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Review article

Management of fungal diseases of *Platanus* under changing climate conditions: Case studies in urban areas

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ABSTRACT

Platanus species, especially *Platanus* × *hispanica* (London plane), play a key role in urban areas due to their ecological, social and aesthetic value. These trees are widely planted along roadsides, in parks and historical gardens, providing shade, reducing air pollution and enhancing the aesthetic appeal of cities all over the world. Known for their resilience to abiotic factors and rapid growth, these trees are vulnerable to pests and diseases, exacerbating urban plant health challenges. While the EU Phytosanitary Regulation aims to control the spread of plant diseases, many pathogens fall outside its scope. Although many of these pathogens are not devastating, they still require continuous management by authorities or private owners. This paper focuses on disease managment guidelines for *Ceratocystis platani*, the only EU regulated fungal disease affecting plane trees, and other pathogens, *Apiognomonia platani*, *Macrodiplodiopsis desmazieri* and *Erysiphe platani*, which compromise the ecosystem services provided by *Platanus* trees and impact human health and safety.

1. Introduction

The urban forest provides environmental, economic and social values among others, and is highly beneficial to the life of the city inhabitants. In cities, healthy trees contribute to human well-being by mitigating temperature extremes (Esperon-Rodriguez et al., 2021), improving air quality (Nowak et al., 2014; Ren et al., 2023), and also reducing energy consumption (McDonald et al., 2020). As urban areas continue to expand, the importance of integrating green spaces, such as parks, gardens and tree-lined streets, has been increasingly recognised for enhancing the quality of life for residents, due to the ecosystem services provided by plants. However, with the rise of urban greenery comes a growing concern: plant diseases. Urban environments, with their unique challenges and conditions, represent a fertile ground for the establishment, spread and exacerbation of plant diseases. The close proximity among urban plants allows pathogens to move rapidly from one host to another, leading to widespread infection. Moreover, urban plants are frequently subjected to different environmental stressors, including pollution, soil compaction, poor irrigation and heat island effects (Leal Filho et al., 2018; Percival, 2023; Piana et al., 2019). These stressors can weaken plants, making them more susceptible to diseases, especially if they are non-native species. In addition, many clonal selections of trees are planted in urban areas, resulting in large numbers of individual plants being susceptible to damage from pests and diseases. In the last century, new planting programs in towns and cities globally led to the introduction of ornamentals, often non-native tree species. Urban settings serve as junctions of international trade and plantings of imported nursery stock. Unfortunately, plant trade is well known as one of the main pathways for the introduction of invasive alien species (Antonelli et al., 2023; Marshall et al., 2021), due to the presence of asymptomatic plants that may harbor latent pathogens in their roots, or epigeal tissues and in the growing substrate used (Antonelli et al., 2023; Laurence et al., 2024). The use of non-native plant species can affect their resilience to site conditions, leading to a higher susceptibility to abiotic and biotic stresses. The consequences of the presence of plant diseases in urban green spaces range from reduced aesthetic appeal and

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psychological impacts, to economic and environmental impacts (Antonelli et al., 2024; Tabassum et al., 2024; Tubby and Pérez-Sierra, 2015).

Extensive research has focused on creating and applying effective strategies to prevent and control introduced pests and pathogens that impact urban and forest trees. In some cases, the results have been integrated into decision-making and the implementation of management practices for disease control. The most recent phytosanitary regulation [(EU) 2016/2031)] is an attempt to present comprehensive defense systems to reduce the spread of specific plant diseases, by combining strict import regulations, post-entry quarantine, movement controls, and specific scientific data, pest risk analysis, impact assessment and survey results. Plants can also harbor other plant pests and pathogens in addition to those considered in EU regulations, which although not devastating, require continuous management by local authorities or private owners, hereinafter referred to as common, not-devastating pathogens (CDP).

The aim of this paper was to identify practices and challenges in prevention and effective management of fungal CDP, which, although not necessarily causing devastating infections, represent the major issues in urban environments, associated with plane trees (*Platanus* spp.). This tree genus has been chosen as a model plant, because it has become an integral part of many international metropolises, particularly along roadsides and historical and botanical gardens. *Platanus orientalis*, the oriental plane tree, stands out for its significant contributions to urban areas, from the Caucasus to the Mediterranean regions. It has been particularly appreciated since Greek and Roman times and throughout the Renaissance (Tsopelas et al., 2017; Ciaffi et al., 2018; Rosati et al., 2015) for the generous shade provided by its large leaves. Over the past three centuries, *P.* x *hispanica* (formerly *P.* x *acerifolia*), a natural hybrid between *P. orientalis* and *P. occidentalis*, has been extensively planted as an ornamental tree due to the multitude of ecological, social and practical benefits provided (Yang et al., 2005; Wang and Tu, 2023). *Platanus* × *hispanica* is one of the few tree genera present in 15 Italian cities chosen along a geographical and bioclimatic gradient (Bartoli et al., 2022), planted for its rapid growth and relative resistance to diseases.

2. Main diseases of *Platanus* in urban areas

Plane trees are appreciated for their adaptability and resilience in urban environments including their ability to tolerate air and pollution run-off, poor soil conditions and drought. However, they can be damaged by roads salt applications and are susceptible to a range of pathogens and pests that can significantly impact their health (Antonelli et al., 2024; Derviş et al., 2020). This study focuses on some of the most noteworthy pathogens affecting plane trees in Europe.

Among biotic stressors, the Ascomycota *Ceratocystis platani* (J.M. Walter) Engelbr. & T.C. Harr. stands out as a major pathogen, responsible for causing a lethal vascular wilt named "canker stain disease" (Fig. 1). The pathogen enters the host through wounds or via root anastomosis and spreads through the vascular system, leading to canopy decline, the formation of characteristic cankers on stems and tree mortality (Tsopelas et al., 2017). As an example of the destructive capacity of the pathogen, it is worth noting that in just over twenty years, it led to the death of 90 % of plane trees in the Italian town of Forte dei Marmi (Panconesi, 1977; Panconesi, 1972). *Ceratocystis platani* remains a critical concern, and is regulated as a harmful organism in the EU by the Commission Implementing Regulations EU, 2019/2072 and 2022/1629 (https://eur-lex.europa.eu/eli/reg_impl/2022/1629/oj), which establish measures for its containment within certain demarcated areas (Brunetti et al., 2022; Luchi et al., 2013; Pilotti et al., 2012). The pathogen is also on the EPPO A2 list of quarantine organisms (EU, 2019/2072; OEPP/EPPO, 1986, 2003, 2014).

The health of *Platanus* is further compromised by other fungal pathogens (Antonelli et al., 2024; Derviş et al., 2020; Scattolini Rimada et al., 2023; Tubby and Pérez-Sierra, 2015). This study is focused on *Apiognomonia platani* (Lév.) L. Lombard, agent of plane anthracnose, *Macrodiplodiopsis desmazieri* (Mont.) Petr. 1922, causal agent of *Massaria* disease, and *Erysiphe platani* (Howe) U. Braun & S. Takam (Pastirčáková et al., 2014), agent of powdery mildew (Fig. 1). These three pathogens do not cause the sudden death of the tree, as in the case of canker stain disease, but they seriously alter the stability of the branches and compromise the photosynthetic activities of leaves (Tubby and Pérez-Sierra, 2015; Kliuchevych et al., 2021). These diseases undermine the ecosystem services provided by plane trees and put public health at risk due to the potential for falling branches.

3. Challenges for growing healthy *Platanus* trees

3.1. Risk-based choices for Platanus planting

Due to the role of trees in the urban landscape, species selection should consider aesthetic, historical, physical, biological and functional factors (Wang and Tu, 2023).

The frequency and intensity of heat stress events have increased globally over the past 20 years (Percival, 2023). Rises in air temperature due to climate change are exacerbated in urban, compared to rural, areas by the heat island effect. Usually, in a temperate climate, this effect will have some benefits in cooler seasons, while in summer it will intensify heat stress and energy used for cooling (Zhao et al., 2023; Watkins et al., 2007). Nevertheless, several studies showed how urban design changes can improve thermal comfort (Zhao et al., 2023). The climate in cities where trees grown has a significant impact on their cooling potential (Rahman et al., 2020). In particular, the density of tree canopies was clearly identified as the most influential factor amongst the different cooling mechanisms (Yin et al., 2024). On the other hand, trees growth and ecosystem services provision strongly depend on temperature and adequate precipitation (Poschenrieder et al., 2022).

Platanus is rather resilient to drought periods due to the ability to mitigate heat stress through morphological and physiological responses, such as transpiration-induced cooling (Bowden and Bauerle, 2008; Poschenrieder et al., 2022), and further physiological changes, such as bark exfoliation and variation in the timing of flowering (Cedro and Nowak, 2006; Milks et al., 2017; Mimet et al., 2009). The health status of *Platanus* is correlated with its growth period as well as the temperature during winter time and the total precipitation in preceding years (Gregorová et al., 2010). Phenological traits of *Platanus* are affected not only by environmental factors but are also under strong genetic control. Velikova et al. (2018) reported that after drought periods Italian *P. orientalis* ecotypes were less damaged and showed a higher stability of chloroplast membrane parameters compared to the Bulgarian ecotypes.

Urban trees are under additional threats from limited water availability and low soil volume (Dowtin et al., 2023; Jim, 2019). In addition, abiotic stresses are compounded by anthropogenic effects. For example, in urban architectural planning, trees are often planted in confined spaces alongside sidewalks, closely surrounded by asphalt and other structures, sometimes up to the very base of the tree stem. In these conditions the soil becomes impermeable, and consequently, water interception and root-level oxygen exchange are reduced. Moreover, the presence of asphalt increases the temperature at the tree collar, which can lead to cracking, splitting, or other forms of deterioration. Once the plant is established, irrigation and climatic conditions are key to ensuring plant growth. In urban environments, plant stress can increase as a result of water shortages. Frequently, in new planting areas, inadequate or improper irrigation can lead to decay, and sometimes plant death. *Platanus* can grow quite large and tall, thus it is important to ensure sufficient space for its growth, both at the level of root system and crown, thus reducing pruning interventions that are often the entry points for pathogens.

