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Original article

Prospective uses of relict trees in the urban landscaping of Azerbaijan for resistance to fungal disease

Posibles usos de los árboles nativos en el paisaje urbano de Azerbaiyán para la resistencia a las enfermedades fúngicas

Possíveis usos das árvores nativos na paisagem urbana de Azerbaijão para a resistência às doenças fúngicas

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ABSTRACT

This study considers the prospective uses of relict plants in the landscaping of urban areas in Azerbaijan in terms of their resistance to pathogenic mycobiota. It used samples from nine relict plants from the local dendroflora, and cultivated and identified mycobiota. The study identified 65 species of Mycota, of which 84.6 % are conditionally pathogenic. The vast majority of species belong to Ascomycota, and representatives of the Basidiomycota and Zygomycota groups were represented to a lesser extent. The most common fungal diseases include spotted and multi-colored rot (about 75 %). The range of dominant pathogens in the relict plants under studies species-specific, which is a favorable condition for limiting the spread of disease in mixed stands. In general, relict trees have a high potential for resistance to pathogenic mycobiota and can be used in urban improvement.

Keywords: Relict trees; Urban gardening; Mycobiota; Phytopathogens; Low quantitative indicators.

RESUMEN

En este estudio, se consideran los usos prospectivos de algunas plantas nativas en los paisajes de zonas urbanas de Azerbaiyán en cuanto a su resistencia a las enfermedades fúngicas. Para ello, se utilizaron nueve especies de plantas nativas de la dendroflora local y se estudiaron su microbiota y la resistencia a las enfermedades causadas por hongos. En el estudio se identificaron 65 especies de Mycota, de las cuales el 84,6 % son condicionalmente patógenas. La gran mayoría de las especies pertenecen a Ascomycota, y los representantes de los grupos Basidiomycota y Zygomycota estuvieron representados en menor medida. Las enfermedades fúngicas más comunes incluyen la podredumbre manchada y la podredumbre multicolor (alrededor del 75 %). La gama de patógenos dominantes en las plantas nativas se estudia en función de las especies, lo que constituye una condición favorable para limitar la propagación de la enfermedad en los rodales mixtos. En general, los árboles nativos tienen un alto potencial de resistencia a la micobiota patógena y pueden utilizarse en el paisajismo de las ciudades.

Palabras clave: Plantas nativas; Jardines urbanos; Microbiota; Fitopatógenos; indicadores cuantitativos bajos.

RESUMO

Neste estudo, as utilizações prospectivas de algumas plantas nativas em paisagens urbanas do Azerbaijão são consideradas em termos da sua resistência a doenças fúngicas. Para este efeito, foram utilizadas nove espécies de plantas nativas da dendroflora local e foram estudadas a sua microbiota e resistência a doenças fúngicas. No estudo foram identificadas 65 espécies de Mycota, das quais 84,6 % são patogénicas do ponto de vista das condições. A grande maioria das espécies pertence a Ascomycota e os representantes dos grupos Basidiomycota e Zygomycota estiveram representados em menor escala. As doenças fúngicas mais comuns incluem a podridão manchada e a podridão multicolorida (cerca de 75 %). A gama de agentes patogénicos dominantes nas plantas nativas é estudada com base na espécie, o que constitui uma condição favorável para limitar a propagação da doença em povoamentos mistos. Em geral, as árvores nativas têm um elevado potencial de resistência à microbiota patogénica e podem ser utilizadas no paisagismo urbano.

Palavras-chave: Plantas nativas; Jardins urbanos; Microbiota; Agentes patogénicos das plantas; Indicadores quantitativos baixos.

