

HEALTH ASSESSMENT OF SPECIES-RICH URBAN LAWN MIXTURES IN SUSTAINABLE URBAN GREEN INFRASTRUCTURE

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INTRODUCTION

Urban green infrastructure has become an essential component of sustainable city development. As urbanization intensifies worldwide, cities increasingly face challenges associated with climate change, biodiversity loss, air pollution, elevated temperatures, and the deterioration of environmental quality. Green spaces, including parks, roadside vegetation, urban meadows, and lawns, provide a wide range of ecosystem services that mitigate these negative impacts while improving the quality of life for urban residents^{1,2,3}.

Lawns represent one of the most widespread elements of urban green infrastructure. Beyond their aesthetic value, they perform numerous ecological functions, including temperature regulation through evapotranspiration, carbon sequestration, reduction of airborne particulate matter, stormwater infiltration, soil stabilization, and noise attenuation⁴. Well-designed grasslands also contribute to urban biodiversity by providing habitats for insects and other organisms, thereby supporting ecological connectivity within highly fragmented urban landscapes⁵.

In recent years, the concept of urban lawns has undergone considerable transformation. Conventional intensively managed lawns, typically composed of a few highly productive grass species and requiring frequent mowing,

¹ Ignatieva M. et al. Lawn as a cultural and ecological phenomenon: a conceptual framework for transdisciplinary research. *Urban forestry & urban greening*. 2015. T. 14. №. 2. P. 383–387.

² Aronson M. F. J. et al. Biodiversity in the city: key challenges for urban green space management. *Frontiers in Ecology and the Environment*. 2017. T. 15. №. 4. P. 189–196.

³ Ignatieva M. et al. Lawns in cities: from a globalised urban green space phenomenon to sustainable nature-based solutions. *Land* 2020, 9, 73.

⁴ Robbins P. Lawn people: How grasses, weeds, and chemicals make us who we are. Temple University Press, 2012.

⁵ Stewart G. H. et al. URban Biotopes of Aotearoa New Zealand (URBANZ)(I): composition and diversity of temperate urban lawns in Christchurch. *Urban Ecosystems*. 2009. T. 12. №. 3. P. 233–248.

irrigation, and fertilization, are increasingly being replaced by more diverse vegetation communities^{6,7}. Species-rich grass-legume-forb mixtures are considered a sustainable alternative because they require fewer maintenance inputs, exhibit greater resilience to climatic extremes, and provide enhanced ecological functions⁸. Such mixtures are particularly suitable for green infrastructure associated with transport corridors, including tram tracks, railway embankments, and roadside verges, where plants are exposed to multiple environmental stresses.

Among European cities, Prague represents an outstanding example of integrating species-rich vegetation into urban transport infrastructure. During the last decade, numerous tramway corridors have been converted into vegetated tracks that combine ecological, aesthetic, and engineering functions by reducing heat accumulation, retaining rainwater, suppressing noise, and improving the urban environment^{9,10}. Within this concept, perennial mixtures based on native grasses, legumes, and herbaceous flowering species have been developed to tolerate drought, temperature fluctuations, nutrient-poor soils, and reduced maintenance while simultaneously supporting urban biodiversity.

Despite the increasing implementation of species-rich urban lawns, their long-term sustainability depends not only on their ecological adaptability but also on their health status. Urban vegetation is continuously exposed to numerous biotic stress factors, including pathogenic fungi capable of reducing plant vigor, biodiversity, and aesthetic quality. Diseases affecting grasses, legumes, and associated herbaceous species may impair ecosystem functioning, shorten the persistence of plant communities, and increase maintenance requirements^{11,12}. Climatic fluctuations, especially periods of prolonged drought followed by intensive rainfall, may further alter pathogen dynamics and disease severity in urban ecosystems.

⁶ Wiewióra B., Żurek G. Amenity grasses – a short insight into species, their applications and functions. *Agronomy*. 2023. T. 13. №. 4. P. 1164.

⁷ Ignatieva M. et al. Lawns in cities: from a globalised urban green space phenomenon to sustainable nature-based solutions. *Land*, 2020, 9, 73.

⁸ Parra L. et al. Evaluating the impact of natural products to improve the sustainability of urban lawns. *Cities*. 2024. T. 150. P. 105097.

⁹ Silnice železnice (2019). Zelená tramvajová trať = cirkulární ekonomika a přizpůsobení se klimatu = kolejový absorber hluku s funkcí retence vody BRENS STERED. Dostupné na: <http://www.silnice-zeleznice.cz/clanek/zelena-tramvajova-trat-cirkularni-ekonomika-a-prizpusobeni-se-klimatu-kolejovy-absorber-hluku-s-funkci-retence-vody-brens-stered/>

¹⁰ Tramvajová trať Divoká Šárka – Dědinská. URL: <https://mhd86.cz/2015/01/06/tramvajova-trat-divoka-sarka-dedinska/>

¹¹ Vargas J. M. Management of turfgrass Diseases. Boca Raton : CRC Press, 1994. 320 p.

¹² Miller Jr G. L. Turfgrass diseases. *Agrios' Plant Pathology. Academic Press*. 2024. P. 823–828.

Although diseases of conventional turfgrass have been extensively investigated^{13,14}, comparatively little attention has been devoted to phytopathological risks associated with species-rich urban grassland mixtures developed for sustainable landscaping. Similarly, information concerning the diversity of fungi colonizing native plant mixtures established along tramway green corridors remains scarce. Understanding the relationships between plant diversity, fungal communities, and disease incidence is therefore essential for developing resilient urban vegetation capable of maintaining both ecological functions and long-term stability^{15,16}.

The present study forms part of the project Genetic Resources for Cities and Landscape, conducted by the Czech Agrifood Research Center (CARC; formerly the Crop Research Institute), Prague, Czech Republic. The project aims to develop sustainable plant mixtures based on native grasses, legumes, and herbaceous species suitable for urban environments. Within this framework, several experimental grassland mixtures were established along Prague tramway corridors and evaluated under field conditions.