Future urban green management should consider selecting *Platanus* trees when they can provide ecosystem services, particularly in the

	BLUE STAIN CANKER DISEASE	MASSARIA DISEASE	ANTHRACNOSE DISEASE	POWDERY MILDEW
				
Causal agent (syn. as reported in Index Fungorum- https://www.indexfungorum.org/)	*Ceratocystis platani* (J.M. Walter) Engelbr. & T.C. Harr. 2005 (syn. *Ceratocystis fimbriata* f.s. *platani* C. May & J.G. Palmer 1959; *Endoconidiophora fimbriata* f. *platani* J.M. Walter). Photo: this study	*Macrodiplodiopsis desmazieri* (Mont) Petr. 1922 (syn. *Hendersonia desmazieri* Mont. 1849; *Macrodiplis desmazieri (Mont.) Clem. & Shear.* Photo: https://www.forestresearch.gov.uk/tools-and-resources/fthr/pest-and-disease-resources/massaria-disease-splanchnonema-platani/	*Apiognomonia platani* (Lév.) L. Lombard 2021 (syn. *Apiognomonia veneta* (Sacc. & Speg.) Höhn., 1920). Photo: https://it.wikipedia.org	*Erysiphe platani* (Howe) U. Braun & S. Takam. (syn. *Microsphaera platani* Howe, in Bessey 1874). Photo: this study
Host	*Platanus occidentalis, P. orientalis* (Main host), their hybrid *P. x acerifolia (= P. x hispanica)* and *P. racemosa* (Panconesi, 1981; Walter et al., 1952).	*Platanus occidentalis, P. orientalis,* their hybrid *P. x acerifolia (= P. x hispanica)* and *P. racemosa* (Nalli, 1981; Grosclaude and Romiti, 1991; Kehr and Krauthausen, 2004; Cech et al., 2007; Mösch et al., 2014).	*Platanus occidentalis, P. orientalis,* their hybrid *P. x acerifolia (= P. x hispanica)* (Santamour, 1976; Simmt et al., 2023).	*Platanus occidentalis, P. orientalis,* their hybrid *P. x acerifolia (= P. x hispanica)* (Heluta et al., 2013; Ligoxigakis et al., 2015; Pastirčáková and Pastirčák, 2006; Pastirčáková et al., 2014; CABI/EPPO 2013). The fungus was also found on *Punica granatum* (pomegranate) (Nemes et al., 2019) and on *Ailanthus altissima* (Beenken, 2017; Marchica et al., 2020).
Origin	*Ceratocystis platani* is thought to have arrived from the USA via infected wood packaging material to several Southern European ports at the end of World War II (Panconesi , 1999; Tsopelas et al., 2017).	*Macrodiplodiopsis desmazieri* is of unknown geographic origin. It has appeared causing problems in urban plantations of *Platanus* in North America and Europe (Kehr, and Krauthausen, 2004).	*Apiognomonia platani* is an ascomycete probably native to Europe (CABI Compendium, 2021).	*Erysiphe platani* is a fungus native to North America (Pastirčáková et al., 2014).
Distribution	*Ceratocystis platani* has been reported in several European countries, including Albania, Armenia, France, Greece, Italy, Switzerland and Turkey. In Spain, although the disease has been reported several times, it has been confirmed only in 2010 in Girona, Catalonia (OEPP/EPPO, 2014). The outbreak in Girona is now considered eradicated. Reports from Armenia and Iran have not been verified (Simonian and Mamikonyan, 1982; Salari et al., 2006).	*Macrodiplodiopsis desmazieri* is common in warmer Mediterranean climates and Northern United States. The pathogen seems to have been in Europe for almost 160 years however, not found further north than the Netherlands (Crous et al., 2015).	*Apiognomonia platani* is present in 13 EU States (CABI, 2021), both in areas where plane trees are planted as amenity trees as well as in North America where *P. occidentalis* is native. In the US the pathogen is present in 10 different States (CABI, 2021). The pathogen has been reported also in South America (Chile) (Luisi et al., 1987) and in South Africa, Pakistan, South Korea, New Zealand and Australia (CABI, 2021).	*Erysiphe platani* has been introduced in South America, South Africa, Australia, Asia, New Zealand, and also in many European countries (CABI/EPPO, 2013; Pastirčáková & Pastirčák 2006; Pastirčáková et al., 2014; Heluta et al., 2013; Ligoxigakis et al. 2015). In Europe the first report was in Italy on *P. occidentalis* (Ciferri and Camera, 1962) and *P. hybrida* (Gullino and Rapetti, 1978; Anselmi et al., 1994).

Fig. 1. *Platanus* diseases in urban areas, reported as case studies in this work (Anselmi et al., 1994; Beenken 2017; CABI/EPPO 2013; CABI Compendium 2021; Ciardini et al., 2016; Ciferri and Camera 1962; Grosclaude and Romiti 1991; Gullino and Rapetti 1978; Heluta, Vasyl et al., 2013; Ligoxigakis et al., 2015; Luisi et al., 1987; Marchica et al., 2020; Nalli 1981; Nemes et al., 2019; Pastirčáková and Pastirčák 2006; Salari et al., 2006; Simonian and Mamikonyan 1982).

context of ongoing climate change.

3.2. Platanus diseases and climatic changes

Climate change also appears to greatly influence the establishment and spread of plant pathogens and may result in new host-pathogen interactions. The magnitude and direction of this interaction varies between microorganisms (Jactel et al., 2012; Raza and Bebber, 2022). Increased temperature and the absence of frost events in many cases allow the invasion and establishment of thermophilic or frost-sensitive pathogens (Franić et al., 2023). There might also be shifts in the interrelations in species communities that are difficult to predict. Some fungal species, previously considered inconsequential from a phytopathology perspective, have caused notable damage in drought periods during the last two decades; native fungi that were previously harmless and therefore received little attention, may suddenly appear as agents of tree diseases (Cech et al., 2007; Engesser et al., 2008). Nevertheless, several authors have hypothesized that the predicted increase in temperature, dry summers and extreme meteorological events, will affect many harmful pathogens by both directly accelerating their propagation rates and weakening host plants (Santini and Ghelardini, 2015; Singh et al., 2023). Adamska (2019) claimed a connection between the reduction in *E. platani* infections and climate conditions in Poland between 2016 and 2017.

The effect of temperature on *C. platani* growth and viability within infected woody tissue or soil is also evident. The pathogen grows at an optimal temperature of 25 °C, while growth stops below 10 °C or above 35 °C; at temperatures above 37 °C the pathogen loses viability (Jeger et al., 2016).

Periods of cool, humid weather in early spring before bud flushing increase the severity of bud and twig blight, which is associated with infections by *A. platani*. Temperatures below 15 °C during bud break and early leaf development favor new infections and the disease development from already infected tissues. Rainfall and/or high relative humidity support both sexual and asexual sporulation, encouraging new infections (Cellerino and Anselmi, 1978). The most affected leaves fall early and, in severe infections, complete defoliation of the plant may occur (Cellerino and Anselmi, 1978).

After the above-average hot and dry summer of 2003 in Switzerland, Austria and Germany, several outbreaks of *Massaria* disease were recorded (Engesser et al., 2008; Kehr and Krauthausen, 2004; Tomiczek et al., 2009). *Macrodiplodiopsis desmazieri* cultures showed the highest

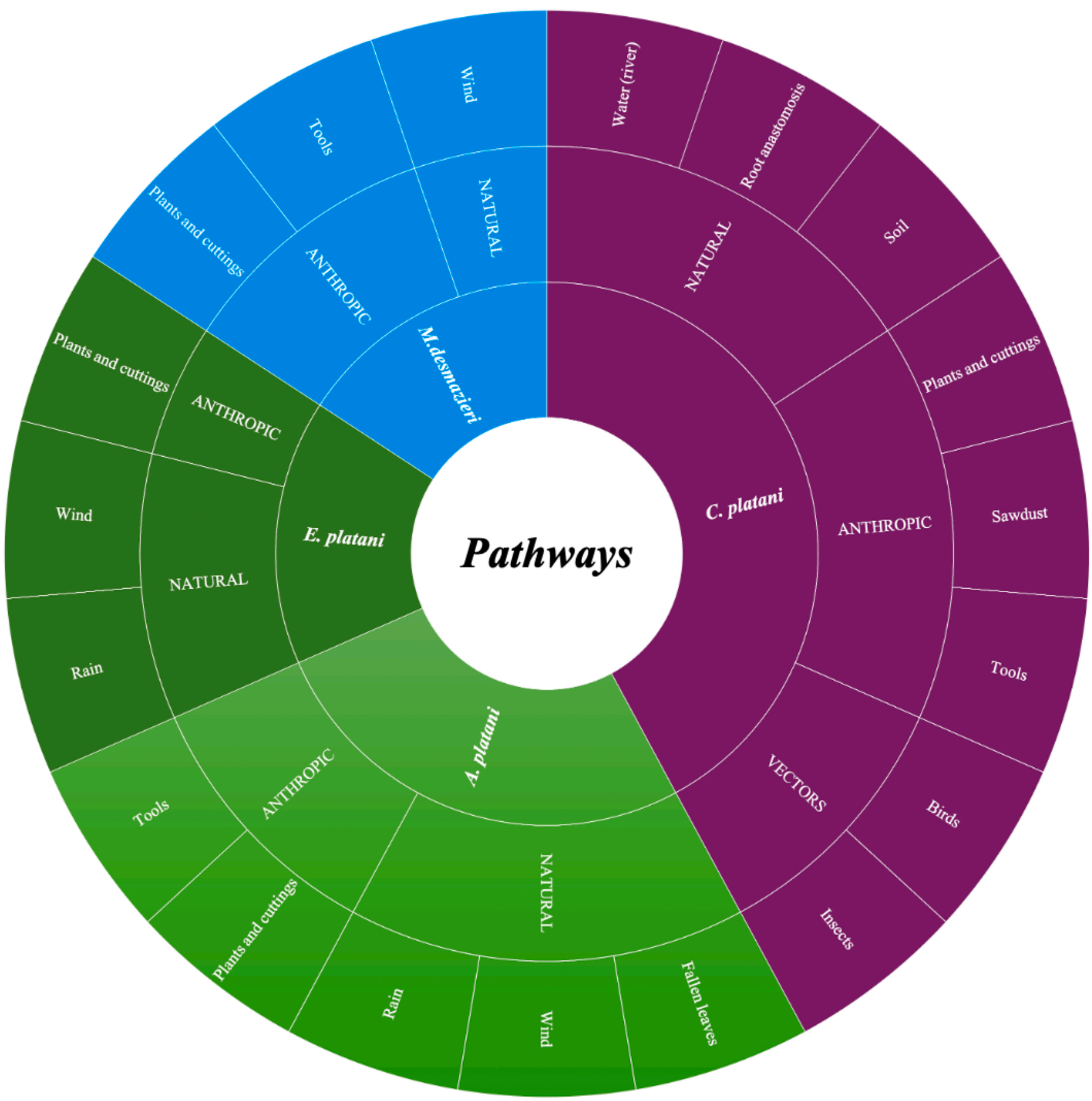

Fig. 2. Main pathways of introduction of *C. platani*, *A. platani*, *M. desmazieri* and *E. platani*.

mycelial growth in a temperature range between 20 °C and 35 °C (Börker, 2019). Greater numbers of pycnidia with incipient sporulation were observed within the temperature range from 30 °C to 35 °C. The pathogen can colonize primarily cortical and secondarily xylem tissues, even under low moisture conditions (Börker, 2019).

Similarly to the pathogens described above, increases in temperature and humidity have led to a rapid spread of *E. platani* infection through spores, despite the application of fungicide treatments (Tello et al., 2000). As climate conditions shift, disease patterns and tree susceptibility also change, necessitating a risk-based approach to disease management that includes regular monitoring in disease surveys focusing on pathogens that are not listed as quarantine microrganisms.

