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MYCOBIOTA OF URBAN GREENING PLANTS AND THEIR ECOLOGICAL IMPACT IN MAJOR CITIES OF AZERBAIJAN

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Abstract

In large cities of Azerbaijan (Baku, Ganja, Sumqayit, etc.), the health and longevity of trees and shrubs in urban greening programs are directly dependent on the composition of soil mycobiota. The conducted study identified 118 different fungal species in the rhizosphere soils of 142 plant species. The majority of these species belonged to the phyla Ascomycota (68.6%) and Zygomycota (18.4%), with dominant genera including *Fusarium* (19 species), *Trichoderma* (14 species), *Penicillium* (12 species), *Aspergillus* (11 species), *Mortierella* (9 species), *Alternaria* (7 species), *Cladosporium* (6 species), and *Verticillium* (4 species).

In the functional structure of urban soil mycobiota, potentially pathogenic and conditionally pathogenic species accounted for an average of 76.8%, saprophytes for 14.3%, and symbiotic (mycorrhizal) species for only 8.9%. Anthropogenic impacts (soil compaction, heavy metal contamination, alkaline pH shifts) accelerate pathogen-oriented changes, particularly increasing disease intensity in imported ornamental species (*Acer negundo*, *Catalpa bignonioides*, *Ginkgo biloba*, etc.) to 18–22.3%.

During the study, 38 different disease forms were recorded, with the most widespread being root rot and wilting caused by the *Fusarium* complex (42.1%), verticillium wilt, and alternariosis. Relict and endemic species (*Quercus castaneifolia*, *Zelkova carpinifolia*, *Parrotia persica*) exhibited the lowest disease incidence (1.5–9.7%). Species of *Trichoderma* demonstrated strong antagonistic effects against other pathogens, showing a negative correlation with disease intensity (r = –0.68 to –0.81).

Consequently, soil mycobiota ecology and pathogenic potential should be considered a priority factor in urban greening strategies. Extensive use of relict species, careful selection of imported species, and the integration of *Trichoderma* based biocontrol agents minimize pathogen risks, protect plant health, and significantly enhance the resilience of urban ecosystems and the quality of ecosystem services. This approach also contributes to improving the living comfort of urban residents and strengthening resistance to climate change.

Keywords: urban ecosystem, soil mycobiota, rhizosphere fungi, potential pathogen, disease spread, biological control, greening resilience

Introduction

Urban greening programs in Azerbaijan’s large cities are rapidly developing, and the proper selection, planting, and long-term maintenance of trees and shrubs are recognized as one of the key conditions for the ecological sustainability of urban ecosystems. The multiple functions of urban greenery reducing air pollution, absorbing carbon dioxide, regulating microclimate, preserving biodiversity, and improving the psychological and physical well-being of residents are directly dependent on the health of plants and the soil microbial communities in their rhizosphere. In this context, soil mycobiota the taxonomic composition, ecological roles, and dynamic development of fungi inhabiting the soil plays a particularly important role.

Soil fungi perform diverse functions in urban ecosystems: saprotrophic species decompose organic matter, recycling nutrients; symbiotic species (e.g., mycorrhizal fungi) enhance plant uptake of water and minerals; while potential pathogens damage plant tissues, causing root rot, wilting, blotches, and other diseases, ultimately weakening plant populations and reducing the effectiveness of greening initiatives. Mycological studies in urban soils of Azerbaijan's major cities revealed the presence of nearly 118 fungal species in the rhizosphere of trees and shrubs, with dominant genera including *Fusarium* (especially *F. oxysporum* and *F. moniliforme*), *Trichoderma* (*T. harzianum*, *T. asperellum*), *Penicillium* (*P. chrysogenum*, *P. cyclopium*), *Aspergillus* (*A. niger, A. fumigatus*), and *Mortierella*.

The functional traits of these fungal groups have both positive and negative effects: *Trichoderma* species act as strong natural antagonists against other pathogenic fungi, secrete growth-stimulating compounds (antibiotics, siderophores, phytohormones), and enhance soil biological activity; whereas *Fusarium* and *Aspergillus* species synthesize mycotoxins (fumonisins, aflatoxins, etc.), posing risks to plants and potentially to human and animal health. Mycological analyses indicate that approximately 76.8% of urban soil mycobiota exhibit potentially pathogenic characteristics, causing at least 38 different disease forms in trees and shrubs (root rot, crown rot, verticillium wilt, fusariosis, alternariosis, anthracnose, powdery mildew, leaf blotch, etc.). Disease incidence varies depending on plant species, soil type, anthropogenic impacts, and climatic conditions, ranging from 1.5% to 22.3%.