INTRODUCTION

The dendroflora of large cities in Azerbaijan is an environmental factor that fulfills sanitary, hygienic, cultural, health, recreational, aesthetic, water protection and soil protection functions (Aronson *et al.,* 2014; Battisti *et al.,* 2019; Ennos, 2015; Kowarik y von der Lippe, 2018; Nilon *et al.,* 2017). However, the urban environment is distinguished by its peculiar environmental features, as well as specific technogenic influences that inhibit plants (Ives *et al.,* 2016; Qiu *et al.,* 2017; Tomoshevich, 2015). Anthropogenic impacts lead to an imbalance in dendrocenoses, a decrease in resistance to disease among tree species as well as mechanical damage to trees, which then leads to an increase in the prevalence of infectious diseases, and various mycoses, in particular (Lukmazova, 2013; Tatarintsev, 2018). Pathogenic mycobiota disrupts the processes of photosynthesis in trees, reduces their productivity and longevity, and can also cause mass die-offs in city green spaces (Brasier y Buck, 2001; Yang *et al.,* 2017). To solve practical landscaping issues, keeping an inventory

of dendropathogens is of great importance, as it makes it possible to scientifically substantiate measures to enrich and update the assortment of urban plantings.

More than a hundred species of local and introduced trees are utilized in the improvement of large cities in Azerbaijan (Abdullayeva, 2017; Kowarik & von der Lippe, 2018; Tomoshevich, 2015). They have different characteristics in accordance with their ecological traits (range, dependence on certain environmental conditions, life cycle, etc.). The influence of these differences on the resistance of urban dendrofauna to infectious disease has been addressed in numerous works, where the dominant forms and species-specificity of various representatives of tree mycobiota have been identified (Abdullayeva, 2017; Lukmazova, 2013; Tatarintsev, 2018; Tomoshevich, 2015). A few works present evidence that some relict plants are resistant to fungal disease, which is associated with a high adaptive potential (Lukmazova, 2013; Qiu *et al.,* 2017). This fact makes relicts a promising object of study for use in urban landscaping. Relict plants are widely planted in large cities in Azerbaijan. For example, Eldar pine *(Pinus eldarica* Medw.) and eastern pine (*Platanus orientalis* L.) are widely used in urban landscaping. In some parks and gardens, ordinary chestnut (*Castanea sativa* Mill.), chestnut oak (*Quercus castaneifolia* CAM), and Caspian locust (*Gleditshia caspia* Desf.) are also planted, however, despite their ubiquity in the urban environments of Azerbaijan, special studies on this plant group's resistance to pathogenic mycobiota have not been carried out. In that regard, this work assesses the prospects for using relict trees in the urban landscaping of large cities, such as Baku and Sumgait, in terms of their resistance to fungal diseases.

MATERIALS AND METHODS

Research material

The study was conducted in 2014 in the cities of Baku and Sumgait, which are the largest cities in Azerbaijan. Samples were taken from the generative (flowers, fruits and seeds) and vegetative (root, stem and leaf) organs of the studied plants. A route sampling method was used (Abdullayeva, 2017; Bahshaliyeva, 2017; Food and Agriculture Organization of the United Nations (FAO), 2006; Golovin *et al.,* 2002). Altogether, about 500 samples were taken from nine species of relict trees (Mammadov *et al.,* 2016; The Ministry of Ecology and Natural Resources of Azerbaijan Republic, 2013):

1. *Lankaran albicia Albizzia julibrissin* Dur. a deciduous tree 6-16 m high, umbrella crown. Natural habitats are the lower mountain belt of the Talysh Mountains in Azerbaijan, as well as China, Korea and Japan. Additionally, distributed throughout the Black Sea coast of northeastern Turkey. It is a popular ornamental plant in the gardens and parks of cities in southern Europe and Asia.
2. *Sweetchestnut Castanea Sativa* Mill. - deciduous woody plant 10-30 meters high, umbrella-crown. Widely distributed in the subtropics of the Mediterranean and the Caucasus.
3. *Fig Ficus carica* L. deciduous woody plant 10-15 m high, in some cases takes the form of a bush. Crown shape of a spherical umbrella. Figs grow in the subtropical and hot regions of Azerbaijan and are widely distributed in Mediterranean countries, Transcaucasia, the Carpathians, and the Krasnodar Territory.
4. Caspian gleditsia *Gleditsia caspia* Desf. a woody deciduous plant 10-15 m high. Halophyte. Common in the forests of the Caucasus, in many regions of Azerbaijan, and in the Absheron, Talysh, and Kur-Araz lowlands.