4. Regular monitoring

Regular monitoring of tree health is critical to the maintenance of urban and suburban landscapes, where various environmental stress can affect plant longevity and vitality. The use of diverse monitoring techniques allows for a full understanding of the health status of trees and rapid action to mitigate diseases and other problems. The monitoring and knowledge of pathogen biology form the basis for effective plant disease management. Different pathogens, such as those considered here, have distinct pathways of dispersal that are related to both anthropogenic and natural factors (Fig. 2). Anthropogenic activities include the transportation and trade of symptom-free infected plants and the use of contaminated cutting tools, which enhance the inoculum diffusion during felling and pruning operations (Fig. 2). Pathogens also spread through natural routes, such as wind and insects.

Apiognomonia platani and *E. platani* can disperse over short distances through perithecia and conidia that mature on infected fallen leaves and buds or within the one-year-old twigs, in the case of *A. platani,* and can be transported by wind and rain splash (Simmt et al., 2023).

In contrast, infected *C. platani* can be disseminated to a distance within 200 m from the contaminated plant through sawdust produced during pruning cuts (Luchi et al., 2013), but can spread even greater distances when carried by water in stream and river as along the Canal du Midi, France (Willsher, 2011). In addition, *C. platani* produces resilient, long-lived chlamydospores that can persist in infected wood or soil. In this scenario there is the potential for the pathogen to be transmitted over long distances via contaminated soil and arboricultural equipments.

Tree disease survey is a complex process that requires careful planning and systematic data collection and analysis. A deep understanding of the elements responsible for the increased probability of the introduction and spread of a pathogen, and estimates of relative risk are essential for performing a tree disease survey (Fig. 3). It is evident that each step must be uniquely designed to suit the pathogen, host and environment under study, tailoring the choices accordingly. A brief description of the main actions that should be considered in monitoring *Platanus* diseases is given below.

4.1. Planning the survey

The aim and timeframe of a disease survey (e.g., assessing the presence of a specific disease and understanding disease distribution) should be well defined, in addition to the locations and plant species under consideration. As with any urban trees, it is crucial that surveyors prioritize areas at high risk for plane tree diseases development, such as for example old trees growing close to each other, in avenues, in close proximity to street and pedestrian traffic, for enhancing the overall success of the survey (Mazurek and Nowik, 2018). In the case of *Platanus* health assessment in urban areas, tree inventory databases are currently

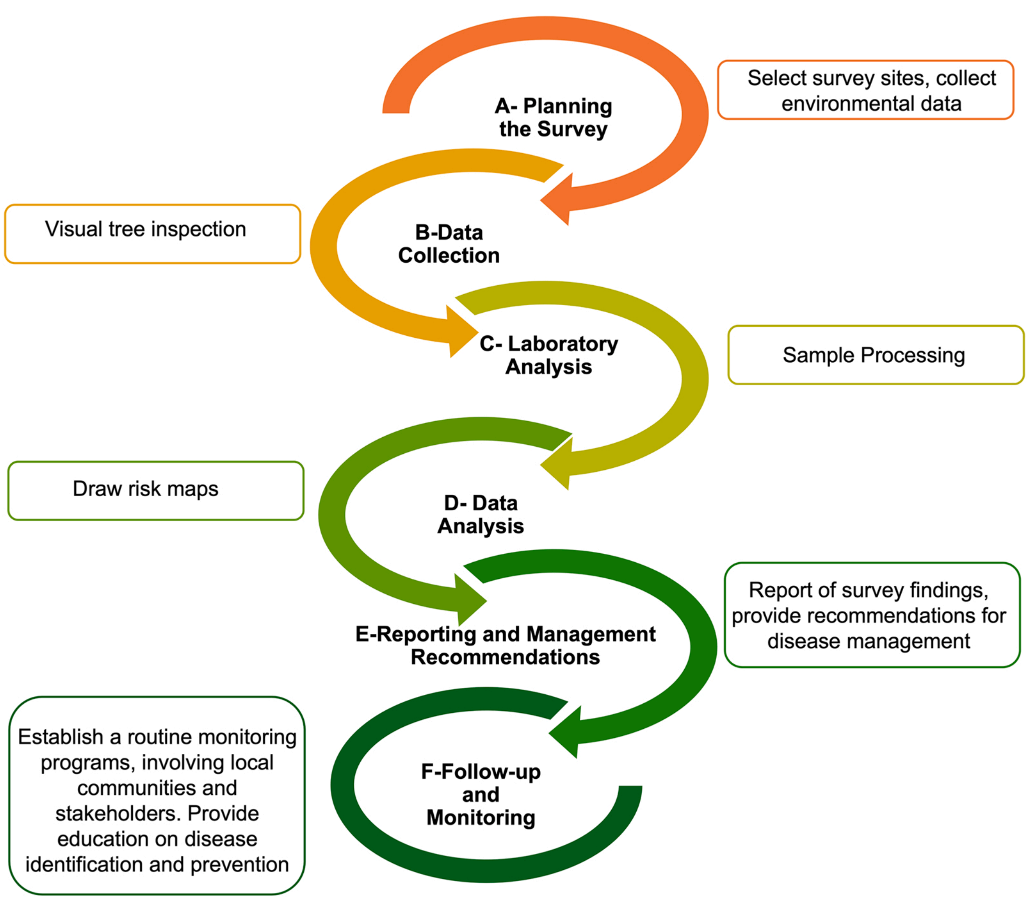

Fig. 3. A general scheme for regular monitoring of tree diseases in surveys.

used as the main background information. The evaluation of plant health status should be conducted annually by well-trained personnel. In fact, a solid knowledge of specific plant diseases is crucial to accurately recognize plant diseases, differentiate between symptoms and identify existing disease hotspots in tree populations. The frequency of monitoring should be decided based on tree characteristics, climate events and incidence and severity of diseases that occurred in previous years or in the area surrounding the survey zone. In addition, in years with increased frequency and intensity of threats from plant pathogens, city-wide and nursery monitoring is required (Kessler and Cech, 2008).

The key aspects of planning and executing a plant disease survey outlined above should be integrated into a unique model as done recently in studies that used mathematical models to identify high-risk locations in the landscape (Parnell et al., 2014).

4.2. Data collection from symptomatic trees

In order to gather accurate data for diagnosis and decision-making for disease management, it is crucial to involve trained personnels and use appropriate survey instruments and approaches, e.g. binoculars, remote sensing or tree climbers (Mösch et al., 2014; Cech et al., 2007). Moreover, accurate identification of plant diseases should be confirmed by laboratory analyses.

4.2.1. Canker stain disease

Symptoms associated with *Ceratocystis platani* generally comprise leaves yellowing and wilting, and sometimes elongated or lens-shaped cankers on bark. Beyond the lesion, staining can be visible in the cambium. Removing the bark reveals infected wood; the staining in colonized tissues is a striking darker color than uninfected tissues and has an irregular shape. A progressive deterioration is observed in the crown with yellowing and brown leaves, reductions in vegetative growth and generally stunted development. The acute symptomatology includes the sudden desiccation of some branches or the whole crown. The infected tree can die in a few months to 2–3 years, depending on its size and vigor (Griffin, 1968; Panconesi, 1999, 1977; Tsopelas et al., 2017; Vigouroux, 1979; Walter, 1946). Earlier in infection development, small cankers may be visible as dark patches underneath cracks in the bark surface. These small cankers are more conspicuous on the smooth bark of *P. occidentalis* and *P. x hispanica* than on the rough, thicker bark of *P. orientalis* (Panconesi, 1981; Walter et al., 1952). Lesions on the trunk are visible throughout the year, while deterioration in the crown is observed exclusively during the growing season (Panconesi, 1981; Walter et al., 1952). Infection by *C. platani* is difficult to detect before clear symptoms appear. The pathogen enters the host through wounds, which can be caused by human activities during arboricultural operations, and via root contacts. The latent period for *C. platani* can depend on environmental conditions and tree health.

4.2.2. Anthracnose disease

Symptoms progress in different tissues such as twigs, buds, shoots and leaves (Himelick and Neely, 1961). On twigs a brown area appears around the bud, as the fungus girdles the vascular tissue leading to bud wilting before it opens. The brownish discoloration in the wood may extend proximally to varying distances from the bud, leading to the death of the distal part. On the discolored bark of dead twigs and branches, small, black fruiting bodies erupt producing asexual spores that infect leaves, slowing expansion and causing necrotic lesions along the veins (Simmt et al., 2023). The disease develops during the growing season in spring and early summer. The fungus attacks the buds and then grows into the twigs soon after the leaves appear. When the pathogen fully colonizes a twig, the formation of cankers is observed on both small twigs and larger branches. In leaves, the pathogen causes necrosis around the veins and in the surrounding tissue, leading to the formation of the typical symptoms of the disease. In late spring a shoot blight stage occurs characterized by the sudden death of expanding shoots and young, immature leaves. On larger branches, cankers may develop, girdling and eventually killing them. The fungus can persist in the host tissues where it frequently becomes latent (Seifers and Ammon, 1980).

4.2.3. Massaria disease

First indications of *Macrodiplodiopsis desmazieri* attacks are pinkish-purple to orange-reddish discolorations of the bark, primarily on the top of the branches in the form of stripes (Mazurek and Nowik, 2018; Mösch et al., 2014; Schmitt et al., 2014; Tubby and Pérez-Sierra, 2015). The infection spreads from the base or the middle of branches towards the tip. The infected zone is sharply demarcated from the healthy wood and, in cross-sections of branches, runs in a V-shape from the outer tissues to the pith. Infected bark becomes cracked, brittle and eventually peels off (Mösch et al., 2014; Tubby and Pérez-Sierra, 2015; Mazurek and Nowik, 2018). In some cases, affected branches can still have sparse apparently healthy leaves. Branches that still appear healthy can break in a few months after the infection occurs (Mösch et al., 2014). Symptoms on the upper part of the branches can be difficult to be spotted from the ground (Mazurek and Nowik, 2018). Research conducted in Poland demonstrated that 95 % of disease incidence was observed on branches with diameters of $<$ 20 cm, and 63 % on branches with diameters of $<$ 10 cm (Mazurek and Nowik, 2018). In contrast, in the case of *Platanus* in streets of Vienna, infection of branches over 10 cm in diameter was rare (Kessler and Cech, 2008). Massive occurrence of *Massaria* disease symptoms usually take place within several months of drought periods (Kehr, 2011; Mösch et al., 2014).

4.2.4. Powdery mildew

The most visible symptoms by *Erysiphe platani* include a typical white powdery coating on the leaf blade, slight leaf chlorosis and distortions, followed by defoliation (Pastirčáková et al., 2014). The pathogen infects young leaves more severely than older ones. Leaf buds can also die (Adamska, 2019). A whitish felt develops on the leaf surface, particularly on young leaves, and at the apex of fresh shoots. In severe attacks, leaf growth is halted, the lamina tears, darkens and then dries out by crumpling upward. The fungus is an epiphytic pathogen that develops on the external surface of the host; it then actively penetrates the plant tissues through the cuticle and feeds on epidermal cells through the formation of specialised structures called haustoria. From the hyaline mycelium developing on tissue surfaces, conidiophores differentiate carrying short chains of conidia that, once released, serve as the means for spreading the disease. Attacks occur in spring and recur in autumn, requiring mild and humid weather conditions.