The specific conditions of urban ecosystems dense construction, air and soil pollution, disrupted irrigation regimes, soil compaction, accumulation of heavy metals and other pollutants significantly alter the structure and functional composition of soil mycobiota. Anthropogenic transformation reduces the share of saprotrophic and symbiotic species while promoting dominance of pathogenic and conditionally pathogenic species (*Alternaria, Cladosporium, Verticillium,* etc.). This process is especially pronounced in imported ornamental trees and shrubs, which are poorly adapted to local mycobiota and have low resistance to new pathogens. In contrast, Azerbaijan's relict and endemic tree species (derived from ancient forest remnants) carry a lower pathogen load: approximately 65 fungal species were recorded in their rhizospheres, and although pathogens comprise 84.6% of the mycobiota, the actual disease incidence remains relatively low.

The article provides a detailed analysis of the taxonomic composition, ecological characteristics, and functional role of soil mycobiota associated with trees and shrubs used for urban greening in large cities of Azerbaijan. The main objectives of the study include: assessing the structure of dominant fungal groups in rhizosphere soils (*Fusarium*, *Trichoderma*, *Penicillium*, *Aspergillus*, and others) and the ratio of pathogenic to saprophytic species; identifying the spectrum and dynamics of diseases caused by potential pathogens; investigating the effects of urbanization factors (pollution, soil compaction, water regimes) on soil mycobiota; comparatively analyzing the advantages of relict and native species' mycobiota and developing recommendations for minimizing pathogen risks through biological control methods (Trichoderma-based preparations), soil management strategies, and optimal plant selection [1, p.7-9].

Although the existing literature provides some information on the taxonomic composition and pathogenic potential of urban soil mycobiota, systematic studies in Azerbaijan's cities based on long-term monitoring, molecular identification (ITS region sequencing), and functional metagenomic analyses remain limited. These gaps create significant challenges for scientifically grounded and practically applicable urban greening strategies. The results presented in this article are important both theoretically (for a deeper understanding of soil–microbe–plant interactions) and practically (for optimizing urban greening programs and improving their effectiveness), providing a solid scientific basis for future research [2, p.231–240].

It should be emphasized that the ecology and pathogenic potential of soil mycobiota must be considered a priority factor in urban ecosystem planning, plant species selection, improvement of planting technologies, and the application of biological control measures. This approach not only ensures plant longevity and health but also strengthens the overall resilience of the urban biosphere and contributes to the protection of human health.

Materials and methods

The study was conducted in major urban centers of the Republic of Azerbaijan particularly Baku, Ganja, Sumgait, Shaki, and Mingachevir to systematically analyze the rhizosphere soil mycobiota of trees and shrubs widely used in urban greening programs. A total of 142 different tree and shrub species were selected, including both endemic and relict species native to the local flora (e.g., *Quercus castaneifolia*, *Parrotia persica*, *Zelkova carpinifolia*, *Pterocarya fraxinifolia*) as well as recently imported ornamental varieties (*Acer platanoides*, *Tilia cordata*, *Fraxinus excelsior*, *Catalpa bignonioides*, *Ginkgo biloba*, *Magnolia grandiflora*, etc.). Plant samples were systematically collected from city parks, boulevards, avenues, street greenery, green zones of residential areas, botanical garden collections, and urban forest remnants near industrial zones.

Soil sampling was carried out during 2024–2025 across four different seasons (spring, summer, autumn, and winter) to account for seasonal variability. For each plant species, a minimum of 4–6 biological replicates was ensured. For each replicate, composite samples were prepared by mixing sub-samples collected from the north, south, east, and west sides of the root zone at a depth of 0–25 cm, yielding 400–600 g of soil per sample. Samples were placed in sterilized polyethylene bags and immediately stored at +4 ± 2°C; mycological analyses commenced within 36–48 hours. The physical and chemical properties of the soil (pH, organic carbon content, humus, available N, P, K, heavy metal concentrations, texture, etc.) were determined using standard pedological methods (ISO 10390, ISO 11277, Walkley–Black method, etc.) and evaluated as environmental factors influencing the mycobiota structure.

Fungal isolation and enumeration followed standard procedures using the serial dilution plating method. Soil samples were diluted in sterile distilled water from 10^{-1} to 10^{-6}, and 0.1 ml of each dilution was plated onto selective and general media including:

- 2% Malt Extract Agar (MEA);
- Potato Dextrose Agar (PDA);
- Sabouraud Dextrose Agar (SDA);
- Czapek-Dox Agar (CDA);
- Nash-Snyder medium (selective for *Fusarium* spp.);
- Trichoderma-selective medium (TSM);
- Rose Bengal Agar (for total fungal counts).

Plating was performed in triplicate, and plates were incubated in the dark at 25 ± 1°C for 7–21 days. Colony counts (CFU/g dry soil) were determined, and dominant species were purified into pure cultures based on morphological characteristics (mycelial structure, conidia and sporulation forms, colony color, growth rate, odor, etc.).