5. Persian parrotia *Parrotia persica* (D.C.) C.A.M. a wood deciduous plant 12-25 m high, the trunk is branched from the base. This tree is distributed in relict forests in the Talysh mountains of Azerbaijan and Iran near the Caspian coast.
6. Eldar pine *Pinus eldarica* Medw. This is a small woody coniferous plant. Its only natural habitat in the world is very limited and covers up to 300 hectares of the northern and northeastern slopes of the Elleroyag chain of dry rocky areas of the Eldar Plain. This is one of the most widely used plants for landscaping in Azerbaijan, and arid regions of the Caucasus and Central Asia.
7. Oriental plane *Platanus orientalis* L. a deciduous wood plant 25-50 m high. The crown is thick, broad, and ovate. Common in the Mediterranean, North America, Central Asia and Asia Minor, and Central Europe. This is one of the most widely used trees in landscaping in Azerbaijan.
8. Pomegranate *Punica granatum* L. a perennial subtropical shrubby deciduous plant with its homeland in Asia Minor. It is widely distributed in South America, Australia, South Africa, Azerbaijan, the Mediterranean basin countries, Afghanistan, India and China. Pomegranate grows naturally along the southern foothills of the Greater and Lesser Caucasus, and along the banks of the Kura River in Azerbaijan. Pomegranate is historically cultivated in almost all regions of Azerbaijan.
9. Chestnut oak *Quercus castaneifolia* (C.A.M.) a tented or wide-pyramidal umbrella tree 40-45 m high. It is widespread in the Greater Caucasus, the Lesser Caucasus and the Talysh zone in Azerbaijan.

Sampling and mycological analysis

In all cases, in order to isolate fungi in a pure culture, standard culture media were used, such as agar malt juice (AMJ), the Czapek medium (ChM), rice agar (RA) and potato agar (PA). Meanwhile, these culture media were also used to store study cultures.

The fungi were identified based on certain identifiers (Horst, 2013; Kirk *et al.,* 2008; Satton *et al.,* 2001). The Latin names of fungi were used and their systematization was carried out in accordance with currently accepted standards (Hawksworth, 2014), as well as with the official website of the International Mycological Association (IMA) (Mammadov *et al.,* 2016).The frequency of occurrence of fungi was determined by the formula $P = (n / N) x100$, where P is the frequency of occurrence of fungi in the sample (or the prevalence rate of the disease caused by the pathogen %), n is the number of fungi found (the number of plants infected with the disease in the study areas gives the number) and N is the total number of samples (total number of plant species in the study area).

RESULTS

Studies of relicts in urban green spaces have revealed a wide variety of pathogen-bearing species. A total of 65 species of micro- and macromycetes have been isolated (Table 1). The largest number of species was recorded in chestnut oak, and the smallest in Eldar pine. The species diversity of mycobiota in other plants ranges from 10-14. That is 1.7 to 2.4 times less compared to the fungi involved in mycobiota formation in chestnut oak, and 1.1 to 1.6 times more than that of Eldar pine. In some cases, cohabitation is noted of two or more types of parasitic fungi on one plant.

A detailed study of the fungi involved in the formation of mycobiota according to their taxonomic distinguishing features found that 67.7 % of the fungi belong to Ascomycota, 21.5 % to Basidiomycota and 10.8 % to Zygomycota.

Table 1. - Numerical characteristics of microbiotia species composition in relict plants

Tree species	Number of fungi species			Total
	Zygomycota	**Ascomycota**	**Bazidiomycota**	
Albizzia julibrissin	1	7	3	11
Castanea sativa	2	7	4	13
Ficus carica	2	10	2	14
Gleditshia caspia	1	11	2	14
Parrotia persica	1	8	2	11
Pinus eldarica	1	5	3	9
Platanus orientalis	1	7	2	10
Punica granatum	0	10	0	10
Quercus castaneifolia	1	16	7	24
Total	7	44	14	65

In total, Ascomycota has 44 species belonging to 11 orders: Botryosphaeriales2, Capondiales 5, Diaporthales 3, Dothideales 1, Eurotiales 8, Ersiphales 5, Helotiales 4, Hypocreales 5, Glomerellales 3, Pleosparales 7, Xylariales 1.