The objectives of this study were to assess the phytosanitary status of experimental urban lawn mixtures established in Prague, to identify fungal pathogens associated with individual plant species using phytopathological and mycological analyses, and to discuss the implications of phytopathological risks for the development of sustainable urban green infrastructure.

1. Materials and Methods

1.1. Study Area

The study was conducted within the framework of the Czech research project Genetic Resources for Cities and Landscape, which aims to develop sustainable plant mixtures suitable for modern urban environments. Field investigations were carried out during the 2022–2023 growing seasons at experimental sites established along tramway corridors in Prague, the capital city of the Czech Republic. Prague (50°05'N, 14°25'E) is located in the temperate climatic zone of Central Europe and is characterized by a humid continental climate with warm summers and cold winters. The city experiences increasing environmental pressures associated with urbanization, including elevated summer temperatures, prolonged drought periods, air pollution, and intensive

¹³ Hsiang T., Matsumoto N., Millett S. M. Biology and management of *Tiphula* snow mold of turfgrass. *Plant Disease*. 1999. V. 3. No 9. P. 788–798.

¹⁴ Miller Jr G. L. Turfgrass diseases. *Agrios' Plant Pathology*. Academic Press, 2024. P. 823–828.

¹⁵ Kiećana I., Cegiełko M., Mielniczuk E. Fungi occurred on turfgrasses in lawn maintenance. *Acta Scientiarum Polonorum. Hortorum Cultus*. 2015. T. 14. №. 3.

¹⁶ Wiewióra B., Żurek G. Amenity grasses – a short insight into species, their applications and functions. *Agronomy*. 2023. T. 13. №. 4. P. 1164.

anthropogenic disturbance, making it an appropriate model for evaluating the performance of species-rich urban vegetation.

Five experimental sites were selected in different parts of Prague to represent a range of urban conditions associated with tramway green corridors (Figure 1). Three sites (Sídliště Řepy, Spořilov, and Bělohorská) contained experimental plots established with low-growing flowering mixtures, tall flowering mixtures, and drought-tolerant mixtures. Two additional sites (Kubánské náměstí and the Tsiolkovského tramway extension between Vlastina and Dědina) were planted with optimized grass–legume–herb mixtures developed during the final phase of the project. The geographical distribution of the study sites enabled evaluation of vegetation performance under varying local environmental conditions, including differences in solar exposure, soil properties, and urban microclimate.

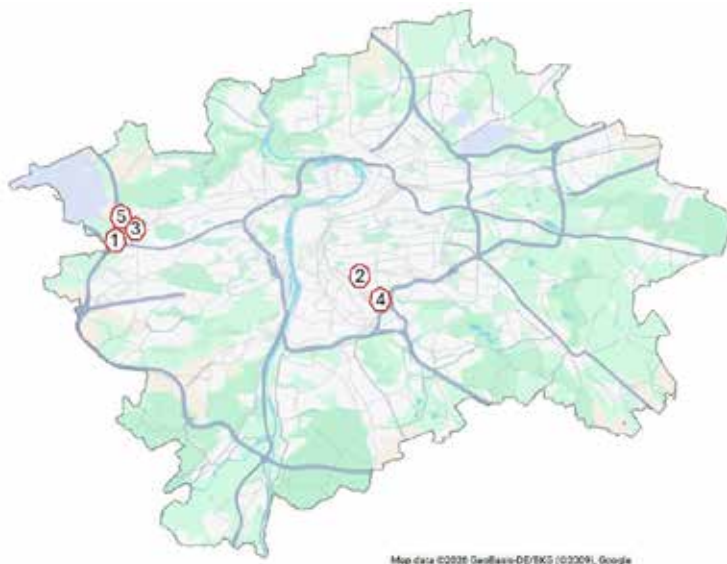


Fig. 1. Location of the experimental sites established along tramway corridors in Prague, Czech Republic. (1) Sídliště Řepy tram terminus; (2) Spořilov tram terminus; (3) Bělohorská tram stop (Prague-Břevnov); (4) Kubánské náměstí tram stop (Prague 10-Vršovice); and (5) Tsiolkovského tram stop between Vlastina and Dědina (Prague 6). Experimental plots included low-growing flowering mixtures, tall flowering mixtures, drought-tolerant mixtures, and optimized grass–legume–herb mixtures established for phytopathological evaluation under urban conditions

Tramway green corridors constitute an important component of Prague's urban green infrastructure. Beyond their aesthetic function, they provide multiple ecosystem services, including biodiversity conservation, mitigation of the urban heat island effect, stormwater infiltration, reduction of dust and noise, and improvement of the urban microclimate. Vegetation established in these corridors is subjected to a combination of abiotic and biotic stress factors, including heat stress, periodic drought, compacted soils, road-derived pollutants, and continuous exposure to naturally occurring plant pathogens. Consequently, tramway corridors represent an ideal environment for evaluating the establishment, persistence, and phytosanitary performance of species-rich lawn mixtures intended for sustainable urban landscaping.

1.2. Experimental Plant Mixtures

Three experimental perennial lawn mixtures were developed within the framework of the project to evaluate alternative approaches to sustainable urban landscaping: (i) a low-growing flowering mixture, (ii) a tall flowering mixture, and (iii) a drought-tolerant mixture. Following the evaluation of their establishment, persistence, and phytosanitary performance under urban conditions, an optimized grass–legume–herb mixture was subsequently developed using the best-performing species.

The mixtures were designed to establish ecologically stable, visually attractive, and low-maintenance vegetation suitable for tramway corridors and other urban green spaces. Species were selected according to their ecological adaptability, ornamental value, drought tolerance, persistence under urban conditions, and compatibility with multispecies plant communities. Particular emphasis was placed on the use of native genetic resources originating from different regions of the Czech Republic. Many of these species naturally occur in habitats characterized by drought, nutrient-poor soils, and other environmental stresses, making them well adapted to the challenging conditions of urban landscapes.