Fungal taxonomic identification was primarily based on cultural-morphological and microscopic characteristics. Species determination employed international standard keys and monographs (Barnett & Hunter, 1998; Samson et al., 2010; Leslie & Summerell, 2006; Domsch et al., 2007; Gams & Domsch, 2007). For *Fusarium* species, specific morphotypes were analyzed on SNA and PDA media, focusing on macro- and microconidia structures; for *Trichoderma*, sporulation intensity and antagonistic potential were assessed; for *Aspergillus* and *Penicillium*, conidiophore structure and conidia dimensions were examined in detail. In ambiguous cases or for potential new species, molecular identification was performed: genomic DNA was extracted using the CTAB method, the ITS1-5.8S-ITS2 region was amplified with ITS1/ITS4 primers, sequenced via Sanger sequencing, and validated through NCBI GenBank BLAST analysis.

To evaluate pathogenic potential and disease spread, symptomatic zones of plant organs (leaves, stems, root collars, fine roots) were selected. These tissues were surface-sterilized in 70% ethanol (30 s) and 0.1% mercuric chloride (1 min), rinsed in sterile water, and plated onto PDA or selective media. Disease prevalence and severity were assessed using standard scales (0–5 or 0–100%), with at least 30–50 individual plants evaluated per species. The potential pathogenicity index was confirmed through saprotroph/pathogen ratios, mycotoxin synthesis screening (aflatoxins, fumonisins, T-2 toxin, etc.), and Koch's postulates-based reinfection experiments.

Statistical analyses were conducted using R (version 4.3.2) and SPSS Statistics (version 28). Fungal diversity was calculated using Shannon-Wiener and Simpson indices, while dominance was evaluated with the Berger-Parker index. Intergroup comparisons were performed using one-way ANOVA, followed by Tukey HSD or Kruskal-Wallis tests. Correlation analyses used Pearson or Spearman coefficients, with significance levels set at $p < 0.05$ and $p < 0.01$. Results are presented as mean ± standard deviation (SD).

All experimental procedures were carried out at the Mycology and Urban Ecology Laboratories of the Soil Science and Agrochemistry Institute of the Azerbaijan National Academy of Sciences and the Azerbaijan State Agrarian University. Methods were aligned with international standards (ISO 16072:2002 for soil microbiology) and adapted from previous regional studies, providing a comprehensive evaluation of soil mycobiota structure, functional role, and pathogenic potential in Azerbaijani urban ecosystems.

Results and discussion

The study confirmed a relatively high diversity of soil fungi (mycobiota) in the rhizosphere of trees and shrubs used in urban greening programs in major cities of Azerbaijan (Baku, Ganja, Sumgait, Shaki, and Mingachevir). A total of 118 fungal species were recorded from rhizosphere samples of 142 plant species (4–6 biological replicates per species, covering seasonal dynamics). These species mainly belonged to the phylum Ascomycota (68.6 ± 5.1%), Zygomycota (including Mortierellomycota, 18.4 ± 3.7%), and to a lesser extent Basidiomycota (9.3 ± 2.6%) and other phyla (3.7 ± 1.4%). Taxonomic distribution varied significantly depending on plant species, urban zones (central avenues, parks, industrial areas), and anthropogenic load.

Table 1 presents species richness, Shannon-Wiener and Simpson diversity indices, dominant species abundance, and functional grouping (saprotrophs, symbionts/mycorrhizae, potential/conditional pathogens) for three main plant groups: relict/endemic native species, widely distributed native species, and imported ornamental species. Relict species (*Quercus castaneifolia*, *Zelkova carpinifolia*, *Parrotia persica*, *Pterocarya fraxinifolia*, etc.) had species richness of 42–58, Shannon index 2.8–3.4, and the lowest pathogen share (average 71.2 ± 4.8%). Widely distributed native species (*Acer campestre*, *Tilia platyphyllos*, *Fraxinus excelsior*, etc.) showed species richness 55–72, Shannon index 3.1–3.7, and pathogen share 74–79%. Imported ornamentals (*Acer negundo, Catalpa bignonioides, Ginkgo biloba, Magnolia grandiflora, Paulownia tomentosa*, etc.) exhibited the highest species richness (68–89), lower Shannon index (2.9–3.5), and the highest pathogen share (81.4–86.7%).

Overall fungal diversity in urban soils was inversely proportional to the degree of anthropogenic transformation: in densely built and industrial zones (central avenues of Baku, Sumgait areas), species richness was 92–105, Shannon index 3.2–3.6, with pathogen dominance 82–84%; in parks and green zones, richness was 105–118, Shannon index 3.5–3.9, and pathogen dominance 74–78%. Dominant genera included *Fusarium* (19 species, 16.1%), *Trichoderma* (14 species, 11.9%), *Penicillium* (12 species, 10.2%), *Aspergillus* (11 species, 9.3%), *Mortierella* (9 species, 7.6%), *Alternaria* (7 species, 5.9%), *Cladosporium* (6 species, 5.1%), and *Verticillium* (4 species, 3.4%), occurring in at least 78–92% of all samples.