The Basidiomycoota group has 14 species belonging to *4* orders: Hymenochaetales 2, Polyporales 5, Pucciniales 5 and Urocystidales 2.

The data obtained show that 83.1% of the registered fungi (54 species) are conditionally pathogenic and belong to the Ascomycota (74.1 %) and Basidiomycota (25.9 %) groups. No phytopathogens were detected among Zygomycota. Representatives of this group mainly participated in the formation of epiphytic mycobiota in the studied trees. Chestnut oak had the highest infection rate of fungal diseases and Eldar pine had the lowest (Table 2).

Table 2. - Numerical characteristics of species composition of microbiota in relict plants

Tree species	The rate of spread of diseases caused by fungi belonging to different taxonomic groups%			Common disease infection rate, %
	Zygomycota	**Ascomycota**	**Bazidiomycota**	
Albizzia julibrissin	0	1.5	0.6	2.1
Castanea sativa		1.2	1.4	2.6
Ficus carica		2.5	1.6	4.1
Gleditshia caspia		2.6	1.1	3.7
Parrotia persica		3.0	1.6	4.6
Pinus eldarica		0.8	0.4	1.2
Platanus orientalis		2.1	1.6	3.7
Punica granatum		4.1	0.3	4.4
Quercus castaneifolia		4.4	3.4	7.8

The most common disease is spotted and multi-colored rot, which accounts for about 75 % of the total number of registered diseases. This pathology is due to the activities of a number of representatives of the Ascomycota and Basidiomycota groups: *Alternaria alternata* (Fr.) Keissl., *Ascochyta quercus* Sacc. et Speg., *Botrytis cinerea* Pers, *Dothistroma septospora* (Dorog.) M. Morelet, *Fomes fomentarius* (L) Fr.,

Fomitopsis pinicola (Sw.) P. Karst., *Heteroporus biennis* (Bull.) Lázaro Ibiza, *Laetiporus sulphureus* Murrill, *Phellinus torulosus* (Pers.) Bourdot & Galzin, *Nectria cinnabarina* (Tode) Fr., *Phoma acicola* (Lév.) Sacc., *Phyllosticta aesculina* Sacc, *Phyllosticta castaneae* Ellis & Everh., etc. Other diseases (wilting, corrosion, necrosis, powdery mildew, etc.) are caused by the fungi *Melampsora pinitorqua* Rostr., *Microsphaera alphitoides* Griff et Maubl., *Tubercularia vulgaris* Tode, *Verticillium dahliae* Kleb, etc. It was also observed that specific species are also included in the composition of pathogens in the relict plants under study. For example, *Ascochyta quercus*, *Melampsora quercus* (Brond.) J. Schröt. and *Microsphaera quercina* (Schwein.) Burrill for *Quercus castaneifolia*, and the fungi *Erysiphe castaneae* U. Braun and *Phylloticta castaneae* for *Castanea sativa* are species specific.

DISCUSSION

Most relict plants are biologically stable in natural conditions and do not show range reduction in habitat. However, the introduction of any plant into the urban dendrofauna can be difficult due to the spread of various infectious diseases. This research on the mycobiota of relict trees in urban stands in Azerbaijan revealed significant diversity in the species composition of fungi. According to taxonomic affiliation, the overwhelming majority of species belong to Ascomycota, and representatives of the Basidiomycota and Zygomycota groups to a lesser extent. An identical picture of the prevalence of Ascomycota in the mycobiota of urban dendrofauna has already been observed in Azerbaijan and some other regions of the former USSR (Abdullayeva, 2017; Lukmazova, 2013; Tomoshevich, 2015). In our case, 82.4 % of Ascomycota are anamorphs, which can be considered the leading sign of microbiota in nature in Azerbaijan (Abdullayeva, 2017).

It is a well-known fact that mushrooms can use plants, including trees, for shelter or food or both. In the first case, fungi form the epiphytic mycobiota of trees and are characterized as saprotrophs mainly due to their ecological and trophic relationships (Tomoshevich, 2015). In this case, the fungi that fall into this category belong to the Zygomycota group. They accounted for only 15.4 % of the total.