The low-growing flowering mixture consisted of 27 species, including 10 grasses (*Agrostis capillaris*, *Anthoxanthum odoratum*, *Festuca rubra* subsp. *trichophylla*, *Festuca rupicola*, *Helictochloa pratensis*, *Phleum bertolonii*, *Phleum phleoides*, *Poa compressa*, *Poa pratensis*, and *Trisetum flavescens*), three legumes (*Anthyllis vulneraria*, *Trifolium incarnatum*, and *Trifolium pratense*), and 14 perennial herbaceous species, including *Dianthus carthusianorum*, *Dianthus deltoides*, *Echium vulgare*, *Filipendula vulgaris*, *Leontodon autumnalis*, *Leontodon hispidus*, *Linaria vulgaris*, *Matricaria chamomilla*, *Origanum vulgare*, *Plantago lanceolata*, *Plantago media*, *Sanguisorba minor*, *Silene vulgaris*, and *Tragopogon pratensis*.

The tall flowering mixture comprised 22 species, including six grasses (*Brachypodium pinnatum*, *Briza media*, *Bromus erectus*, *Cynosurus cristatus*, *Koeleria pyramidata*, and *Trisetum flavescens*), four legumes (*Astragalus cicer*, *Medicago sativa*, *Onobrychis viciifolia*, and *Securigera varia*), and 12 perennial herbaceous species, including *Achillea ptarmica*, *Anchusa officinalis*, *Artemisia absinthium*, *Betonica officinalis*, *Carum carvi*, *Cichorium intybus*, *Echinops sphaerocephalus*, *Galium album*, *Galium verum*, *Hypericum perforatum*, *Sanguisorba officinalis*, and *Scabiosa ochroleuca*.

The drought-tolerant mixture included 27 species, comprising 12 grasses (*Agrostis capillaris*, *Bothriochloa ischaemum*, *Bromus erectus*, *Festuca filiformis*, *Festuca pallens*, *Festuca rupicola*, *Festuca valesiaca*, *Helictochloa pratensis*, *Melica transsilvanica*, *Phleum bertolonii*, *Poa compressa*, and *Stipa capillata*), five legumes (*Anthyllis vulneraria*, *Lotus corniculatus*, *Medicago lupulina*, *Trifolium incarnatum*, and *Trifolium repens*), and ten perennial herbaceous species (*Achillea millefolium*, *Cichorium intybus*, *Dianthus carthusianorum*, *Plantago lanceolata*, *Plantago media*, *Potentilla argentea*, *Ranunculus bulbosus*, *Sanguisorba minor*, *Thymus pulegioides*, and *Tragopogon pratensis*).

Although the botanical composition differed among the three mixtures, all were designed according to the same ecological principles: the combination of perennial grasses providing structural stability, nitrogen-fixing legumes improving soil fertility, and flowering herbaceous species enhancing biodiversity, ornamental value, and ecological resilience. This multispecies approach was intended to create self-sustaining urban vegetation capable of tolerating drought, low soil fertility, and other environmental stresses while requiring only minimal maintenance.

1.3. Phytopathological Monitoring

Field observations were conducted throughout the 2022–2023 growing seasons, with particular emphasis on periods favorable for the development of fungal diseases. Experimental plots were inspected regularly to evaluate the phytosanitary status of all plant species included in the lawn mixtures. Visual assessments focused on the occurrence of disease symptoms, including leaf spots, chlorosis, necrosis, powdery mildew, anthracnose, stem lesions, wilting, and other abnormalities indicative of pathogen infection.

Plants exhibiting visible disease symptoms were photographed, documented, and collected for subsequent laboratory examination. Representative samples of symptomatic grasses, legumes, and herbaceous species collected during field surveys are shown in Figure 2. The collected material served as the basis for phytopathological diagnosis and mycological isolation of fungal species associated with naturally occurring infections.



Fig. 2. Representative plant samples collected from experimental species-rich lawn mixtures during phytopathological monitoring. Symptomatic grasses, legumes, and herbaceous species were sampled for laboratory diagnosis and mycological analysis

Disease incidence was evaluated for all botanical groups to compare their susceptibility to naturally occurring fungal infections under urban environmental conditions. Particular attention was paid to differences in disease occurrence among grasses, legumes, and herbaceous flowering species, as well as to the distribution and severity of symptoms within the experimental mixtures. No fungicides or other plant protection treatments were applied during the study, allowing the assessment of disease development under natural field conditions.

1.4. Mycological Analysis

Plant samples exhibiting disease symptoms were transported to the laboratory for mycological examination immediately after collection^{17,18}. Leaf, stem, and other infected tissues were processed according to standard phytopathological procedures. Following surface sterilization, tissue fragments were aseptically transferred onto potato dextrose agar (PDA) supplemented with antibiotics to suppress bacterial contamination. Representative plant samples cultured on PDA prior to fungal isolation are shown in Figure 3.

The inoculated Petri dishes were incubated under controlled laboratory conditions until fungal colonies developed. Emerging colonies were examined regularly, and morphologically distinct isolates were subcultured to obtain pure cultures for subsequent identification.

Fungal isolates were identified on the basis of colony morphology and microscopic characteristics using standard taxonomic keys and diagnostic

¹⁷ Watanabe, T. Pictorial Atlas of Soil and Seed Fungi; CRC Press: Boca Raton, FL, USA, 2002. 504 p. [CrossRef]

¹⁸ Seifert, K. A., Morgan-Jones, G. A., Gams, W.; Kendrick, B. The Genera of Hyphomycetes; CBS Biodiversity (Series 10); CBS Fungal Diversity Centre: Utrecht, The Netherlands, 2011. 997 p.

manuals. Identification focused primarily on fungi associated with foliar diseases, anthracnose, powdery mildew, stem lesions, and other diseases affecting grasses, legumes, and herbaceous flowering species. Whenever more than one fungal taxon was isolated from a single host, each isolate was recorded separately to characterize the diversity of the fungal community associated with symptomatic plants.