4.3. Laboratory analysis

Accurate and rapid diagnosis is crucial for successful disease management. Thus, laboratory tests must be performed to establish the causal agent of a disease, as several different pathogens may cause similar symptoms. For instance, the presence of chlorotic and wilting foliage can be correlated with both *M. desmazieri* and *C. platani* attacks during the initial stages of infection. It is noteworthy that *C. platani* is lethal to plane trees, whereas *M. desmazieri* does not cause the death of trees (Mösch et al., 2014). Traditionally, *C. platani, A. platani* and *M. desmazieri* detection has relied on a number of isolation methods and morphological observations, which can be time consuming and lead to false negative results (OEPP/EPPO, 2014; Pilotti et al., 2012; Lumia et al., 2018). Conversely, leaves infected by *E. platani* are evaluated by light microscopy (Adamaska, 2019).

Among the pathogens considered in this study, specific and sensitive molecular analysis has been developed only for *C. platani*, mainly using Real-Time PCR based methods (Brunetti et al., 2022; Luchi et al., 2013; Lumia et al., 2018; Pilotti et al., 2012). It is also important to highlight that a detailed understanding of the population structure of a pathogen is essential for accurate diagnosis and effective disease management. Different pathogen lineages may have different levels of virulence and host preference (Armitage et al., 2021; Jung et al., 2021). For example, *Phytophthora ramorum* lineages exhibit differences in morphological traits, temperature-growth rate responses and pathogenicity (Grünwald et al., 2008; Jung et al., 2021; Mascheretti et al., 2009). Transcriptomic analysis of genomes of *P. cactorum* isolates, collected from strawberry and apple samples, demonstrated the gain and loss of effector complements, which could be determinants of host specialization (Armitage et al., 2021; Nellist et al., 2021). Similarly, *Gnomoniopsis castanea* halotypes exhibit significant genetic diversity and variations in virulence (Seddaiu et al., 2023). Thus, the lack of understanding of the population structure of a pathogen could lead to inefficacy of detection and management strategies.

Focusing on the pathogens of the present study, the genetic homogeneity of *C. platani* in Europe suggests that this population underwent a genetic bottleneck, probably due to the introduction of a single genotype into Europe on infected material transported during World War II from the United States (Engelbrecht et al., 2004). Conversely, although genetic diversity was found within *A. veneta* populations, there is no hypothesis regarding the center of origin (Sogonov et al., 2007).

4.4. Population structure of *Erysiphe platani* and *Macrodiplodiopsis desmazieri*: differences between geographical origins

Phylogenetic analysis of *E. platani,* based on the ITS1–5.8S-ITS2 sequences (Table SF1), and *M. desmazieri*, based on the 18S rRNA (SSU) and 28S rRNA (LSU) sequences (Table 1), were performed using the Neighbor-Joining method. Sequences were retrieved from the NCBI database. Evolutionary distances were computed using the Kimura 2-parameter method. Evolutionary analyses were conducted using MEGA 11 (Kumar et al., 2018).

The homogeneity of *E. platani* global populations was consistent with findings previously reported by Scholler et al. (2012) (Fig. SF1).

The population analysis of *M. desmazieri* revealed two distinct groups: North American and European (Fig. 4). Interestingly, the 18S region analysis of isolates from Switzerland showed that the strains UASWS2027 and UASWS2028 clustered with isolates from the USA, while strains CBS 123811 and CBS 123812 grouped together with other European isolates. We can assume, therefore, that the pathogen spread from the USA to Switzerland and subsequently to other European countries. In agreement with Crous et al. (2015), strain MFLUCC 12–0088, a specimen collected by Erio Camporesi in Forlì-Cesena Province (Ibola Valley) from branches of *Platanus x hispanica,* was excluded from the phylogenetic analysis due to an erroneous identification. The diversity within plant pathogen populations may reflect adaptations to different ecological niches, such as varying soil types, climatic conditions, hosts and different virulence levels. Accordingly, the introduction of new genotypes could have serious implications in the implementation of control measures to mitigate the impact of a pathogen. Knowledge of the population structure of a pathogen, therefore, can guide management strategies, which must integrate an awareness of continuous new factors affecting plant disease associated with climate change and the intensification of plant trade.

4.5. Data analysis

Modern approaches to the epidemiology of pests and diseases include the use of mathematical models that, once all available data (e.g., pathogen growth and virulence, environmental factors, distribution of hosts) have been acquired, can predict the dynamic of disease spread and the potential effectiveness of management intervention efforts. In recent years, the use of risk maps has become increasingly widespread, providing a valuable tool for enhancing the ability to predict, prevent and manage disease outbreaks (Baxter et al., 2017; Firester et al., 2018; Manici et al., 2014). These tools commonly integrate climatic data with host and pathogen information, and sometimes also include historical data to identify trends in disease incidence, prevalence and spread. For example, some National Plant Health Inspection Services currently incorporate epidemiological information into surveying strategies using risk-based methods to develop sampling programs (Parnell et al., 2014).

Other factors, such us traffic and co-presence of other pathogens and pests that can threaten the plant, are generally not included in disease risk-maps, although they could impact the severity and incidence of plant diseases. Adamska (2019) showed that in high traffic areas and co-presence of *A. platani*, the infection rate of *E. platani* increased.

The European Food Safety Authority (EFSA) conducts pest risk analysis to evaluate the risk of the introduction and spread of newly detected pests, their impact in the EU, and the appropriate phytosanitary measures required to protect plant resources (Jeger et al., 2017, 2016).

Table 1
Macrodiplodiopsis desmazieri 18S and 28S sequences used for phylogenetic analysis.

Genes	Specie	GenBank Accession Number	Strain code	Geographic Origin	Host
18S	*Darksidea alpha*	JN859360	REF140	Hungary	*Stipa borysthenica*
	Macrodiplodiopsis desmazieri	NR 132924	CPC 24971	Switzerland	*Platanus sp.*
	Macrodiplodiopsis desmazieri	KR873233	CBS 123811	Austria	*Platanus x acerifolia*
	Macrodiplodiopsis desmazieri	KR873234	CBS 123812	Austria	*Platanus x acerifolia*
	Macrodiplodiopsis desmazieri	KR873235	CBS 125026	London, UK	*Platanus x acerifolia*
	Macrodiplodiopsis desmazieri	KR873236	CBS 221.37	USA	*Platanus occidentalis*
	Macrodiplodiopsis desmazieri	Kr873237	CPC 22645	Germany	*Platanus orientalis*
	Macrodiplodiopsis desmazieri	KR873239	CPC 24648	Germany	*Platanus orientalis*
	Macrodiplodiopsis desmazieri	KR873240	CPC 24971	Switzerland	*Platanus sp.*
	Macrodiplodiopsis desmazieri	KR873241	CPC 24972	Switzerland	*Platanus sp.*
	Macrodiplodiopsis desmazieri	KR873242	CPC 24973	Switzerland	*Platanus sp.*
	Macrodiplodiopsis desmazieri	KR873243	L138	Spain	*Platanus orientalis*
	Splanchnonema platani	MN833926	UASWS2027	Switzerland	*Platanus sp.*
	Splanchnonema platani	MN833927	UASWS2028	Switzerland	*Platanus sp.*
28S	*Darksidea alpha*	JN859482	REF132	Hungary	*Ailanthus altissima*
	Macrodiplodiopsis desmazieri	NG 058182	CPC 24971	Switzerland	*Platanus sp.*
	Macrodiplodiopsis desmazieri	KR873268	CBS 123811	Austria	*Platanus x acerifolia*
	Macrodiplodiopsis desmazieri	KR873269	CBS 123812	Austria	*Platanus x acerifolia*
	Macrodiplodiopsis desmazieri	KR873270	CBS 125026	UK	*Platanus x acerifolia*
	Macrodiplodiopsis desmazieri	KR873271	CPC 24648	Germany	*Platanus orientalis*
	Macrodiplodiopsis desmazieri	KR873272	CPC 24971	Switzerland	*Platanus sp.*
	Macrodiplodiopsis desmazieri	KR873273	CPC 24972	Switzerland	*Platanus sp.*
	Macrodiplodiopsis desmazieri	KR873274	L138	Spain	*Platanus orientalis*
	Splanchnonema platani	JX681100	CBS 221.37	USA	*Platanus occidentalis*
	Splanchnonema platani	KR909316	CBS 222.37	USA	*Platanus occidentalis*

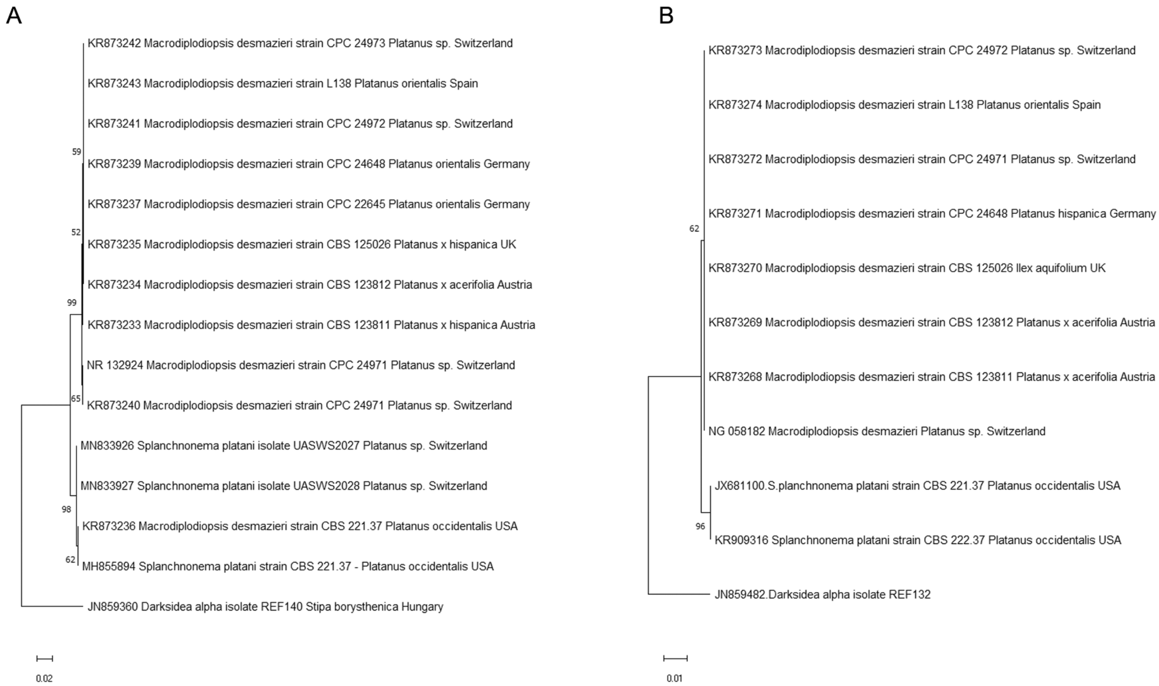

Fig. 4. Neighbor joining (bootstrap repeat is 10,000) phylogenetic trees of *M. desmazieri* sequences, based on 18S rDNA (A) and 28SrDNA (B) regions. *Darksidea alpha* was used as an outgroup. Numbers above the branches represent bootstrap values based on 1000 replicates. Highest possible support is 100. Values below 70 are considered weak, and values below 50 are not shown.

