant [8]. Diagnosis of diseases includes the following stages:
determination the type of a disease – set of the anatomic, morphological and physiological changes caused by the disease; determination of nature of a disease (infectious or noninfectious); determination of the causative agent of illness; appointment of protective measures. Pathographic, microscopic and mycologic analyses were applied in these researches [9-11]. Frequency of occurrence of pathogens was estimated with a 3-grade scale where:

1. grade – a mass look;
2. grade – a usual look;
3. grade – a rare species [12].

3. Results
In the “Dynamo” park plants of 21 genera, 27 species and 4 varieties of trees and bushes have been determined that shows the rather high level of biological diversity of the planting (Table 1).

| No. | Species of Trees and Bushes | Family |
|-----|-----------------------------|--------|
| 1   | Acer campestre L.           | Sapindaceae |
| 2   | Acer negundo L.             | Sapindaceae |
| 3   | Acer platanoides L.         | Sapindaceae |
| 4   | Aesculushippocastanum L.    | Hippocastanaceae |
| 5   | Alnusglutinosa (L.) Gaertn. | Betulaceae |
| 6   | Betulasthunbergii DC        | Berberidaceae |
| 7   | Betula pendula Ehrh.        | Betulaceae |
| 8   | Corylus avellana L.         | Betulaceae |
| 9   | Crataegus monogyna Jacq.    | Rosaceae |
| 10  | Fraxinus excelsior L.       | Oleaceae |
| 11  | Malus sylvestris P. Mill.   | Rosaceae |
| 12  | Picea obovata Ldb.          | Pinaceae |
| 13  | Picea pungens Engelm.       | Pinaceae |
| 14  | Pirus communis L.           | Rosaceae |
| 15  | Populus alba L.             | Salicaceae |
| 16  | Populus tremula L.          | Salicaceae |
| 17  | Pseudotsuga menziesii (Mirb.) Franco. | Pinaceae |
| 18  | Quercus robur L.            | Fagaceae |
| 19  | Quercus rubra L.            | Fagaceae |
| 20  | Robinia pseudoacacia L.     | Fabaceae |
| 21  | Rosa acicularis Lindl. ‘Crimson Meillandecor’ | Rosaceae |
| 22  | Rosa acicularis Lindl. ‘Fiona’ | Rosaceae |
| 23  | Rosa acicularis Lindl. ‘Fleurette’ | Rosaceae |
| 24  | Salix babylonica L.         | Salicaceae |
| 25  | Salix fragilis L.           | Salicaceae |
| 26  | Spiraea vanhouttei (Briot.) Zab. | Rosaceae |
| 27  | Symphoricarposalbus (L.) Blake. | Caprifoliaceae |
| 28  | Tilia cordata Mill.         | Malvaceae |
| 29  | Ulmus parvifolia Jacq.      | Ulmaceae |
There are 1062 trees in total in the investigated territory of the “Dynamo” park. 1048 trees from them are in good shape (99%), 14 trees have to be removed because of their critical condition (1%). There are 5150 bushes in total among which there are no copies which have to be removed.

The “Scarlet Sails” park has less rich biodiversity. 82% of plants are 50-year-old pines. A specific variety of plantings of the “Scarlet Sails” park is presented in the Table 2.

**Table 2.** Specific structure of wood and shrubby vegetation growing in the “Scarlet Sails” park.

| No. | Species of Trees and Bushes | Family          |
|-----|-----------------------------|-----------------|
| 1   | *Acer negundo* L.           | Sapindaceae     |
| 2   | *Aesculus hippocastanum* L. | Sapindaceae     |
| 3   | *Alnus glutinosa* (L.) Gaertn. | Sapindaceae    |
| 4   | *Berberis thunbergii* DC    | Hippocastanaceae |
| 5   | *Berberis vulgaris* L.      | Betulaceae      |
| 6   | *Betula pendula* Ehrh.      | Berberidaceae   |
| 7   | *Fraxinus excelsior* L.     | Betulaceae      |
| 8   | *Picea pungens* Engelm.     | Betulaceae      |
| 9   | *Pinus sylvestris* L.       | Rosaceae        |
| 10  | *Populus nigra* L.          | Oleaceae        |
| 11  | *Populus suaveolens* Fish.  | Rosaceae        |
| 12  | *Quercus rubra* L.          | Pinaceae        |
| 13  | *Robinia pseudoacacia* L.   | Pinaceae        |
| 14  | *Rosa acicularis* Lindl. ‘Fiona’ | Rosaceae    |
| 15  | *Rosa canina* L. ‘Meilland’, ‘Liane Foly’ | Salicaceae  |
| 16  | *Rosa rugosa* Thunb. ‘Tegala’ | Salicaceae  |
| 17  | *Salix babylonica* L.       | Pinaceae        |
| 18  | *Sorbus aucuparia* L.       | Fagaceae        |
| 19  | *Spiraeavanhouttei* (Briot) Zabel | Fagaceae     |
| 20  | *Symphoricarpos albus* (L.) Blake. | Fabaceae  |
| 21  | *Syringa vulgaris* L.       | Rosaceae        |
| 22  | *Tilia cordata* Mill.       | Rosaceae        |
| 23  | *Ulmus laevis* Pall.        | Rosaceae        |
| 24  | *Ulmus parvifolia* Jacq.    | Salicaceae      |
| 25  | *Viburnum opulus* L. ‘Roseum’ | Salicaceae  |

In total there are 581 trees in the territory of the “Scarlet Sails” park. Most of them (99%, or 577 trees) are in good shape, 4 trees, or 1%, have to be removed because of their critical condition. The quantity of bushes is 1085 which are in good shape.