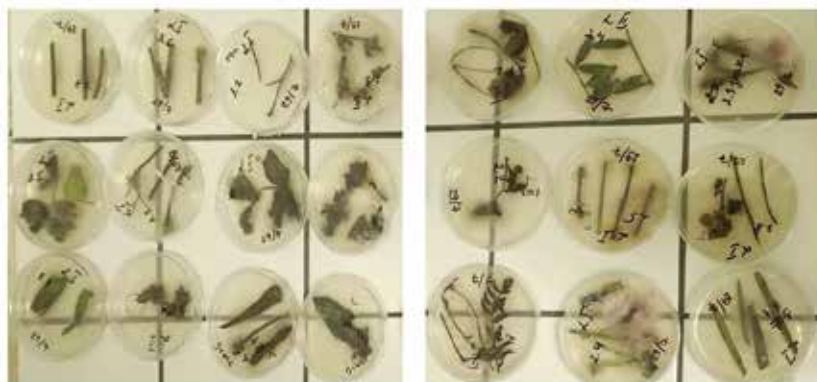


Fig. 3. Representative symptomatic plant samples cultured on potato dextrose agar (PDA) for the isolation of fungi associated with species-rich urban lawn mixtures

1.5. Data Evaluation

The results were evaluated using a descriptive comparative approach, with emphasis on the phytosanitary status of the experimental lawn mixtures, disease incidence among different botanical groups, and the diversity of fungi associated with symptomatic plants. Comparative analyses focused on differences in susceptibility among grasses, legumes, and herbaceous flowering species, as well as on the composition and frequency of fungal taxa isolated from infected plant material.

The identified fungi were grouped according to their taxonomic affiliation and ecological role, enabling comparison of fungal communities associated with the different experimental mixtures. Particular attention was given to the occurrence of the principal phytopathogenic fungi affecting urban lawn vegetation and their distribution among host species.

The results are presented in the following sections using descriptive text supported by photographs and graphical summaries illustrating disease symptoms, fungal diversity, and the comparative phytosanitary performance of the experimental lawn mixtures.

2. Results

2.1. General Health of Experimental Lawns

Phytopathological monitoring conducted during the 2022–2023 growing seasons demonstrated that the experimental species-rich lawn mixtures established at the Prague study sites maintained a generally satisfactory phytosanitary status throughout the observation period. Despite continuous exposure to typical urban environmental stressors, including elevated summer temperatures, periodic soil moisture deficits, atmospheric pollution, and intensive anthropogenic influence, the experimental vegetation established successfully and retained both its ecological functionality and ornamental value.

Most investigated plant species exhibited vigorous growth, good adaptation to local environmental conditions, and no visible signs of serious disease. Throughout the study period, no widespread disease outbreaks or extensive plant mortality were recorded. Disease symptoms, when observed, were generally localized and affected individual plants or species rather than entire plant communities. Consequently, the overall structure, species diversity, and visual quality of the experimental lawns remained stable.

Clear differences in phytosanitary performance were observed among the botanical groups included in the experimental mixtures. Grasses exhibited the highest level of resistance and remained largely free of visible disease symptoms during field observations. In contrast, several leguminous species and, to a lesser extent, some herbaceous flowering plants showed symptoms of fungal diseases, including powdery mildew, anthracnose, and leaf spot diseases. Nevertheless, disease incidence remained low, and infections did not significantly reduce plant vitality, persistence, or competitive ability within the plant communities.

The optimized grass–legume–herb mixture established during the final phase of the project demonstrated particularly good adaptation to urban conditions. The vegetation established rapidly, maintained a balanced species composition, and exhibited only isolated cases of disease throughout the monitoring period. These observations indicate that careful selection of plant species can enhance both the ecological stability and phytosanitary performance of species-rich urban lawns.

Overall, the results demonstrate that perennial mixtures composed of native grasses, legumes, and herbaceous flowering species can maintain good phytosanitary status under challenging urban conditions. The absence of severe disease outbreaks indicates that diverse plant communities are capable of providing stable, resilient, and aesthetically valuable vegetation suitable for sustainable urban green infrastructure. These findings provide the basis for the more detailed evaluation of disease incidence and fungal diversity presented in the following sections.

2.2. Disease Incidence among Plant Groups

The incidence and severity of diseases differed considerably among the botanical groups included in the experimental lawn mixtures, reflecting differences in host susceptibility under urban environmental conditions. Although all mixtures were exposed to similar climatic and anthropogenic stress factors, the occurrence and severity of disease symptoms varied markedly among grasses, legumes, and herbaceous flowering species.

Grasses exhibited the highest level of phytosanitary stability throughout the monitoring period. Most grass species remained free from visible disease symptoms and maintained normal growth and development during both growing seasons. Only isolated cases of minor leaf lesions were observed, and these had no measurable effect on plant vitality or the ornamental quality of the experimental lawns. The generally high resistance of grasses contributed substantially to the long-term stability of the species-rich plant communities.

In contrast, leguminous species proved to be the most susceptible botanical group. Powdery mildew caused by *Erysiphe trifolii* was the most frequently observed disease, particularly on *Trifolium incarnatum* and *Trifolium pratense* during the 2022 growing season. Characteristic white superficial mycelial colonies developed on infected leaves, reducing the photosynthetically active surface and impairing the aesthetic appearance of affected plants. In addition, anthracnose symptoms associated with *Colletotrichum* spp. were recorded on several clover plants, where they appeared as necrotic lesions affecting leaves and petioles. Representative symptoms of both diseases observed during field monitoring are presented in Figure 4.



Fig. 4. Representative symptoms of powdery mildew caused by *Erysiphe trifolii* (upper left and lower left) and anthracnose caused by *Colletotrichum* spp. (right) on clover (*Trifolium* spp.) leaves collected from the experimental lawn mixtures

Besides clover species, symptoms of anthracnose and leaf spot diseases were also observed on several other legumes, including *Medicago sativa*, *Medicago lupulina*, *Onobrychis viciifolia*, and *Securigera varia*. Although symptom expression varied among host species, infections generally remained localized and did not spread extensively within the experimental plots.