In 2014, the EFSA Panel on Plant Health performed a pest categorization for *C. fimbriata f.* sp. *platani* Walter, now known as *C. platani* (EFSA-Q-2014–00261), and in 2021 the full pest survey card on *C. platani* was published and made available online in the EFSA Plant Pest Survey Cards Gallery (https://arcg.is/15CyXW). *Apiognomonia platani*, *M. desmazieri* and *E. platani* have historically been underrepresented in such studies, possibly due to their perceived lower economic impact compared to *C. platani*.

4.6. Reporting and management recommendations

The final step which can translate the results of a survey into strategies for effectively containing the disease spread and mitigating its impact comprises an accurate report that includes findings, risks of spread and management recommendations. Even when present, European regulations provide a general framework, allowing room for further details at the national or local level. For instance, the EU Regulation 2022/1629 (Article 4) for the containment of *C. platani*, does not clearly define the exact period for wood removal or the type of treatment required.

4.7. Proper pruning practices

Although it is well known that pruning activities improve air circulation in the tree crown and result in microclimatic conditions that are less favorable to fungal infections, such as those caused by *A. platani*, one of the main reason for plant pruning in cities is public safety and the interference of tree branches with power lines, traffic signals and buildings. The risk of falling branches can be exacerbated by diseases, such as *Massaria* which causes branches death and break (Kehr and Krauthausen, 2004; Stobbe and Dujesiefken, 2011; Mösch et al., 2014).

According to Pilotti et al. (2016), when *C. platani* is considered, only the coldest and driest periods of the year should be considered less conducive to new infections and are also the most suitable times of the year for removing infected trees and conducting pruning activities. Unfortunatly, severe pruning practices are often carried out during late spring, commonly on large branches, causing extensive lesions that are more vulnerable to pathogen infections.

4.8. Sanitation practices

Pathogens can spread through infected seeds, transplants, irrigation water, contaminated equipments or human activities. For these reasons, sanitation is one of the most important methods helping to prevent the infection of healthy trees, by reducing the inoculum load through pruning and destroying of all infected materials. Pruning tools and machinery should be cleaned and disinfected between uses to avoid transferring pathogens from one tree to another, as described by EPPO protocols for the management of canker stain disease (OEPP/EPPO, 2014).

4.9. Chemical and biological treatments

In urban areas, the use of chemical treatments is limited as much as possible for human health reasons and it is generally not allowed. The chosen option should be directed toward products that are as selective as possible against pathogens and have minimal effects on human health and the wider environment.

Regarding the pathogens reported in this paper, *M. desmazieri* cannot be controlled chemically or biologically (Mösch et al., 2014), while some studies found effective control of anthracnose through the injection of systemic fungicides in the fall before leaf abscission occurs (Himelick and Duncan, 1982; Himelick and Neely, 1988). Treatments with products that have specific action against powdery mildew (e.g., sulfur powder), carried out during the first fungal attacks, can be effective in controlling this disease. A continuously repeated application of fungicidal treatments with chemical products, especially against airborne canopy pathogens, such as *A. veneta* and *E. platani* is unaffordable in practice especially in urban areas (Tello et al., 2000).

External chemical treatments against *C. platani* are not particularly effective (Panconesi, 1999). Conversely, pressure injection of fungicides has been successful in temporarily arresting the infection, but not in eliminating the pathogen from the plant (Panconesi, 1999; Causin et al., 1995). These chemicals were not approved for this type of use and are not applied in urban areas. Biocontrol measures also fail to provide good levels of control against *C. platani* (Accordi, 1989; Turchetti and Panconesi, 1982).

4.10. Cultural practices

To minimize plane diseases impact long-term site improvement measures should be considered. Nevertheless, these measures reach their natural limits particularly in older tree specimens and in site and climatic conditions stressful for the trees and favorable for pathogens reproduction and spread (Mösch et al., 2014). As a general consideration, it is evident that healthy soils support the development of root systems and enhance the resilience of plants. For these reasons, practices such as fertilization and the application of organic amendments containing plant growth promoting bacteria can improve plant health. In urban areas, it is also necessary to implement correct procedures to standardize maintenance work and develop suitable arboricultural practices. These actions must take into consideration when regular inspections are carried out, as well as risk assessment and prioritization regarding the need of removing infected branches or plants. All of these requirements can not only help reduce the pathogen inoculum load but also contribute to safeguarding public safety in urban environments.

4.11. Resistant plane varieties

Different species of *Platanus* exhibit varying degrees of resistance to pests and diseases, as well as to environmental stresses. Understanding resistance is important for selecting appropriate plane species, hybrids and varieties for urban green spaces. For instance, *P. occidentalis* is more susceptible to anthracnose compared to *P. orientalis* (Santamour, 1976; Simmt et al., 2023). Conversely, *P. x acerifolia*, being a hybrid between *P. occidentalis* and *P. orientalis*, mainly seed propagated, shows an extremely high degree of variability in susceptibility (Santamour, 1976). Since 1984, plane trees have mainly been propagated by cloning, which has resulted in lower genetic diversity compared to seed propagation (Morton and Gruszka, 2008).

Different levels of susceptibility against anthracnose and powdery mildew are also evident among different plane cultivars (Santamour, 1984; Svihra and McCain, 1992).

There is only one patented and registered variety of plane tree resistant to diseases available on the market: PLATANOR® 'Vallis Clausa'. It is resistant to canker stain and anthracnose, and it offers greater resistance to lace bugs and powdery mildew compared to the common hybrid plane tree *P.* x *acerifolia* (Vigouroux, 2006). Recently, PLATANOR ® 'Vallis Clausa' has been observed dying if planted in *C. platani*- contaminated soils (Anses Rapport d'expertise collective, 2019). To our knowledge, there are no indications of varieties resistant to *Massaria* disease.

4.12. Follow-up and monitoring

Disease monitoring should be carried out routinely in order to track disease spread and incidence and the effectiveness of management strategies. Data collected regularly should be included in the risk maps. It is now universally recognized that to prevent the establishment and spread of a pathogen, it is crucial to identify the causal agent(s) early. It is also evident that most National Plant Protection authorities have limited capacity in terms of professionals involved in greenspace management as well as financial resources. Thus, the use of public participation has been successfully explored in a range of citizen science projects. Although this approach offers valuable opportunities, certain limitations need to be acknowledged and addressed for effective disease management strategies. In particular, along with adequate training of citizen volunteers and their adherence to protocols of reporting, the validation and verification of the reports is still necessary to avoid the risk of misidentification or failure to detect symptoms.

In the new technology era, community engagement has been facilitated through many mobile apps designed for plant disease detection, diagnosis and treatments. Nevertheless, Siddiqua et al. (2022) evaluated 606 mobile apps, reporting that most lacked many basic and important functions to detect plant disease and some provided incorrect diagnoses.

4.13. Challenges and future perspectives

Plane disease management faces significant challenges, as described above. By combining knowledge with technologies and sustainable practices, tree disease management can overcome these challenges. Recently, many studies have reported the development of machine learning (ML)-based systems for early detection of plant diseases. These approaches, mainly applied in agriculture, provide quite reliable results, and are neither time consuming nor costly compared to traditional detection methods. Plant diseases surveillance should be based on an integrated model (IM) including: a) ML for image recognition to identify disease symptoms based on visual patterns; b) Internet of Things (IoT) devices which can collect data on environmental conditions (e.g., temperature, humidity, soil moisture) that strongly influence plant health and pathogen fitness; c) predictive models that assess the likelihood of disease outbreaks based on current and forecasted conditions; d) Geographic Information System (GIS) integration for spatial analysis of disease patterns. The IM strategy will allow urban foresters to achieve more accurate, efficient and dynamic disease management, leading to urban ecosystems more resilient to pest and disease outbreaks and to climate change. Moreover, IM will help prioritize areas for intervention basing on disease risk and optimizing resources allocation. Collaborative efforts with local authorities, scientific communities and citizens are also needed for a successful disease control. In particular, public awareness and community engagement can expand the areas monitored, raise the chance for an early detection, and lower the cost of surveys and treatments, including the removal of dead trees.

5. Conclusions

As global temperatures continue to rise, understanding and adapting to these changes is crucial for maintaining the health and ecological functions of urban trees. By acknowledging the impacts of climate change and implementing well-informed urban forestry practices, we can ensure that plane trees and other urban greenery continue to thrive in our cities.

In the future, the risks posed by *A. platani*, *M. desmazieri* and *E. platani* could become more significant under changing climatic conditions. Changes in temperature, humidity and precipitation patterns could enhance their virulence or expand their geographic range, leading to unforeseen impacts on plant health. Therefore, including pathogens like *A. platani*, *M. desmazieri* and *E. platani* in future assessments could provide a more comprehensive understanding of how climate change may influence plant disease dynamics.

Urban green planners and managers must take a proactive approach, considering the long-term implications of greenspace designs and making informed decisions based on ecological principles. Collaborations between arborists, landscape architects and environmental scientists can enhance the effectiveness of urban forestry projects. Last but not least, public education and community engagement are essential for fostering a culture of care and appreciation for urban green spaces.

CRediT authorship contribution statement

Alberto Santini: Writing – review & editing. **Hatice Tuğba Doğmuş Lehtijarvi:** Writing – review & editing. **Nikoleta Soulioti:** Writing – review & editing. **Steve Woodward:** Conceptualization, Data curation, Writing – review & editing. **Anna Maria Vettraino:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Dinka Matosevic:** Writing – review & editing. **Nicola Luchi:** Conceptualization, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing, Data curation, Formal analysis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2025.128750.

References

Accordi, S.M., 1989. The survival of *Ceratocystis fimbriata* f.sp. *platani* in the soil. Inf. Fitopatol. 39, 57–62.

Adamska, I., 2019. Epidemic of *Erysiphe platani* in urban areas on the example of the Szczecin (NW Poland). Ecol. Quest. 30, 71–81. https://doi.org/10.12775/EQ.2019.029.

Anselmi, N., Cardin, L., Nicolotti, G., 1994. Plane decline in European and Mediterranean countries: associated pests and their interactions. Bull. OEPP/EPPO Bull. 24, 159–171.

Anses Rapport d'expertise collective, 2019. Résistance de la variété Platanor contre Ceratocystis platani: évaluation des résultats d'expérimentation de contournement. Agence nationale de sécurité sanitaire et de l'alimentation, de l'environnement et du travail, Saisine «no 2018-SA-0069, n.d. Platanor». p. 62–p.