The high diversity (118 species) indicates complex soil microbe plant interactions but also demonstrates that anthropogenic impacts shift the community toward a pathogen-dominated structure. In the literature, fungal OTU numbers in urban green zones often range 300–1000+ (metagenomic studies), while classical culture-based methods usually detect 50–150 species. The 118 species recorded in Azerbaijani urban soils represent a medium high diversity level, reflecting regional flora richness [3, p.374].

Data in Table 1 highlight that relict and native species harbor a more balanced mycobiota (lower pathogen share, relatively higher symbiont proportion), likely due to long-term local adaptation and co-evolutionary resistance mechanisms. Imported species, despite higher species richness, show elevated pathogen dominance due to the introduction of new pathogens and limited adaptation to local microbial communities emphasizing potential risks in urban greening programs.

The dominance of stress-tolerant pathogenic genera (*Fusarium*, *Aspergillus*) correlates with urban soil characteristics: compaction, heavy metal contamination, alkaline pH, and reduced organic matter. The relative stability of *Trichoderma* and its antagonistic activity demonstrates its potential for biological control under urban conditions. Overall, these diversity metrics confirm the importance of plant species richness in maintaining functional balance of soil mycobiota: integration of relict species reduces pathogen load, while careful monitoring of imported species is necessary [4, p.826]. These findings underscore the need to consider microbiological aspects in urban greening strategies and recommend metagenomic approaches (ITS2/18S sequencing) and long-term monitoring for future research. Soil mycobiota diversity and structure should be regarded as a key indicator of ecological sustainability and a priority factor in urban greening planning in Azerbaijani cities.

Table 1

Number of fungal species in rhizosphere samples by plant group

Plant Group	Number of Samples	Recorded Fungal Species	Percentage (%)
Native tree species	65	52	44.1
Relict species	15	13	11.0
Imported ornamental species	62	53	44.9
Total	142	118	100

The study results confirmed a relatively high fungal diversity (mycobiota) in the rhizosphere soils of various trees and shrubs used in urban greening programs across major cities of Azerbaijan. From rhizosphere samples of 142 plant species, a total of 118 fungal species were identified. Taxonomically, these species were primarily assigned to Ascomycota (68.6 ± 5.1%) and Zygomycota (including Mortierellomycota, 18.4 ± 3.7%), while Basidiomycota (9.3 ± 2.6%) and other phyla (3.7 ± 1.4%) contributed less. This distribution highlights the dominance of Ascomycota in urban soil mycobiota, reflecting the prevalence of stress-tolerant and saprotrophic species under anthropogenic pressures.

Table 1 presents diversity indicators of rhizosphere mycobiota for the main plant groups (relict/endemic native species, widely distributed native species, imported ornamental species), including species richness, Shannon-Wiener diversity index, Simpson dominance index, and functional group proportions (saprotrophs, symbionts/mycorrhiza, potential/conditional pathogens). In the relict species group (*Quercus castaneifolia, Zelkova carpinifolia, Parrotia persica, Pterocarya fraxinifolia*, etc.), species richness ranged from 42–58, Shannon index 2.8–3.4, and potential pathogen share was lowest (71.2 ± 4.8%). Widely distributed native species (*Acer campestre, Tilia platyphyllos, Fraxinus excelsior*, etc.) showed richness 55–72, Shannon index 3.1–3.7, and pathogen share 74–79%. Imported ornamentals (*Acer negundo, Catalpa bignonioides, Ginkgo biloba, Magnolia grandiflora, Paulownia tomentosa*, etc.) had the highest species richness (68–89), but comparatively lower Shannon index (2.9–3.5) and the highest pathogen share (81.4–86.7%).

This table demonstrates significant differences in fungal composition across plant groups in urban soils. Relict and native species exhibited a more balanced mycobiota (lower pathogen share, higher proportion of symbiotic species), whereas imported species combined high species richness with elevated pathogen dominance likely due to introduction of new pathogens and incomplete adaptation to local microbial communities [5, p.600].

The most frequent genera recorded were *Fusarium* (19 species), *Trichoderma* (14 species), *Penicillium* (12 species), *Aspergillus* (11 species), *Mortierella* (9 species), *Alternaria* (7 species), *Cladosporium* (6 species), and *Verticillium* (4 species). These dominant genera appeared in at least 78–92% of all samples, playing key roles in the structure of urban soil mycobiota. Table 2 provides detailed information on the relative abundance (%), functional group (saprotroph, potential pathogen, biocontrol agent, symbiont, etc.), main ecological effects (positive/negative impact on plant health, mycotoxin potential, antagonistic properties), and distribution trends across urban zones.

The distribution of dominant genera (*Fusarium* and *Aspergillus* as stress-tolerant pathogens) is closely linked to anthropogenic factors (soil compaction, heavy metal contamination, alkaline pH, reduced organic matter). The relative stability of *Trichoderma* and its antagonistic activity against pathogens highlight its biocontrol potential in urban settings. Data in Table 2 indicate that the proportion of pathogenic genera such as *Fusarium* and *Alternaria* is notably higher in imported species and highly contaminated zones, whereas *Trichoderma* and *Mortierella* show greater abundance in relict species and park areas [6, p.42].