Disease symptoms were less frequent among the herbaceous flowering species and were usually restricted to individual plants. Occasional leaf spots, necrotic lesions, and minor tissue discoloration were recorded on *Achillea millefolium*, *Betonica officinalis*, *Cichorium intybus*, and *Silene vulgaris*. Despite these symptoms, the affected plants maintained satisfactory growth and continued to contribute to the structural diversity and ecological value of the lawn mixtures.

Overall, disease incidence remained low across all experimental sites. Differences in susceptibility were associated primarily with plant taxonomic group and host species rather than with the geographical location of the experimental plots. These findings indicate that plant species composition is one of the principal factors influencing the phytosanitary performance of species-rich urban lawns and should therefore be carefully considered when designing resilient vegetation mixtures for sustainable urban green infrastructure.

2.3. Diversity of Fungal Species Associated with Experimental Lawn Mixtures

Laboratory mycological analyses revealed a diverse assemblage of fungi associated with symptomatic plants collected from the experimental lawn mixtures. The recovered isolates comprised phytopathogenic fungi together with saprotrophic and opportunistic species that naturally occur in urban grassland ecosystems. These fungi were associated with a broad spectrum of symptoms, including leaf spots, anthracnose, stem lesions, powdery mildew, and other foliar diseases, reflecting the complexity of fungal communities colonizing species-rich urban vegetation.

Representative symptomatic plant tissues collected during field monitoring and cultured on potato dextrose agar (PDA) are shown in Figure 5. Incubation of infected plant material enabled the isolation of fungal colonies that were subsequently purified and identified using morphological and microscopic characteristics.

Mycological examination identified numerous fungal taxa belonging to both phytopathogenic and saprotrophic groups. The most frequently isolated genera included *Alternaria*, *Fusarium*, *Colletotrichum*, *Cladosporium*, *Stemphylium*, *Nigrospora*, *Epicoccum*, *Volutella*, and *Cymadothea*, together with a range of

less frequently occurring fungi. Powdery mildew caused by *Erysiphe trifolii* represented the most conspicuous disease observed under field conditions, whereas *Colletotrichum* spp. were associated with anthracnose symptoms affecting several leguminous species.



Fig. 5. Isolation of fungi from symptomatic plant tissues collected from experimental species-rich lawn mixtures. Representative samples cultured on potato dextrose agar (PDA) prior to fungal identification

Representative microscopic structures of the principal fungal genera identified during the investigation are presented in Figure 6. The considerable variation in colony morphology, conidial shape, pigmentation, and reproductive structures illustrates the taxonomic diversity of fungi associated with the investigated urban lawn vegetation and confirms the reliability of the morphological identification.

The composition of fungal communities differed among the investigated host plants. Leguminous species supported the richest assemblage of fungi, whereas grasses were colonized predominantly by fungi exhibiting relatively low pathogenic activity. Herbaceous flowering species showed an intermediate level of fungal occurrence. Despite the wide taxonomic spectrum of recovered fungi, infections generally remained localized and were not associated with substantial deterioration of plant vitality or the ornamental quality of the lawn communities.

The frequency of occurrence of individual fungal genera isolated during the two-year investigation is summarized in Figure 7. *Alternaria*, *Fusarium*, and *Cladosporium* were among the most frequently detected genera in both growing seasons, while *Epicoccum*, *Stemphylium*, *Nigrospora*, and several other fungi occurred regularly but at lower frequencies. In contrast, genera such as

Volutella, *Sordaria*, and *Trichotecium* were detected only occasionally. Besides phytopathogenic fungi, isolates belonging to saprotrophic and potentially antagonistic genera, including *Trichoderma*, *Chaetomium*, and *Gliocladium*, were also recovered. The coexistence of fungi with different ecological functions reflects the complexity of the microbial communities inhabiting species-rich urban lawns.

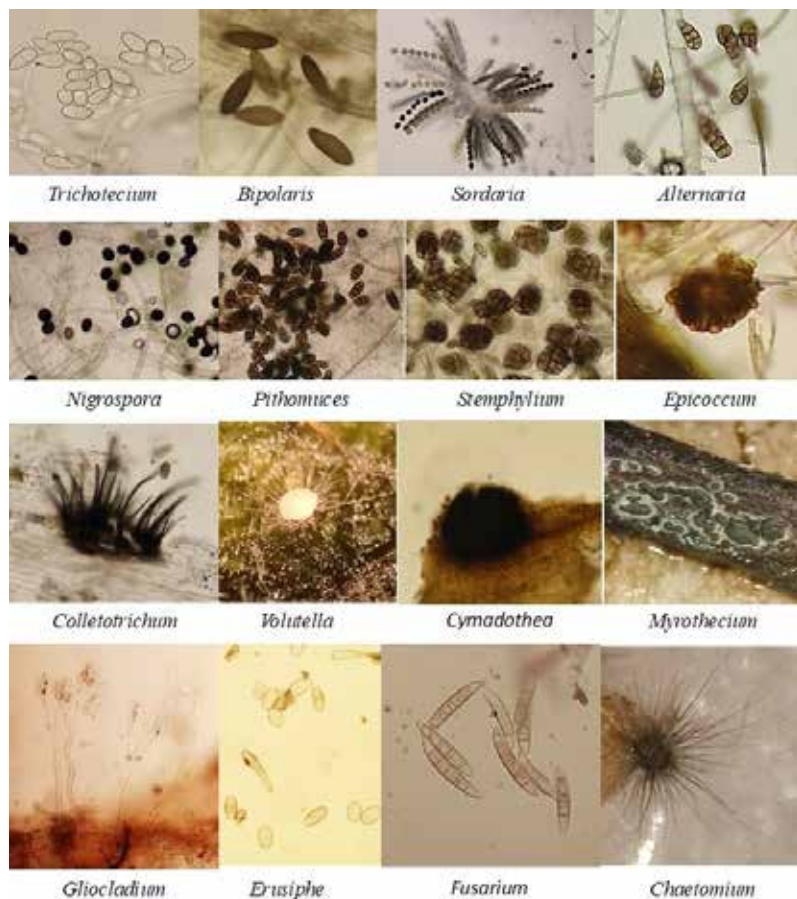


Fig. 6. Representative microscopic structures of selected fungal genera isolated from symptomatic plant tissues collected from experimental lawn mixtures in Prague during the 2022–2023 growing seasons