Antonelli, C., Biscontri, M., Tabet, D., Vettraino, A.M., 2023. The never-ending presence of *Phytophthora* species in Italian nurseries. Pathogens 12. https://doi.org/10.3390/pathogens12010015.

Antonelli, C., Soulioti, N., Linaldeddu, B.T., Tsopelas, P., Biscontri, M., Tsoukas, C., Paplomatas, E., Kuzminsky, E., Vettraino, A.M., 2024. *Phytophthora nicotianae* and *Ph. mediterranea*: a biosecurity threat to *Platanus orientalis* and *P.* x *acerifolia* in urban green areas in Greece. Urban For. Urban Green. 95, 128281. https://doi.org/10.1016/j.ufug.2024.128281.

Armitage, A., Nellist, C., Bates, H., Sobczyk, M., Luberti, M., Lewis, L., Harrison, R., 2021. Comparative analysis of host-associated variation in *Phytophthora cactorum*. Front. Microbiol. 12. https://doi.org/10.3389/fmicb.2021.679936.

Bartoli, F., Savo, V., Caneva, G., 2022. Biodiversity of urban street trees in Italian cities: a comparative analysis. Plant Biosyst. - Int. J. Deal. Asp. Plant Biol. 156, 649–662. https://doi.org/10.1080/11263504.2021.1906347.

Baxter, P., Woodley, A., Hamilton, G., 2017. Modeling the spatial spread risk of plant pests and pathogens for strategic management decisions. In: {C}Syme, G., Fulton, B., Piantadosi, J., Hatton MacDonald, D. (Eds{C}.), Proceedings of the 22nd International Congress on Modelling and Simulation (MODSIM2017). Presented at the International Congress on Modelling and Simulation, Modelling and Simulation Society of Australia and New Zealand Inc. (MSSANZ), Australia, pp. 209–215. https://www.mssanz.org.au/modsim2017/B1/baxter.pdf.

Beenken, L., 2017. First records of powdery mildew *Erysiphe platani* and *E. alphitoides* on *Ailanthus altissima* reveal host jumps independent of host phylogeny. Mycol. Prog. 16, 135–143. https://doi.org/10.1007/s11557-016-1260-2.

Börker, T., 2019. Mykologische und holzanatomische Untersuchungen zur Massaria-Krankheit an Platanen. Dissertation. Universität Freiburg. https://doi.org/10.6094/UNIFR/150039.

Bowden, J.D., Bauerle, W.L., 2008. Measuring and modeling the variation in species-specific transpiration in temperate deciduous hardwoods. Tree Physiol. 28, 1675–1683. https://doi.org/10.1093/treephys/28.11.1675.

Brunetti, A., Heungens, K., Hubert, J., Ioos, R., Bianchi, G.L., De Amicis, F., Chandelier, A., Van Der Linde, S., Perez-Sierra, A., Gualandri, V., Silletti, M.R., Trisciuzzi, V.N., Rimondi, S., Baschieri, T., Romano, E., Lumia, V., Luigi, M., Faggioli, F., Pilotti, M., 2022. Interlaboratory performance of a real-time PCR Method for detection of *Ceratocystis platani*, the agent of canker stain of *Platanus* spp. J. Fungi 8 (8). https://doi.org/10.3390/jof8080778.

CABI Compendium, 2021. *Apiognomonia veneta* (sycamore anthracnose). ⟨http://doi.org/10.1079/cabicompendium.25552⟩.

CABI/EPPO, 2013. *Erysiphe platani*. Distribution Maps of Plant Diseases, No.April. Wallingford, UK: CABI, Map 1140 (Edition 1).

Causin, R., Galbero, G., Lodi, M., Montecchio, L., Accordi, S.M., 1995. Control of *Ceratocystis fimbriata* f.sp. *platani* by injections of fungicides into the trunk Informatore. Fitopatologico 45 (1), 28–31.

Cech, T.L., Brandstetter, M., Tomiczek, C., 2007. Massaria-Krankheit der Platane nun auch in Österreich. Bundesforschungs- Ausbildungszentrum Für Wald Naturgefahren Landsch. BFW Inst. F. üR. Waldschutz, Forstsch. Aktuel. 40, 26 https://bfw.ac.at/400/pdf/fsaktuell_40_9.pdf.

Cedro, A., Nowak, G., 2006. Effects of climatic conditions on annual tree ring growth of the *Platanus* x *hispanica* "Acerifolia" under urban conditions of Szczecin. Dendrobiology 55, 11–17.

Cellerino, G.P., Anselmi, N., 1978. Distribuzione in Italia della *Gnomonia platani* Kleb. e considerazioni relative alla suscettibilità dell'ospite, all'epifitologia ed alla lotta [Distribution of *Gnomonia platani* Kleb. and notes about host susceptibility, epiphytology and control. Inf. Fitopatol. 11 (12), 53–64.

Ciaffi, M., Alicandri, E., Vettraino, A.M., Paolacci, A.R., Tamantini, M., Tomao, A., Agrimi, M., Kuzminsky, E., 2018. Conservation of veteran trees within historical gardens (COVE): a case study applied to *Platanus orientalis* L. in central Italy. Urban For. Urban Green. 34, 336–347. https://doi.org/10.1016/j.ufug.2018.07.022.

Ciferri, R., Camera, C., 1962. Tentativo di elencazione dei funghi italiani. I. Erisifali. Quad. Ist. Bot. Univ. Pavia 21, 1–46.

Crous, P.W., Carris, L.M., Giraldo, A., Groenewald, J.Z., Hawksworth, D.L., Hernández-Restrepo, M., Jaklitsch, W.M., Lebrun, M.H., Schumacher, R.K., Stielow, J.B., van der Linde, E.J., Vilcāne, J., Voglmayr, H., Wood, A.R., 2015. The Genera of Fungi - fixing the application of the type species of generic names - G2: *Allantophomopsis*, *Latorua*, *Macrodiplodiopsis*, *Macrohilum*, *Milospium*, *Protostegia*, *Pyricularia*, *Robillarda*, *Rotula*, *Septoriella*, *Torula* and *Wojnowicia*. IMA Fungus 6 (1), 163–198. https://doi.org/10.5598/imafungus.2015.06.01.11.

Derviş, S., Türkölmez, Ş., Çiftçi, O., Özer, G., Serçe, Ç .U., Dikilitas, M., 2020. *Phytopythium litorale*: A novel killer pathogen of plane (*Platanus orientalis*) causing canker stain and root and collar rot. Plant Dis. 104 (10), 2642–2648. https://doi.org/10.1094/PDIS-01-20-0141-RE.

Dowtin, A.L., Cregg, B.C., Nowak, D.J., Levia, D.F., 2023. Towards optimized runoff reduction by urban tree cover: a review of key physical tree traits, site conditions, and management strategies. Landsc. Urban Plan. 239, 104849. https://doi.org/10.1016/j.landurbplan.2023.104849.

Engelbrecht, C.J.B., Harrington, T.C., Steimel, J., Capretti, P., 2004. Genetic variation in eastern North American and putatively introduced populations of *Ceratocystis fimbriata* f. *platani*. Mol. Ecol. 13, 2995–3005. https://doi.org/10.1111/j.1365-294X.2004.02312.x.

Engesser, R., Forster, B., Meier, F., Wermelinger, B., 2008. Forstliche Schadorganismen im Zeichen des Klimawandels | Effects of climate change on forest pests and diseases. Schweiz. Z. Forstwes. 159, 344–351. https://doi.org/10.3188/szf.2008.0344.

Esperon-Rodriguez, M., Baumgartner, J.B., Beaumont, L.J., Lenoir, J., Nipperess, D., Power, S.A., Richard, B., Rymer, P.D., Tjoelker, M.G., Gallagher, R.V., 2021. Climate-change risk analysis for global urban forests. bioRxiv 2021 05 (09), 443030. https://doi.org/10.1101/2021.05.09.443030.

EU, 2019. Commission Implementing Regulation (EU) 2019/2072. Off. J. Eur. Union, 319, 1-278. Available online: ⟨http://data.europa.eu/eli/reg_impl/2019/2072/oj/eng⟩ (Accessed on 7 August 2024).

Firester, B., Shtienberg, D., Blank, L., 2018. Modelling the spatiotemporal dynamics of *Phytophthora infestans* at a regional scale. Plant Pathol. 67, 1552–1561. https://doi.org/10.1111/ppa.12860.

Franić, I., Allan, E., Prospero, S., et al., 2023. Climate, host and geography shape insect and fungal communities of trees. Sci. Rep. 13, 11570. https://doi.org/10.1038/s41598-023-36795-w.

Gregorová, B., Černý, K., Holub, V., Strnadová, V., 2010. Effects of climatic factors and air pollution on damage of London plane (*Platanus hispanica* Mill.). Hortic. Sci. 37, 109–117. https://doi.org/10.17221/47/2009-HORTSCI.

Griffin, H.D., 1968. The genus *Ceratocystis* in Ontario. Can. J. Bot. 46, 689–718. https://doi.org/10.1139/b68-094.

Grosclaude, C., Romiti, C., 1991. Observations sur *Massaria platani* parasite du platane en Provence. Petra 1, 189–194.

Grünwald, N.J., Goss, E.M., Press, C.M., 2008. *Phytophthora ramorum*: a pathogen with a remarkably wide host range causing sudden oak death on oaks and ramorum blight on woody ornamentals. Mol. Plant Pathol. 9, 729–740. https://doi.org/10.1111/j.1364-3703.2008.00500.x.

Gullino, G., Rapetti, S., 1978. Un mal bianco del Platano [A Powdery mildew of oriental (London) lane tree]. Inf. Fitopatol. 11 (12), 65–66.

Heluta, Vasyl, P., Viktoria, G., Korytnianska, Ilgaz, Akata, 2013. Distribution of *Erysiphe platani* (Erysiphales) in Ukraine. Acta Mycol. 48 (1).

Himelick, E., Duncan, D., 1982. Control of sycamore anthracnose with infections of Arbotect 20-S, 1981 [Sycamore (*Platanus occidentalis*), anthracnose; *Gnomonia platani*]. Fungicide and nematicide tests results. Results Am. Phytopathol. Soc. 37.

Himelick, E.B., Neely, D., 1961. Prevention of bark beetle development in undesirable Elms for the control of Dutch Elm disease. Plant Dis. Rep. 45 (3), 180–184.

Himelick, E.B., Neely, D., 1988. Systemic chemical control of sycamore anthracnose. J. Arboric. 14 (6), 137–141.

Jactel, H., Petit, J., Desprez-Loustau, M., Delzon, S., Piou, D., Battisti, A., Koricheva, J., 2012. Drought effects on damage by forest insects and pathogens: a meta-analysis. Glob. Change Biol. 18, 267–276. https://doi.org/10.1111/j.1365-2486.2011.02512.x.