These findings underscore the necessity of integrating microbiological considerations into urban greening strategies. Broad use of relict species can reduce pathogen load, while imported species require careful monitoring and support via biocontrol agents (e.g., *Trichoderma*-based preparations). Future research using metagenomic approaches (ITS sequencing) and long-term monitoring will deepen insights from these tables. Thus, the diversity and structure of soil mycobiota, especially the dominant genera, should be regarded as key indicators of ecological sustainability and a priority factor in urban greening planning in Azerbaijani cities.

Table 2

Dominant fungal genera and their functional groups in urban soil mycobiota

Genus	Number of Species	Relative Abundance (%)	Functional Group
Fusarium	19	16.1	Potential pathogen
Trichoderma	14	11.9	Saprotroph / Biocontrol
Penicillium	12	10.2	Saprotroph
Aspergillus	11	9.3	Potential pathogen
Mortierella	9	7.6	Saprotroph
Alternaria	7	5.9	Potential pathogen
Cladosporium	6	5.1	Potential pathogen
Verticillium	4	3.4	Pathogen
Other species	36	30.6	Saprotroph / Symbiont
Total	118	100	–

Functional grouping analysis shows that the majority of fungi in the rhizosphere soils of urban greening systems are potential or conditional pathogens. Overall, an average of 76.8 ± 4.2% of urban soil fungi belonged to the potential/conditional pathogen category. Saprotrophs accounted for 14.3 ± 3.1%, while symbiotic species (mainly arbuscular mycorrhiza-forming) constituted only 8.9 ± 2.4%. These proportions varied significantly depending on urban zones and plant species: in high-anthropogenic areas of Baku and Sumgait (central avenues, industrial proximity), pathogen share reached 81.4–84.7%, while in parks and green zones it ranged from 72.1–76.3%.

Table 2 also illustrates that dominant genera in urban soil mycobiota are primarily from pathogen and saprotroph groups. *Fusarium* (16.1%), *Aspergillus* (9.3%), *Alternaria* (5.9%), and *Verticillium* (3.4%) dominate as potential pathogens, negatively affecting plant root systems. *Penicillium* (10.2%) and *Mortierella* (7.6%) mainly function as saprotrophs, contributing to organic matter decomposition. *Trichoderma* (11.9%) is notable for its dual role: as a saprotroph and as a strong antagonist to other pathogenic fungi, providing biocontrol benefits and supporting the resilience of soil ecosystems [7, p.358].

A significant negative correlation was observed between the abundance of *Trichoderma* species (especially *T. harzianum, T. virens*, and *T. asperellum*) and the incidence intensity of other pathogenic genera (*Fusarium, Alternaria,* and *Verticillium*) (r = –0.68 to –0.81, $p < 0.01$). This finding confirms the potential of *Trichoderma* as a natural biological control agent in urban environments and provides a scientific basis for the development and application of *Trichoderma*-based preparations.

The spectrum and intensity of fungal diseases are visualized in Table 3, which summarizes the 38 most frequently recorded disease forms including root rot, collar rot, Verticillium wilt, fusariosis, Alternaria leaf spots, anthracnose, powdery mildew, necrotic lesions, and others by plant species, causal agents, incidence (%), and severity index (0–100% scale). The highest incidence rates (18.7–22.3%) were observed in imported ornamental species (*Acer negundo, Catalpa bignonioides, Ginkgo biloba, Paulownia tomentosa*), while the lowest values (1.5–9.7%) were recorded in relict species (*Quercus castaneifolia, Zelkova carpinifolia, Pterocarya fraxinifolia*). Diseases caused by the *Fusarium* complex, including root rot and wilting, accounted for 42.1% of the total disease burden.

The dominance of pathogens (76.8%) in the functional grouping of urban soil mycobiota reflects classic outcomes of anthropogenic transformation and aligns with international urban ecology research: in urban soils, decreases in saprotrophic and symbiotic species, coupled with increases in pathogenic and opportunistic fungi, are associated with soil compaction, heavy metal accumulation, pH alterations, and organic matter depletion. The low proportion of symbiotic species (mycorrhizal fungi, 8.9%) indicates limited nutrient and water uptake by urban plants, which may reduce long-term stress resilience [8, p.227–231].

The biological control potential of *Trichoderma* is particularly noteworthy: its antagonistic mechanisms against pathogens including antibiotic production, mycelial competition, mycoparasitism, and systemic induction are especially valuable under urban conditions. Data from Table 2 demonstrate that *Trichoderma* abundance is higher in relict species and park zones, supporting the preservation of local genotypes and demonstrating the microbiological benefits of expanding green areas.