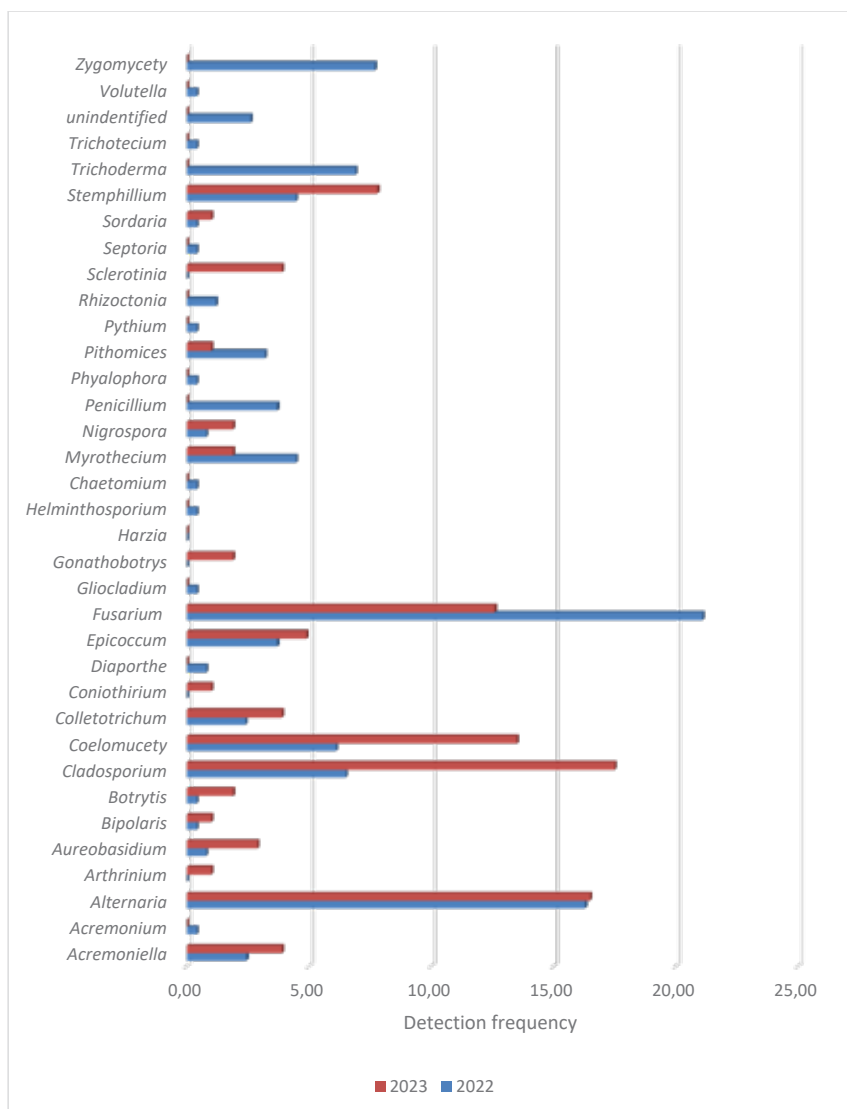


Fig. 7. Frequency of occurrence of fungal genera isolated from experimental species-rich lawn mixtures in Prague during the 2022–2023 growing seasons

Overall, the recovered fungal community represents the natural mycobiota associated with species-rich urban lawns under Central European conditions. Although fungal diversity was relatively high, disease severity remained low throughout the study, indicating that diverse perennial plant communities can maintain satisfactory phytosanitary stability despite the presence of numerous fungal taxa. These findings suggest that increasing plant diversity does not necessarily increase disease risk and further support the use of species-rich lawn mixtures as resilient components of sustainable urban green infrastructure.

2.4. Comparison among Experimental Mixtures

Comparative evaluation of the experimental lawn mixtures demonstrated clear differences in phytosanitary performance, reflecting the influence of botanical composition on disease susceptibility and overall vegetation stability. Although all mixtures were established under comparable environmental conditions and exposed to similar climatic and anthropogenic stress factors, their response to naturally occurring fungal infections differed according to the proportion of grasses, legumes, and herbaceous flowering species.

The low-growing flowering mixture exhibited the highest incidence of disease symptoms, primarily due to the greater susceptibility of clover species to powdery mildew caused by *Erysiphe trifolii*. Although infected plants developed characteristic white mycelial colonies on leaves during periods favorable for disease development, infections remained localized and did not spread throughout the plant community. Consequently, neither the ecological integrity nor the visual quality of the mixture was substantially affected.

The tall flowering mixture was characterized mainly by localized leaf spot diseases and anthracnose affecting several leguminous species. Fungal infections associated with *Colletotrichum*, *Alternaria*, and *Ascochyta* spp. occurred more frequently than in the other mixtures; however, disease severity remained low and had little influence on plant growth, species composition, or community stability.

Among the investigated mixtures, the drought-tolerant mixture demonstrated the highest level of phytosanitary stability. Disease symptoms occurred only sporadically despite prolonged exposure to elevated temperatures, limited soil moisture, and periodic drought. The predominance of drought-adapted grasses and perennial herbaceous species contributed to the resilience of this vegetation type and reduced the overall incidence of fungal diseases.

During the final phase of the project, an optimized grass–legume–herb mixture was developed using the best-performing species identified during field evaluation. Information panels installed at the experimental sites informed the public about the objectives and composition of the three experimental mixtures,

illustrating the practical application of the research within Prague's urban green infrastructure (Figure 8).



Fig. 8. Information panels describing the experimental low-growing flowering, tall flowering, and drought-tolerant lawn mixtures established along Prague tramway corridors as part of the project Genetic Resources for Cities and Landscape

The optimized mixture showed excellent adaptation to urban conditions, combining rapid establishment, balanced species composition, and consistently satisfactory phytosanitary status throughout the monitoring period. Only isolated disease symptoms were observed, indicating that careful selection of compatible species can substantially improve both ecological stability and resistance to naturally occurring fungal infections.