Jeger, M., Bragard, C., Chatzivassiliou, E., Dehnen-Schmutz, K., Gilioli, G., Miret, J.A.J., MacLeod, A., Navarro, M.N., Niere, B., Parnell, S., Potting, R., Rafoss, T., Urek, G., Van Bruggen, A., Van der Werf, W., West, J., Winter, S., Santini, A., Tsopelas, P., Vloutoglou, I., Pautasso, M., Rossi, V., PLH, E.P.P.H., 2016. Risk assessment and reduction options for *Ceratocystis platani* in the *EU*. EFSA J. 14 (12). https://doi.org/10.2903/j.efsa.2016.4640, 4640, 65pp.

Jeger, M., Caffier, D., Candresse, T., Chatzivassiliou, E., Dehnen-Schmutz, K., Gilioli, G., Grégoire, J., Jaques Miret, J.A., MacLeod, A., Navajas Navarro, M., Niere, B., Parnell, S., Potting, R., Rafoss, T., Urek, G., Van Bruggen, A., Van Der Werf, W., West, J., Winter, S., Boberg, J., Porta Puglia, A., Vettraino, A.M., Pautasso, M., Rossi, V., 2017. Pest risk assessment of *Atropellis* spp. for the EU territory. EFSA J. 15. https://doi.org/10.2903/j.efsa.2017.4877.

Jim, C.Y., 2019. Resolving intractable soil constraints in urban forestry through research–practice synergy. Socio-Ecol. Pract. Res. 1, 41–53. https://doi.org/10.1007/s42532-018-00005-z.

Jung, T., Horta Jung, M., Webber, J.F., Kageyama, K., Hieno, A., Masuya, H., Uematsu, S., Pérez-Sierra, A., Harris, A.R., Forster, J., Rees, H., Scanu, B., Patra, S., Kudláček, T., Janoušek, J., Corcobado, T., Milenković, I., Nagy, Z., Csorba, I., Bakonyi, J., Brasier, C.M., 2021. The destructive tree pathogen *Phytophthora ramorum* originates from the Laurosilva Forests of East Asia. J. Fungi 7, 226. https://doi.org/10.3390/jof7030226.

Kehr, R., 2011. Entwicklung der *Massaria*-Krankheit in Deutschland in den letzten Jahren [Recent development of *Massaria* disease of plane trees in Germany. Jahrb. Baumpflege Year b. Tree Care 179–190.

Kehr, R., Krauthausen, H.-J., 2004. Erstmaliger Nachweis von Schäden an Platanen (*Platanus* x *hispanica*) durch den Pilz *Splanchnonema platani* in Deutschland. Nachr. Dtsch. Pflanzenschutzd. 56, 245–251.

Kessler, M., Cech, T.L., 2008. Situation der Massaria-Krankheit der Platane in Wien erste Ergebnisse des Monitorings. Forstsch. Aktuel-.-. 43, 35–36.

Kliuchevych, M., Stoliar, S., Chumak, P., Strygun, O., Babych, I., Vigera, S., Hrytsenko, O., 2021. New data on the expansion of *Erysiphe platani* (Howe) U. Braun & S. Takam.(Erysiphales, Ascomycota) in Ukraine. Ukr. J. Ecol. 11 (5), 9–14.

Kumar, S., Stecher, G., Li, M., Knyaz, C., Tamura, K., 2018. MEGA X: molecular evolutionary genetics analysis across computing platforms. Mol. Biol. Evolut. 35, 1547–1549. https://doi.org/10.1093/molbev/msy096.

Laurence, M.H., Mertin, A.A., Scarlett, K., Pang, C., Tabassum, S., Leishman, M.R., Burgess, T.I., Guest, D.I., Summerell, B.A., 2024. *Phytophthora* in urban tree planting stock: Are we managing the risk to the urban forest and natural ecosystems? Plant Pathol. 00, 1–13. https://doi.org/10.1111/ppa.13960.

Leal Filho, W., Icaza, L.E., Neht, A., Klavins, M., Morgan, E.A., 2018. Coping with the impacts of urban heat islands. A literature based study on understanding urban heat vulnerability and the need for resilience in cities in a global climate change context. J. Clean. Prod. 171, 1140–1149. https://doi.org/10.1016/j.jclepro.2017.10.086.

Ligoxigakis, E.K., Markakis, E.A., Papaioannou, I.A., Typas, M.A., 2015. First report of powdery mildew of *Platanus*× *acerifolia* and *P. occidentalis* caused by *Erysiphe platani* in Greece. Plant Dis. 99 (2), 286–2816. https://doi.org/10.1094/PDIS-07-14-0713-PDN.

Luchi, N., Ghelardini, L., Belbahri, L., Quartier, M., Santini, A., 2013. Rapid detection of *Ceratocystis platani* inoculum by quantitative real-time PCR assay. Appl. Environ. Microbiol. 79 (17), 5394–5404. https://doi.org/10.1128/AEM.01484-13.

Luisi, N., Bravo, T.J., Valdivieso, J.A., 1987. Anthracnose of the genus *Platanus* in the central-southern region of Chile. Bosque 8 (1), 3–6.

Lumia, V., Modesti, V., Brunetti, A., Wilkinson, C.L., Lernia, G.D., Harrington, T.C., Pilotti, M., 2018. Real-time PCR for *Ceratocystis platani* detection: In-depth validation to assess the diagnostic potential and include additional technical options. IForest 11 (4), 499–509. https://doi.org/10.3832/ifor2527-011.

Manici, L.M., Bregaglio, S., Fumagalli, D., Donatelli, M., 2014. Modelling soil borne fungal pathogens of arable crops under climate change. Int. J. Biometeorol. 58, 2071–2083. https://doi.org/10.1007/s00484-014-0808-6.

Marchica, A., Pisuttu, C., Calzone, A., Bernardi, R., Lorenzini, G., 2020. First report of powdery mildew caused by *Erysiphe platani* in *Ailanthus altissima*, the tree-of-heaven, in the Mediterranean basin, Italy. J. Gen. Plant Pathol. 86, 428–431. https://doi.org/10.1007/s10327-020-00935-1.

Marshall, M., Sutherland, R., Hulme, P.E., 2021. Assessing the role of plant trade networks in the vulnerability of forest nurseries to plant pathogens. Australas. Plant Pathol. 50, 671–681. https://doi.org/10.1007/s13313-021-00816-x.

Mascheretti, S., Croucher, P.J.P., Kozanitas, M., Baker, L., Garbelotto, M., 2009. Genetic epidemiology of the Sudden Oak Death pathogen *Phytophthora ramorum* in California. Mol. Ecol. 18, 4577–4590. https://doi.org/10.1111/j.1365-294X.2009.04379.x.

Mazurek, J., Nowik, K., 2018. Pests and diseases of urban trees. Biosecurity recommendations. Fundacja EkoRozwoju. Wroc. ław 40. ISBN: 978-83-63573-23-2.

McDonald, R.I., Kroeger, T., Zhang, P., Hamel, P., 2020. The value of US urban tree cover for reducing heat-related health impacts and electricity consumption. Ecosystems 23, 137–150. https://doi.org/10.1007/s10021-019-00395-5.

Milks, J.R., Hibbard, J., Rooney, T.P., 2017. Exfoliating bark does not protect *Platanus occidentalis* from root-climbing lianas. Northeast. Nat. 24, 520–525.

Mimet, A., Pellissier, V., Quénol, H., Aguejdad, R., Dubreuil, V., Rozé, F., 2009. Urbanisation induces early flowering: evidence from *Platanus acerifolia* and *Prunus cerasus*. Int. J. Biometeorol. 53, 287–298. https://doi.org/10.1007/s00484-009-0214-7.

Morton, C.M., Gruszka, P., 2008. AFLP assessment of genetic variability in old vs. new London plane trees (*Platanus* x *acerfolia*). J. Hortic. Sci. Biotechnol. 83 (4), 532–537. https://doi.org/10.1080/14620316.2008.11512418.

Mösch, S., Hommes, M., Werres, S., 2014. Massaria-Krankheit der Platane: *Splanchnonema platani*. Julius Kühn-Institut - Bundesforschungsinstitut für Kulturpflanzen. Braunschweig. 2 S. https://doi.org/10.5073/JKI.2014.009.

Nalli, R., 1981. A canker of *Platanus* caused by *Massaria platani* Ces. in Latium. Ann. dell'Ist. Sper. per la Patol. Veg. Roma 7, 27–37.

Nellist, C.F., Armitage, A.D., Bates, H.J., Sobczyk, M.K., Luberti, M., Lewis, L.A., Harrison, R.J., 2021. Comparative analysis of host-associated variation in *Phytophthora cactorum*. Front. Microbiol. 12, 679936. https://doi.org/10.3389/fmicb.2021.679936.

Nemes, K., Salánki, K., Pintye, A., 2019. *Punica granatum* (pomegranate) as new host of *Erysiphe platani* and *Podosphaera xanthii*. Phytopathol. Mediter. 58 (3), 707–711. https://doi.org/10.14601/Phyto-10890.

Nowak, D.J., Hirabayashi, S., Bodine, A., Greenfield, E., 2014. Tree and forest effects on air quality and human health in the United States. Environ. Pollut. 193, 119–129. https://doi.org/10.1016/j.envpol.2014.05.028.

OEPP/EPPO, 1986. *Ceratocystis fimbriata* (Ell. Halsted) f.sp. *platani* (Walter). OEPP/. EPPO Bull. 16, 21–24. https://doi.org/10.1111/j.1365-2338.1986.tb01129.x.

OEPP/EPPO, 2003. PM 7/014 (1): *Ceratocystis fimbriata* f. sp. *platani OEPP*. EPPO Bull. 33, 249–255. https://doi.org/10.1046/j.1365-2338.2003.00640.x.

OEPP/EPPO, 2014. PM 7/014 (2): *Ceratocystis platani* OEPP. EPPO Bull. 44, 338–349. https://doi.org/10.1111/epp.12159.

Panconesi, A., 1972. I nostri platani sono in pericolo. Inf. Fitopatol. 22, 10–13.

Panconesi, A., 1977. Canker stain of plane-trees in Versilia [Italy]. Spreading of the disease and control possibilities. Inf. Fitopatol. 3, 10–13.

Panconesi, A., 1981. *Ceratocystis fimbriata* of plane trees in Italy: biological aspects and control possibility. Eur. J. For. Pathol. 11 (7), 385–395.

Panconesi, A., 1999. Canker stain of plane trees: a serious danger to urban plantings in Europe. J. Plant Pathol. 81, 3–15 https://www.jstor.org/stable/41997936.

Parnell, S., Gottwald, T.R., Riley, T., van den Bosch, F., 2014. A generic risk-based surveying method for invading plant pathogens. Ecol. Appl. 24, 779–790. https://doi.org/10.1890/13-0704.1.

Pastirčáková, K., Pastirčák, M., 2006. The anamorph of *Erysiphe platani* on *Platanus*× *hispanica* in Slovakia. Mycotaxon 97, 189–194.