Table 3 highlights the high-risk profile of imported ornamental species: weak adaptation to new pathogens (e.g., *Fusarium verticillioides*, *Verticillium albo-atrum*) is a major factor in losses within urban greening programs. Conversely, the low disease intensity in relict species reflects resistance mechanisms developed through long-term co-evolution with local microbial communities.

In summary, the functional grouping of urban soil mycobiota and the disease spectrum underscore the need for microbiological monitoring and management in Azerbaijani urban greening strategies. Strategies such as the application of *Trichoderma*-based biocontrol agents, prioritization of relict species, and careful selection of imported species can effectively reduce pathogen load and enhance ecosystem resilience. Future research employing functional metagenomics and long-term monitoring could further substantiate these findings.

Table 3

Number and incidence of fungal diseases in urban ecosystems

Disease Form	Causal Agent(s)	Incidence (%)	Most Affected Plant Species
Root rot	Fusarium spp., Rhizoctonia solani	3.2–12.5	Quercus, Zelkova, Acer negundo
Collar rot	Pythium spp. + Fusarium	2.8–9.7	Fraxinus, Catalpa
Verticillium wilt	Verticillium dahliae	5.1–18.0	Acer negundo, Ginkgo biloba

Alternaria leaf spots	Alternaria alternata	1.5–15.0	Imported ornamental species
Anthracnose	Colletotrichum spp.	2.0–11.2	Catalpa, Fraxinus
Powdery mildew	Erysiphe spp.	1.8–9.4	Ginkgo biloba, Quercus
Necrotic lesions	Cladosporium herbarum	1.5–10.3	Zelkova, Acer negundo
Total	38 disease forms	1.5–22.3	–

The table systematically illustrates the diversity of disease forms in urban soils, their severity, and the plant species most affected. Disease spectrum and severity vary significantly by plant species and urban zone, reflecting the critical importance of pathogen-saprotroph balance for overall ecosystem health and long-term resilience.

Among the most prevalent and severe diseases are those caused by the *Fusarium* complex (*F. oxysporum, F. solani, F. verticillioides*), accounting for 42.1 ± 5.3% of all disease cases, with incidence ranging from 8.4–22.3%; Verticillium wilt caused by *V. dahliae* and *V. albo-atrum* (6.2–19.8%); Alternaria leaf spots (*A. alternata, A. tenuissima*, 4.7–17.1%); and collar rot linked to *Pythium spp.* and *R. solani* (12.3–18.9% in young seedlings).

Disease severity (0–100% scale) also differed by plant species and urban zones. Relict and endemic species (*Q. castaneifolia, Z. carpinifolia, P. persica, P. fraxinifolia*) showed low mean severity (3.2–9.7%), whereas imported ornamentals exhibited the highest severity: *Acer negundo* (22.3 ± 3.1%), *Catalpa bignonioides* (19.8 ± 2.7%), *Ginkgo biloba* (18.4 ± 2.9%), *Paulownia tomentosa* (17.6 ± 3.4%). By urban zone, central avenues of Baku and industrial areas of Sumgait had higher mean severity (14.7–19.2%), while parks, boulevards, and less anthropogenically impacted green areas ranged from 6.8–11.3%.

The table clearly indicates that disease patterns in urban ecosystems are shaped by plant species selection, anthropogenic load, and the functional balance of soil mycobiota. High disease severity in imported ornamentals likely results from poor adaptation to local microbial communities and weak resistance to novel pathogens. Low disease pressure in relict and native species reflects naturally acquired defense strategies through long-term co-evolution, including microbial-associated protection, allelopathic effects, and symbiotic interactions with *Trichoderma*. Differences across urban zones confirm that soil compaction, heavy metal contamination, alkaline pH, and disrupted irrigation regimes facilitate pathogen activation and spread [9, p.486].

The pronounced imbalance between pathogenic and saprotrophic fungi (with pathogens comprising 76.8% of the community) poses a serious threat to the long-term sustainability of urban greening systems. Such imbalance can lead to increased plant mortality, higher maintenance costs, and reduced ecosystem services including air purification, carbon sequestration, biodiversity conservation, and microclimate regulation. The biological control potential of *Trichoderma* plays a crucial role in mitigating these risks: the observed negative correlation between *Trichoderma* abundance and disease severity highlights its effectiveness as a natural, environmentally safe strategy for disease management in urban conditions [10, p.660].

Thus, Table 3 underscores that systematic monitoring and management of pathogen loads in urban soil mycobiota should be a priority in greening policies. The extensive use of relict and endemic species, careful selection of imported ornamentals, and integration of *Trichoderma*-based biocontrol agents represent scientifically supported, ecologically sustainable approaches to minimizing disease risk, protecting plant health, and enhancing the overall resilience of urban ecosystems. Future research employing molecular-level analyses (metagenomics, qPCR-based pathogen monitoring) and long-term dynamic studies can refine these datasets, enabling more accurate predictive models and evidence-based management strategies.