The long-term success of the optimized vegetation is illustrated in Figure 9, which shows a mature species-rich lawn established along the Tšiolkovského tramway extension in Prague. Several years after sowing, the vegetation had developed into a dense, visually attractive, and stable perennial community with a satisfactory phytosanitary condition despite continuous exposure to urban environmental stress.

The comparative evaluation indicates that species composition is one of the principal factors influencing disease development in species-rich urban lawns. Mixtures containing a higher proportion of susceptible leguminous species tended to support greater fungal diversity and higher disease incidence, whereas mixtures dominated by well-adapted grasses and drought-tolerant perennial species exhibited greater resistance to fungal infections. Nevertheless, none of the experimental mixtures experienced disease outbreaks severe enough to impair vegetation establishment, reduce biodiversity, or compromise long-term persistence under urban conditions.

Overall, all investigated mixtures fulfilled the phytosanitary requirements for sustainable urban landscaping, although their performance differed according to botanical composition. The drought-tolerant and optimized mixtures demonstrated the greatest resilience, whereas the low-growing flowering mixture required more careful consideration of susceptible leguminous species

during mixture design. These findings demonstrate that appropriately selected species-rich lawn mixtures can provide durable, biodiverse, and phytosanitarily stable vegetation suitable for modern urban green infrastructure and form the basis for the broader ecological interpretation presented in the following Discussion.

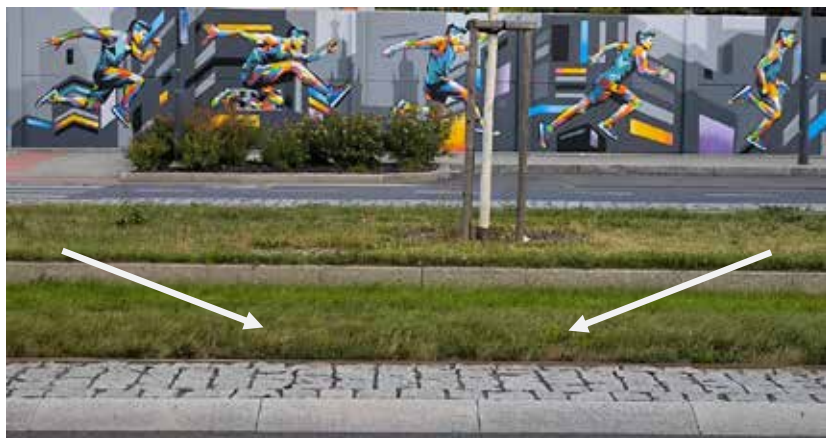


Fig. 9. Established species-rich lawn along the Tsiolkovského tramway extension, Prague, demonstrating successful long-term adaptation and satisfactory phytosanitary performance under urban conditions (summer 2026)

3. Discussion

The present study demonstrates that species-rich urban lawn mixtures composed of native grasses, legumes, and herbaceous flowering plants can maintain satisfactory phytosanitary status under the challenging environmental conditions of a large metropolitan area. Despite continuous exposure to urban stressors, including elevated summer temperatures, periodic soil moisture deficits, atmospheric pollution, and intensive anthropogenic disturbance, the experimental vegetation remained healthy throughout the monitoring period. No severe disease outbreaks or extensive plant mortality were recorded, indicating that species-rich urban lawns can combine ecological functionality with long-term phytosanitary stability^{19,20}.

¹⁹ Ignatieva M. et al. Lawns in cities: from a globalised urban green space phenomenon to sustainable nature-based solutions. *Land* 2020, 9, 73.

²⁰ Wiewióra B., Żurek G. Amenity grasses—a short insight into species, their applications and functions. *Agronomy*. 2023. T. 13. №. 4. P. 1164.

These findings support the growing recognition that increasing plant diversity enhances the resilience of urban green infrastructure²¹. Compared with conventional species-poor turfgrass, diverse perennial plant communities provide greater ecological stability by reducing the dominance of susceptible host species, improving resource utilization, and increasing resistance to both abiotic and biotic stress²². Similar relationships between plant diversity and ecosystem resilience have been reported for natural and semi-natural grasslands, where greater species richness is associated with improved resistance to pests, diseases, and environmental disturbances.

One of the most consistent findings of this study was the difference in disease susceptibility among botanical groups. Grasses remained largely free from visible disease symptoms throughout the monitoring period, whereas leguminous species exhibited greater susceptibility to powdery mildew, anthracnose, and leaf spot diseases^{23,24}. These observations agree with previous studies demonstrating that legumes generally support a more diverse community of fungal pathogens than grasses because of differences in host physiology, canopy structure, and species-specific host–pathogen interactions²⁵.

Although laboratory analyses revealed a diverse assemblage of fungi associated with symptomatic plants, most taxa occurred at relatively low frequencies and caused only localized infections. Importantly, the recovered fungal community comprised not only phytopathogenic fungi but also saprotrophic and potentially antagonistic species^{26,27}. The coexistence of these ecological groups indicates that species-rich urban lawns support complex microbial communities that may contribute to the natural regulation of plant diseases through competition, niche occupation, and other ecological interactions. Consequently, high fungal diversity should not necessarily be interpreted as an increased phytopathological risk.

A particularly important practical outcome of the study was the successful long-term establishment of the experimental lawn mixtures along Prague

²¹ Aronson M. F. J. et al. Biodiversity in the city: key challenges for urban green space management. *Frontiers in Ecology and the Environment*. 2017. T. 15. №. 4. P. 189–196.

²² Stewart G. H. et al. Urban Biotopes of Aotearoa New Zealand (URBANZ)(I): composition and diversity of temperate urban lawns in Christchurch. *Urban Ecosystems*. 2009. T. 12. №. 3. P. 233–248.

²³ Kobes M. et al. The occurrence of *Erysiphe trifolii* on *Lathyrus pratensis* in a foothill area of South Bohemia. *Journal of Agrobiology*. 2011. T. 28. №. 1. P. 25.