As a result of the conducted researches in plantings of the “Scarlet Sails” park, 4 species and 3 specialized forms of fungi were found – causative agents of mildew developing on leaves of 9 species of trees and bushes (Table 3). All identified types of pathogens are highly specialized obligate parasites and are strictly dated for a certain wood breed or a bush. Their presence on leaves and green sprouts was determined on existence of raid mycelium on which dark dot fruiting bodies – cleistothecium forms – are formed at the end of summer.
A table of mildew fungi diversity in plantings of the “Scarlet Sails” park:

| No. | Causative agent | Host plants | Score of damage |
|-----|----------------|-------------|-----------------|
| 1   | Microsphaera berberidis (DC.) Lev. | Berberis vulgaris L. | 1 |
| 2   | M. syringae Jacq. | Syringa vulgaris L. | 2 |
| 3   | Phyllactinia suffulta f. betulae (Rebent.) Sacc. | Betula pendula Ehrh. | 2 |
| 4   | P. suffulta f. fraxini Jacz. | Fraxinus excelsior L. | 3 |
| 5   | Sphaerotheca pannosa var. rosae Woron. | Rosa acicularis Lindl. ‘Fiona’, R. canina L. ‘Meilland’, R. canina L. ‘Liane Foly’, R. rugosa Thurb. ‘Tegala’ | 2 |
| 6   | Uncinula clandestina (Biv.) J. Schröter | Ulmus parvifolia Jacq | 3 |
| 7   | U. adunca f. populorum (Wallr.) Lev. | Populus nigra L. | 2 |

One species of the causative agent of mildew was revealed on all plants. Fungi activators of the mildew on Berberis vulgaris L. (the causative agent – Microsphaera berberidis (DC.) Lev) are referred to the mass types which are often found on objects of researches. It was 14% of all identified pathogens.

2 species and 2 forms of pathogens were referred to ordinary types – on Betula pendula Ehrh. (the causative agent – Phyllactinia suffulta f. betulae (Rebent.) Sacc.), roses – Rosa acicularis Lindl. ‘Fiona’, R. canina L. ‘Meilland’, R. canina L. ‘Liane Foly’, R. rugosa Thurb. ‘Tegala’, (the causative agent – Sphaerotheca pannosa var. rosae Woron.), Populus nigra L. (the causative agent – Uncinula adunca f. populorum (Wallr.) Lev.) and Syringa vulgaris L. (the causative agent – Microsphaera syringae Jacz.), that in the percentage ratio makes 57%.

One species and one form of pathogens were referred to rare species – Fraxinus excelsior L. (the causative agent – Phyllactinia suffulta f. fraxini) and Ulmus parvifolia Jacq. (the causative agent – Uncinula clandestina (Biv.) J. Schröter.) that in the percentage ratio makes 29%.

The studies conducted in the “Dynamo” park have revealed 8 species and 4 specialized forms of fungi – causative agents of mildew developing on leaves of 14 species of trees and bushes (Table 4). The identified types of pathogens are also highly specialized obligate parasites and are dated for a certain species of plants.

One species of the causative agent of mildew was revealed on all plants.

Fungi activators of mildew on Acer campestre L. (the causative agent – Uncinula aceris (DC.) Sacc.), Berberis thunbergii DC (the causative agent – Microsphaera berberidis (DC.) Lev.), Quercus robur L. (the causative agent – Microsphaera alpitoideas Griffon & Maubl) and Rosa acicularis Lindl. ‘Fiona’ and ‘Fleurette’ (the causative agent – Sphaerotheca pannosa var. rosae Woron.) are referred to the mass species which are often found on objects of researches. It was 33% of all identified pathogens.

3 species and 3 forms of pathogens were referred to ordinary types – on Acer negundo L. (the causative agent – Uncinula clandestina (Biv.) J. Schröter.), Acer platanoides L. (the causative agent – Uncinula tulasnei Fuckel.), Betula pendula Ehrh. (the causative agent – Phyllactinia suffulta f. betulae (Rebent.) Sacc), Corylus avellana L. (the causative agent – Microsphaera corly (Jacz.) Golovin), Crataegus monogyna Jacq. (the causative agent – Podosphaera clandestina f. crataegi (Wallr.) Lev.), Salix fragilis L. (the causative agent – Uncinula f. salice (Biv.) J. Schröter) and Ulmus parvifolia Jacq. (the causative agent – Uncinula clandestina (Biv.) J. Schröter.). That in the percentage ratio makes 50%.