Fungi that feed off plants are grouped as biotopes and polytrophs in terms of their ecological and trophic relationships. Symptoms of the latter are manifested in various pathologies and, as a consequence, in the appearance of trees, their biological productivity. They also influence which characteristics are subject to change. The pathogenic microflora of the relict trees studied was formed by representatives of Ascomycota or Basidiomycota and was characterized by a significant degree of prevalence. The most dangerous and common disease is spotted and multi-colored rot, which is characteristic for the majority of woody plants in urban areas. These pathogens disrupt the processes of photosynthesis and deprive plants of their decorative qualities by forming numerous small brownish-purple leaves that fall away over time. This affects not only the beauty of plants but also significantly reduces the assimilation surface of the leaves, which weakens the plants.

Despite the fact that most relict plants have significant adaptive potential, a serious impediment to their introduction into the culture may be a mismatch of the local microclimate and, accordingly, vulnerability to infectious disease. Some authors, using biocenotic approaches to the study of relict populations, divided relict species into groups classified based on their ability to adapt to modern conditions: 1) flourishing or progressing relicts, 2) relicts, and 3) regressing relicts (Didukh, 1988; Tatarintsev, 2018). The least resistant to the complex of pathogens among the studied trees was chestnut leaf oak, which is in a state of mobile equilibrium like most of the studied species. Such species, under favorable conditions, are quite

viable and well-developed and they firmly hold their positions in stands; with a sharp change in environmental conditions, however, they may die. A higher level of infection with dendropathogens in chestnut oak may indicate an unsatisfactory life state for this species in the given environmental conditions.

However, a comparative analysis of the obtained results with the literature data showed that almost all the studied relic plants are more resistant to disease than modern complex dendrofauna. For example, according to Abdullayeva (2017), the infection level among trees such as white acacia, common poplar, japanese sophora, elm, southern willow, etc., used for landscaping in large cities in Azerbaijan, ranges from 9.8 to 56.7 %, which is 1.25-7.27 times higher than that of chestnut oak. Also, the taxonomic diversity of the fungi involved in the formation of the mycobiota of these trees is quite large compared to the relict dendroflora. For example, 22 species of fungi form the mycobiota in japanese sophora, which dominates the landscape design of the Baku city (Abdullayeva, 2017).

The species composition of pathogens depends on the species diversity of woody plants and the condition of the landscaping. From this point of view, it is advisable to note that the primary pathogens in the studied relict plants are species-specific. This is advantageous for limiting the spread of disease in mixed stands, while fungi with a wide range of potential hosts can cause more damage to dendroflora (Horst, 2013). At the same time, not all the fungi identified are found in a pathogenic form, and the breadth of their distribution does not indicate the degree of harm they cause. The latter, most likely, depends on the aggressiveness of the pathogen, the life state of the plant and the specific microclimate of the area.

Finally, urban landscape planning works to optimize the process of incorporating healthy trees into the city plan. More than a hundred local and introduced tree species are planted in large cities in Azerbaijan, which include relict plants that theoretically have high adaptive potential. A comparative quantitative and qualitative analysis of the composition of pathogenic microbiota in urban plantings showed that relict plants are more resistant to fungal diseases than modern complex dendroflora. The least resistant to pathogens among the relict trees studied was chestnut oak, which may be due to poor environmental conditions for this species. Spotted and multi-colored rot, which is characteristic of most forested park complexes in urban areas, is a common disease in all tree species studied. However, the composition of dominant pathogens in the relict plants studied is species-specific, which is favorable for limiting the spread of disease in mixed stands. In general, studies have shown that relict trees have a high potential for resistance to pathogenic mycobiota and can be successfully used to improve urban areas in Azerbaijan.

The formation of pathogenic mycobiota varies depending on the nature of the urban environment. In order to identify the dynamics of different diseases and implement timely protective measures, further monitoring of pathogens in the urban dendrofauna of Azerbaijan is necessary.

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