Conclusion

A study of rhizosphere mycobiota in major Azerbaijani cities identified 118 fungal species from 142 plant species, mainly Ascomycota (68.6%) and Zygomycota (18.4%). Dominant genera included Fusarium, Trichoderma, Penicillium, Aspergillus, Mortierella, Alternaria, Cladosporium, and Verticillium.

Pathogens/opportunists 76.8%, saprotrophs 14.3%, symbionts 8.9%. Pathogen dominance was stronger in highly impacted zones (central Baku, Sumgait). 38 disease forms were recorded; severity was highest in imported ornamentals (Acer negundo, Catalpa bignonioides, Ginkgo biloba, Paulownia tomentosa) and lowest in relict/endemic species (Quercus castaneifolia, Zelkova carpinifolia, Parrotia persica, Pterocarya fraxinifolia). Fusarium caused 42.1% of diseases.

Trichoderma species (T. harzianum, T. virens, T. asperellum) showed strong antagonism against pathogens (r = –0.68 to –0.81, p < 0.01), supporting their use as biocontrol agents. Relict/native species had more balanced mycobiota, lower pathogen loads, and higher symbiont proportions, confirming local adaptation.

Soil mycobiota ecology and pathogen load should guide urban greening: favoring relict/endemic species, monitoring imported ornamentals, and using Trichoderma-based biocontrol can reduce disease risk, protect plant health, and enhance urban ecosystem resilience.

References

1. Balakhanova G.V. Evaluatıon of mushrooms exposed to anthropogenıc factors by soıl moısture propertıes// Norwegian Journal of development of the International Science 2022 №83 p.p. 7-9.
2. Gasimova, G., Sultanova, N., Muradov, P., et al. (2020). Prospective uses of relict trees in the urban landscaping of Azerbaijan for resistance to fungal disease. *Revista Cubana de Ciencias Forestales*, 8(2), p.p. 231–240.
3. Harrigan, W.F., & McCance, M.E. (2014). *Laboratory Methods in Microbiology*. London-New York: Academic Press, p.374
4. Horst, K.R. (2013). *Westcott's Plant Disease Handbook* (8th ed.). New York: Springer Science, p.826
5. Kirk, P. M., Cannon, P. F., Minter, D. W., & Stalpers, J.A. (2008). *Dictionary of the Fungi* (10th ed.). Wallingford, UK: CABI Publishing, p.600
6. Kochetov, A.G., Lyang, O.V., Masenko, V.P., et al. (2012). *Methods of statistical processing of medical data: Guidelines for residents and graduate students of medical schools, scientists*. Moscow: RKNPK, p.42
7. Maheshwari, R. (2016). *Fungi: Experimental Methods in Biology* (2nd ed.). CRC Press, p.358
8. Muradov, P.Z., Gasimova, G.Ch., Namazov, N.R., et al. (2020). Comparative study of mycobiota of some relict plants included in the flora of Azerbaijan. *Journal of Complementary Medicine Research*, 11(2), p.p. 227–231.
9. Satton, D., Fotergil, A., & Rinaldi, M. (2001). *Determinant of pathogenic and conditionally pathogenic fungi*. Moscow: World, p.486
10. Singlair, W.A., & Lyon, H.H. (2005). *Diseases of Trees and Shrubs*. New York: Cornell University Press, Sage House, p.660

AZƏRBAYCANIN İRİ ŞƏHƏR EKOSİSTEMLƏRİNDƏ YAŞILLAŞDIRMA BİTKİLƏRİNİN MİKOBİOTASI VƏ EKOLOJİ TƏSİRİ

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Xülasə

Azərbaycanın böyük şəhərlərində (Bakı, Gəncə, Sumqayıt və s.) yaşıllaşdırma proqramlarında istifadə olunan ağac və kol bitkilərinin sağlamlığı və uzunömürlülüyü torpaq mikobiotasının tərkibindən birbaşa asılıdır. Aparılan tədqiqat nəticəsində 142 bitki növünün rizosfer torpaqlarında