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**Table 3.** Mildew fungi diversity in plantings of the “Scarlet Sails” park.
Table 4. Mildew fungi diversity in plantings of the “Dynamo” park.

| No. | Causative agent | Host plants | Score of damage |
|-----|-----------------|-------------|-----------------|
| 1   | Microsphaera alphitoides Griffon & Maubl. | Quercus robur L. | 1 |
| 2   | M. berberidis (DC.) Lév. | Berberis thunbergii DC | 1 |
| 3   | M. coryli (Jacz.) Golovin | Corylus avellana L. | 2 |
| 4   | Phyllactinia suffulta f. betulae (Rebent.) Sacc. | Betula pendula Ehrh. | 2 |
| 5   | Ph. suffulta f. fraxini Jacz. | Fraxinus excelsior L. | 3 |
| 6   | Podosphaera clandestina f. crataegi (Wallr.) Lev. | Crataegus monogyna Jacq. | 2 |
| 7   | Sphaerotheca pannosa var. rosae Woron. | Rosa acicularis Lindl. ‘Fiona’ and ‘Fleurette’ | 1 |
| 8   | Uncinula aceris (DC.) Sacc. | Acer campestre L. | 1 |
| 9   | U. clandestina (Biv.) J. Schröt. | Acer negundo L., Ulmus parvifolia Jacq. | 2 |
| 10  | U. clandestina f. salicis (Biv.) J. Schröt. | Salix fragilis L. | 2 |
| 11  | U. flexuosa Peck. | Aesculus hippocastanum L. | 3 |
| 12  | U. tulasnei Fuckel. | Acer platanoides L. | 2 |

One species and one form of pathogens were referred to rare species on Aesculus hippocastanum L. (the causative agent – Uncinula flexuosa Peck.) and Fraxinus excelsior L. (the causative agent – Phyllactinia suffulta f. fraxini Jacz.) that in the percentage ratio makes 17% (Table 4).

4. Discussion
Powdery mildew is one of the widespread pathologies of deciduous trees and bushes in park plantings of the city territory. This pathology of plants is a moderately harmful disease. Consequences of infection are partially reversible. They cause decrease in growth rates and weakening of plants that negatively affects on decorative effect and useful properties of plantings.

In plantings of the “Dynamo” park mildew is met on 14 species of trees and bushes. The degree of prevalence of trees is 36%, bushes – 28%. In the “Scarlet Sails” park mildew is found on 7 species of trees and bushes. The degree of prevalence of trees is 24%, bushes – 21%.

When comparing degree of prevalence of local species of plants (natives) and introduced species (exotic plants) it was revealed that 58% of natives and 42% of introduced species of the total number of species of the trees and bushes were struck with mildew.

Both parks belong to the closed type of spatial structure, but in their territory there are open and half-open spaces. Mildew in the most cases is met in the depth of plantings. The lack of normal aeration and insolation promoted formation of the favorable environment for development of mildew fungi.

Mildew generally develops on leaves of plants, however on roses mildew fungi are noted not only on leaves, but also on sprouts and buds.

In plantings of the “Dynamo” park 8 types and 4 specialized forms of causative agents of mildew fungi develop on leaves of 14 species of trees and bushes. In the “Scarlet Sails” park 4 types and 3 specialized forms of causative agents of mildew fungi developing on leaves of 7 species of trees and bushes were found. In the whole powdery mildew fungi are met on the plants relating to 9 families – Berberidaceae, Betulaceae, Fagaceae, Hippocastanaceae, Oleaceae, Rosaceae, Salicaceae,
Sapindaceae and Ulmaceae. The pathogens causing mildew are not found on the plants relating to the Adoxaceae, Caprifoliaceae, Fabaceae, Malvaceae and Pinaceae families.

Infection of plants by mildew fungi reduces their stability to other factors and leads to settling by sucking (plant louses, ticks) and gnawing (a rose chafer, sawflies) wreckers that leads to their further weakening, and in some cases to dying off.

The major ecological factors promoting distribution of powdery mildew fungi are insufficient aeration of plantings and low level of insolation. The strong cutting of tree crowns and excess of nitrogen fertilizers also create favorable conditions for development of mildew.

The major preventive action is using of steady species of plants. The immunity of plants to this pathology can be increased by competent use of fertilizers - restriction of nitrogen and timely application of phosphorus and potassium. When the preventive actions are inefficient it is necessary to apply chemical processing of plants.

5. Conclusion
During creation of new plantings and reconstruction of the existing ones it is necessary to pay special attention to degree of stability of species of deciduous plants to mildew fungi. The major preventive action is removal of the infected vegetable remains from an object. Resistance to pathogens increases at timely application of phosphorus-potassium fertilizers. As destructive actions at emergence of the first symptoms of a disease it is necessary to mention processing plants by contact medicines.

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