Pastirčáková, K., Pastirčák, M., Adamčiková, K., Bouznad, Z., Kedad, A., El Guilli, M., Diminic, D., Hofte, M., 2014. Global distribution of *Erysiphe platani*: new records, teleomorph formation and re-examination of herbarium collections. Cryptogam. Mycol. 35 (2), 163–176. https://doi.org/10.7872/crym.v35.iss2.2014.163.

Percival, G.C., 2023. Heat tolerance of urban trees – a review. Urban For. Urban Green. 86, 128021. https://doi.org/10.1016/j.ufug.2023.128021.

Piana, M.R., Aronson, M.F., Pickett, S.T., Handel, S.N., 2019. Plants in the city: understanding recruitment dynamics in urban landscapes. Front. Ecol. Environ. 17 (8), 455–463. https://doi.org/10.1002/fee.2098.

Pilotti, M., Di Lernia, G., Modesti, V., Lumia, V., Brunetti, A., 2016. Outcome of *Ceratocystis platani* inoculations in *Platanus*× *acerifolia* in relation to season and inoculum dose. IForest-Biogeosci. For. 9 (4), 608. https://doi.org/10.3832/ifor1594-008.

Pilotti, M., Lumia, V., Di Lernia, G., Brunetti, A., 2012. Development of Real-Time PCR for in wood-detection of *Ceratocystis platani*, the agent of canker stain of *Platanus* spp. Eur. J. Plant Pathol. 134, 61–79. https://doi.org/10.1007/s10658-012-0022-5.

Poschenrieder, W., Rötzer, T., Biber, P., Uhl, E., Dervishi, V., Pretzsch, H., 2022. Sustainable management of urban tree stocks based on multi-criteria scenario modelling. Urban For. Urban Green. 74, 127666. https://doi.org/10.1016/j.ufug.2022.127666.

Rahman, M.A., Stratopoulos, L.M.F., Moser-Reischl, A., Zölch, T., Häberle, K.-H., Rötzer, T., Pretzsch, H., Pauleit, S., 2020. Traits of trees for cooling urban heat islands: a meta-analysis. Build. Environ. 170, 106606. https://doi.org/10.1016/j.buildenv.2019.106606.

Raza, M.M., Bebber, D.P., 2022. Climate change and plant pathogens. Curr. Opin. Microbiol. 70, 102233. https://doi.org/10.1016/j.mib.2022.102233.

Ren, F., Qiu, Z., Liu, Z., Bai, H., Gao, H.O., 2023. Trees help reduce street-side air pollution: a focus on cyclist and pedestrian exposure risk. Build. Environ. 229, 109923. https://doi.org/10.1016/j.buildenv.2022.109923.

Rosati, L., Masi, A., Giardini, M., Marignani, M., 2015. Under the shadow of a big plane tree: why *Platanus orientalis* should be considered an archaeophyte in Italy. Plant Biosyst. - Int. J. Deal. Asp. Plant Biol. 149, 185–194. https://doi.org/10.1080/11263504.2014.998312.

Salari, A.N., Arefipoor, M.R., Jami, F., Zahedi, M., Mehrabi, A., and Zeinali, S. 2006. First report of *Ceratocystis fimbriata* f. sp. *platani* causal agent of canker stain of sycamore trees in Iran. Page 401. In: Proceedings of the 17th Iranian Plant Protection Congress, 2-5 September 2006. University of Tehran Karaj, Iran.

Santamour, F.S., 1976. Resistance to sycamore anthracnose disease in hybrid *Platanus*. Plant Dis. Rep. 60 (1–6), 161.

Santamour, F.S., Jr, 1984. Columbia' and 'Liberty' plane trees. Hort. Sci. 19 (6), 901–902.

Santini, A., Ghelardini, L., 2015. Plant pathogen evolution and climate change. CABI Rev. 1–8. https://doi.org/10.1079/PAVSNNR201510035.

Scattolini Rimada, A.C., Coelho Duarte, A.P., Torrano, C., Cazzola, V., Larramendy, P., Silvera, A., Parinis, L., Moreira, V., Silvera Perez, E., 2023. Fungi associated to *Platanus x acerifolia* in Uruguay and failure indicators. Agrocienc. Urug. 27, e989. 〈https://agrocienciauruguay.uy/index.php/agrociencia/article/view/989〉.

Schmitt, U., Lüer, B., Dujesiefken, D., Koch, G., 2014. The *Massaria* disease of plane trees: its wood decay mechanism. IAWA J. 35, 395–406. https://doi.org/10.1163/22941932-00000074.

Scholler, M., Hemm, V., Lutz, M., 2012. *Erysiphe platani:* monitoring of an epidemic spread in Germany and molecular characterization based on rDNA sequence data. Andrias 19, 263–272.

Seddaiu, S., Mello, A., Sarais, L., Mulas, A., Sechi, C., Ruiu, P.A., Vettraino, A.M., Petruccioli, M., Gonthier, P., Sillo, F., Bregant, C., Montecchio, L., Linaldeddu, B.T., 2023. Haplotypes distribution and virulence of *Gnomoniopsis castaneae* in Italy. J. Plant Pathol. 105, 1135–1140. https://doi.org/10.1007/s42161-023-01459-1.

Seifers, D., Ammon, V., 1980. Mode of penetration of sycamore leaves by *Gloeosporium platani*. Phytopathology 70, 1050–1055.

Siddiqua, A., Kabir, M.A., Ferdous, T., Ali, I.B., Weston, L.A., 2022. Evaluating plant disease detection mobile applications: quality and limitations. Agronomy 12, 1869. https://doi.org/10.3390/agronomy12081869.

Simmt, C.F., Sydnor, D., White, E.L., Wooten, A., Hand, F.P., Bonello, P., 2023. Field resistance of American Sycamore 'Davis' to canker pathogens. Arboric. Urban For. 49, 170–178. https://doi.org/10.48044/jauf.2023.013.

Simonian, S.A., Mamikonyan, T.O., 1982. Disease of plane tree. Zashchita-Rastenii 8, 23–24.

Singh, B.K., Delgado-Baquerizo, M., Egidi, E., Guirado, E., Leach, L.E., Liu, H., Trivedi, P., 2023. Climate change impacts on plant pathogens, food security and paths forward. Nat. Rev. Microbiol. 21, 640–656. https://doi.org/10.1038/s41579-023-00900-7.

Sogonov, M.V., Castlebury, L.A., Rossman, A.Y., White, J.F., 2007. The type species of *Apiognomonia*, *A. veneta*, with its *Discula* anamorph is distinct from *A. errabunda*. Mycol. Res. 111, 693–709. https://doi.org/10.1016/j.mycres.2007.03.013.

Stobbe, H., Dujesiefken, D., 2011. Können vorbeugende Schnittmaßnahmen in der Krone den Befall durch die Massaria-Krankheit vermindern? Jahrbuch der Baumpflege 2011. Haymarket Media, Braunschweig, pp. 208–214.

Svihra, P., McCain, A.H., 1992. Susceptibility of plane trees to anthracnose and powdery mildew in California. J. Arboric. 18 (3), 161–163.

Tabassum, S., Manea, A., Leishman, M.R., 2024. Limiting the impact of insect pests on urban trees under climate change. *Urban* For. Urban Green. 94, 128246. https://doi.org/10.1016/j.ufug.2024.128246.

Tello, M.L., Redondo, C., Mateo-Sagasta, E., 2000. Health status of plane trees (*Platanus* spp.) in Spain. Arboric. Urb. For. 26 (5), 246–254. https://doi.org/10.48044/jauf.2000.030.

Tomiczek, C., Cech, T.L., Fürst, A., Hoyer-Tomiczek, U., Krehan, H., Perny, B., Steyrer, G., 2009. Forstschutzsituation 2008 in Österreich. 〈https://bfw.ac.at/400/pdf/fsaktuell_46_1.pdf〉.

Tsopelas, P., Santini, A., Wingfield, M.J., De Beer, Z.W., 2017. Canker stain: a lethal disease destroying iconic plane trees. Plant Dis. 101 (5), 645–658. https://doi.org/10.1094/PDIS-09-16-1235-FE.

Tubby, K.V., Pérez-Sierra, A., 2015. Pests and pathogen threats to plane (*Platanus*) in Britain. Arboric. J. 37 (2), 85–98. https://doi.org/10.1080/03071375.2015.1066558.

Turchetti, T., Panconesi, A., 1982. Osservazioni preliminari sull'antagonismo di alcune specie di Bacillus verso *Ceratocystis fimbriata* (Ell. & Halst.) Davidson *f. platani* Walter. Riv. di Patol. Veg. 18, 71–76.

Velikova, V., Tsonev, T., Tattini, M., Arena, C., Krumova, S., Koleva, D., Peeva, V., Stojchev, S., Todinova, S., Izzo, L.G., Brunetti, C., Stefanova, M., Taneva, S., Loreto, F., 2018. Physiological and structural adjustments of two ecotypes of *Platanus orientalis* L. from different habitats in response to drought and re-watering. Conserv. Physiol. 6, coy073. https://doi.org/10.1093/conphys/coy073.

Vigouroux, A., 1979. Les dépérissements des platanes. Causes-Importance-Mesures envisageables. Rev. For. Fr. 31, 28–39 https://hal.science/hal-03397236/document.

Vigouroux, A., 2006. Chancre coloré du platane: obtention d'un plant résistant. Courr. De. l'Environ. De. l'Inra 53, 137–138.

Walter, J.M., 1946. Canker stain of plane-trees. Circular 742. U.S. Dep. Agric. Wash. DC.

Walter, J.M., Rex, E.G., Schreiber, R., 1952. The rate of progress and destructiveness of canker stain of plane-trees. Phytopathology 42, 236–239.

Wang, C.W., Tu, H.M., 2023. Evaluating criteria weights of street tree selection between residents and experts. Landsc. Ecol. Eng. 19, 633–646. https://doi.org/10.1007/s11355-023-00568-4.

Watkins, R., Palmer, J., Kolokotroni, M., 2007. Increased temperature and intensification of the urban heat island: implications for human comfort and urban design. Built Environ. 33 (1), 85–96. https://doi.org/10.2148/benv.33.1.85.

Willsher, K., 2011. Epic beauty of tree-lined Canal du Midi under threat as fungus strikes. 〈http://www.guardian.co.uk/world/2011/aug/13/canal-du-midi-under-threat〉.

Yang, J., McBride, J., Zhou, J., Sun, Z., 2005. The urban forest in Beijing and its role in air pollution reduction. Urban For. Urban Green. 3 (2), 65–78. https://doi.org/10.1016/j.ufug.2004.09.001.

Yin, Y., Li, S., Xing, X., Zhou, X., Kang, Y., Hu, Q., Li, Y., 2024. Cooling benefits of urban tree canopy: a systematic review. Sustainability 16, 4955. https://doi.org/10.3390/su16124955.

Zhao, J., Zhao, X., Wu, D., Meili, N., Fatichi, S., 2023. Satellite-based evidence highlights a considerable increase of urban tree cooling benefits from 2000 to 2015. Glob. Change Biol. 29, 3085–3097. https://doi.org/10.1111/gcb.16667.