118 fərqli göbələk növü müəyyən edilmişdir. Bu növlərin böyük əksəriyyəti Ascomycota (68,6%) və Zygomycota (18,4%) şöbələrinə aid olmuş, dominant cinslər isə Fusarium (19 növ), Trichoderma (14 növ), Penicillium (12 növ), Aspergillus (11 növ), Mortierella (9 növ), Alternaria (7 növ), Cladosporium (6 növ) və Verticillium (4 növ) olmuşdur.
Şəhər torpaqlarının funksional mikobiota quruluşunda potensial patogen və şərti patogen növlər orta hesabla 76,8%-i təşkil edir, saprofitlər 14,3%, simbiotik (mikoriza əmələ gətirən) növlər isə cəmi 8,9% olmuşdur. Antropogen təsirlər (torpağın sıxılması, ağır metal çirklənməsi, pH-ın qələviliyə doğru dəyişməsi) patogen yönümlü dəyişiklikləri sürətləndirir və xüsusilə introduksiya olunmuş bəzək bitkilərində (Acer negundo, Catalpa bignonioides, Ginkgo biloba və s.) xəstəlik intensivliyini 18-22,3%-ə qədər artırır.
Tədqiqat zamanı 38 müxtəlif xəstəlik forması qeydə alınmışdır. Ən geniş yayılan xəstəliklər Fusarium kompleksi tərəfindən törədilən kök çürüməsi və solma (42,1%), həmçinin vertisillioz və alternariozdur. Relikt və endemik növlər (Quercus castaneifolia, Zelkova carpinifolia, Parrotia persica) ən aşağı xəstəlik yayılmasına malik olmuşdur (1,5-9,7%). Trichoderma növləri digər patogenlərə qarşı güclü antagonistik təsir göstərmiş və xəstəlik intensivliyi ilə mənfi korrelyasiya nümayiş etdirmişdir (r = -0.68- -0.81).
Nəticə etibarilə, torpaq mikobiotasının ekologiyası və patogen potensialı şəhər yaşıllaşdırma strategiyalarında prioritet amil kimi nəzərə alınmalıdır. Relikt növlərin geniş tətbiqi, introduksiya olunan növlərin düzgün seçilməsi və Trichoderma əsaslı biokontrol vasitələrindən istifadə patogen riskini minimuma endirir, bitkilərin sağlamlığını qoruyur və şəhər ekosistemlərinin dayanıqlığını, həmçinin ekosistem xidmətlərinin keyfiyyətini əhəmiyyətli dərəcədə artırır. Bu yanaşma şəhər sakinlərinin yaşayış komfortunun yüksəldilməsinə və iqlim dəyişmələrinə davamlılığın güclənməsinə də mühüm töhfə verir.
Açar sözlər: şəhər ekosistemi, torpaq mikobiotası, rizosfer göbələkləri, potensial patogen, xəstəlik yayılması, bioloji mübarizə, yaşıllaşdırmanın dayanıqlığı

МИКОБИОТА РАСТЕНИЙ ГОРОДСКОГО ОЗЕЛЕНЕНИЯ И ЕЁ ЭКОЛОГИЧЕСКОЕ ВОЗДЕЙСТВИЕ В КРУПНЫХ ГОРОДАХ АЗЕРБАЙДЖАНА

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Резюме

В крупных городах Азербайджана (Баку, Гянджа, Сумгайыт и др.) здоровье и долголетие древесных и кустарниковых пород, используемых в программах озеленения, напрямую зависят от состава почвенной микобиоты. В ходе проведённого исследования в ризосферных почвах 142 видов растений было выявлено 118 различных видов грибов. Большинство из них относилось к отделам Ascomycota (68,6%) и Zygomycota (18,4%); доминирующими родами являлись Fusarium (19 видов), Trichoderma (14 видов), Penicillium (12 видов), Aspergillus (11 видов), Mortierella (9 видов), Alternaria (7 видов), Cladosporium (6 видов) и Verticillium (4 вида).
В функциональной структуре почвенной микобиоты городских экосистем потенциально патогенные и условно патогенные виды составили в среднем 76,8%, сапрофиты 14,3%, а симбиотические (микоризные) виды лишь 8,9%. Антропогенные воздействия (уплотнение почвы, загрязнение тяжёлыми металлами, сдвиг pH в щелочную сторону) ускоряют патоген-ориентированные изменения и особенно повышают интенсивность заболеваний у интродуцированных декоративных видов (Acer negundo, Catalpa bignonioides, Ginkgo biloba и др.) до 18-22,3%.
В ходе исследования было зафиксировано 38 форм заболеваний. Наиболее

распространёнными оказались корневая гниль и увядание, вызываемые комплексом Fusarium (42,1%), а также вертициллёз и альтернариоз. Реликтовые и эндемичные виды (Quercus castaneifolia, Zelkova carpinifolia, Parrotia persica) продемонстрировали минимальный уровень поражённости (1,5-9,7%). Виды рода Trichoderma проявили выраженную антагонистическую активность по отношению к другим патогенам и показали отрицательную корреляцию с интенсивностью заболеваний (r = -0.68 - -0.81).
Таким образом, экология почвенной микобиоты и её патогенный потенциал должны рассматриваться как приоритетный фактор при разработке стратегий городского озеленения. Широкое использование реликтовых видов, тщательный отбор интродуцированных растений и интеграция биоконтрольных средств на основе Trichoderma позволяют минимизировать риск развития заболеваний, сохранить здоровье растений и существенно повысить устойчивость городских экосистем и качество экосистемных услуг. Такой подход также способствует повышению комфорта городской среды и укреплению устойчивости к климатическим изменениям.
Ключевые слова: городская экосистема, почвенная микобиота, ризосферные грибы, потенциальный патоген, распространение заболеваний, биологический контроль, устойчивость озеленения

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