²⁴ Kiecana I., Cegiello M., Mielniczuk E. Fungi occurred on turfgrasses in lawn maintenance. *Acta Scientiarum Polonorum. Hortorum Cultus*. 2015. T. 14. №. 3.

²⁵ Simon U. K., Groenewald J. Z., Crous P. W. *Cymadothea trifolii*, an obligate biotrophic leaf parasite of *Trifolium*, belongs to *Mycosphaerellaceae* as shown by nuclear ribosomal DNA analyses. *Persoonia-Molecular Phylogeny and Evolution of Fungi*. 2009. T. 22. №. 1. P. 49–55.

²⁶ Watanabe, T. Pictorial Atlas of Soil and Seed Fungi; CRC Press: Boca Raton, FL, USA, 2002. 504 p.

²⁷ Seifert, K. A., Morgan-Jones, G. A., Gams, W., Kendrick, B. The Genera of Hyphomycetes; CBS Biodiversity (Series 10); CBS Fungal Diversity Centre: Utrecht, The Netherlands, 2011. 997 p.

tramway corridors. The comparison between newly established vegetation and mature perennial stands demonstrated that carefully designed species-rich mixtures can develop into stable, visually attractive, and phytosanitarily healthy plant communities under intensive urban conditions. These findings confirm that tramway corridors can function not only as transportation infrastructure but also as valuable components of urban green infrastructure, contributing to biodiversity conservation, climate-change adaptation, and the improvement of urban environmental quality²⁸.

From a practical perspective, the results indicate that careful selection of compatible native grasses, legumes, and perennial herbaceous species is essential for developing resilient urban lawns. Regular phytopathological monitoring remains an important management tool for the early detection of emerging diseases; however, the low disease incidence observed throughout the study suggests that well-designed species-rich lawns can be maintained with minimal reliance on fungicides. This approach is consistent with current principles of sustainable urban landscaping and integrated plant protection.

Although the present investigation was limited to experimental sites within Prague and covered two consecutive growing seasons, the results provide valuable evidence supporting the wider application of species-rich lawn mixtures in urban environments. Further long-term studies conducted under different climatic conditions would improve our understanding of the interactions among vegetation diversity, fungal communities, and environmental stress in urban ecosystems.

Overall, the findings demonstrate that species-rich lawn mixtures based on native plant species represent a sustainable alternative to conventional urban turfgrass. Their ability to maintain biodiversity, satisfactory phytosanitary status, and long-term ecological stability supports their wider use in tramway corridors, public parks, residential areas, and other multifunctional urban green spaces. The integrated approach adopted in this study, combining field phytopathological monitoring with laboratory mycological diagnostics, provides a practical framework for evaluating the health and resilience of urban grassland ecosystems.

CONCLUSIONS

The present study demonstrated that species-rich urban lawn mixtures based on native grasses, legumes, and herbaceous flowering plants can maintain satisfactory phytosanitary status under the environmental conditions of a large

²⁸ Winkler J. et al. Green space in an extremely exposed part of the city center «Aorta of Warsaw» – Case study of the urban lawn. *Urban Ecosystems*. 2023. T. 26. №. 5. P. 1225–1238.

metropolitan area. Despite continuous exposure to multiple urban stress factors, disease incidence remained generally low, confirming the suitability of these mixtures for sustainable urban landscaping.

The investigation revealed clear differences in disease susceptibility among botanical groups. Grasses exhibited the highest phytosanitary stability, whereas leguminous species were more frequently affected by fungal diseases, particularly powdery mildew and anthracnose. Laboratory mycological analyses demonstrated that the experimental lawns supported a diverse assemblage of fungi; however, most infections remained localized and did not compromise the ecological stability or visual quality of the vegetation.

Overall, the results confirm that appropriately designed species-rich lawn mixtures represent a resilient and environmentally sustainable alternative to conventional urban turfgrass. The integration of phytopathological monitoring with mycological diagnostics provides valuable information for the management of urban green infrastructure and supports the long-term development of biodiverse, low-maintenance, and climate-resilient urban landscapes.

SUMMARY

Urban green infrastructure plays an increasingly important role in sustainable city development by improving environmental quality, mitigating climate change impacts, supporting biodiversity, and enhancing human well-being. Species-rich urban lawns composed of grasses, legumes, and herbaceous flowering plants are increasingly used as sustainable alternatives to conventional turfgrass because they require lower maintenance while providing a wide range of ecosystem services. However, the long-term sustainability of these vegetation communities depends not only on appropriate species selection and adaptation to urban environments but also on their phytosanitary condition and resistance to plant pathogens. This chapter presents the results of a comprehensive phytopathological assessment of experimental species-rich lawn mixtures established along tramway corridors in Prague, Czech Republic, within the framework of the project *Genetic Resources for Cities and Landscape*. Field phytopathological monitoring and laboratory mycological analyses were conducted to evaluate disease incidence, compare the health status of grasses, legumes, and herbaceous species, and identify fungal taxa associated with naturally occurring infections under urban conditions. The experimental lawns maintained a generally satisfactory phytosanitary status throughout the monitoring period despite exposure to multiple abiotic and biotic stress factors. Disease symptoms occurred predominantly on leguminous species, whereas grasses exhibited substantially greater resistance to fungal infections. Mycological analyses revealed a diverse assemblage of fungi,

including representatives of the genera *Alternaria*, *Fusarium*, *Colletotrichum*, *Ascochyta*, *Stemphylium*, *Nigrospora*, and several others. Although numerous fungal taxa were identified, most infections remained localized and did not compromise the stability, biodiversity, or aesthetic quality of the experimental vegetation. The results demonstrate that appropriately designed species-rich lawn mixtures based on native plant species combine high ecological value with satisfactory phytosanitary performance and are well suited for sustainable urban landscaping. The integration of field phytopathological monitoring with laboratory mycological diagnostics provides a reliable framework for evaluating the health and long-term resilience of species-rich urban lawns and supports evidence-based management of multifunctional urban green infrastructure under changing environmental conditions.

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