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IMPACT OF *PLATANUS* L. SPECIES ON THE POLLEN EMISSIONS AND AIR POLLUTION OF SOFIA

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Abstract

In the last decades, the presence of Platanus species in the green infrastructure of Sofia has increased. The species are quite tolerant to urban conditions, which makes them preferable for landscaping. Their increased quantity leads to a risk of increased allergenic potential.
The aim of this research was to establish the dynamics of Platanus L. pollen concentrations and to assess their relation to meteorological variables, as well as the impact of plane-tree pollen emissions on the air quality in Sofia.
The analysis of the aeropalynological data on the city of Sofia for the period 2013-2022 found a difference in the length of the flowering period over the 10 years of observation. In general, at the beginning of the studied 10-year period, flowering started in the second half of March, while in 2018 and from 2020 to 2022, it began from the first half of April. The shortest flowering period was in 2015, in contrast to the longest duration's in the following two years (2016 and 2017). In 2016 and 2017, the flowering continued in June and the beginning of July. In 2013, 2014 and 2019 the peak was similarly in the second half of April when temperatures rose and the pollen season was extended to about 75 days.
The results of the study showed that the meteorological factors which directly affect the concentrations of airborne pollen were wind speed, relative humidity, atmospheric pressure and solar radiation.
For the time being, the amount of Platanus pollen in Sofia is relatively low. However, in recent years there has been an upward trend. That growth trend is expected to continue due to the degree of maturity of Platanus specimens. The presence of that species as a dominant element in the urban green infrastructure of Sofia should be reconsidered, not only to improve air quality, but also to enhance urban biodiversity, its resilience and ecosystem services.The obtained correlations between seasonal pollen levels and some particulate matter 10 (PM_{10}) also highlight the possible contribution of Platanus pollen to air quality deterioration in Sofia.

***Key words**: Platanus, allergenic pollen, meteorological variables, PM_{10}.*

INTRODUCTION

Platanus L. species are popular urban woody ornamentals cultivated in large numbers as street and park trees all over Europe (Pauleit et al., 2002) and worldwide, in Australia and in North and South America (McBride, 2017), in China (Jing et al., 2020).
The genus consists of fast-growing and long-lived species with high ornamental qualities. Along with their good ecological adaptability to urban conditions and tolerance to air pollution, they have a high capacity to retain particulate matter (Baldachini et al., 2017).
However, the presence of *Platanus* species in the urban green infrastructure is associated with disservices, such as emissions of allergens (Cariñanos et al., 2020; Vrinceanu et al., 2021) and Biogenic Volatile Organic Compounds (BVOCs), both contributing negatively to air quality. *Platanus* spp. are proved to be one of the main urban emitters of monoterpenes and sesquiterpenes, which are BVOCs participating in the formation of atmospheric ozone (Xiaoshan et al., 2000; Curtis et al., 2014, Jing et al, 2020). Moreover, the London plane has an Allergenic Potential Value of 24 (VPA), one of the highest in the database of parameters for the calculation of the Index of Allergenicity of Urban Green Zones (IUGZA) (Cariñanos et al., 2019). According to Magyar et al. (2022) *Platanus* x *acerifolia* (Aiton) Willd. falls within the category of taxa having very high potential allergenicity under an evidence-based categorization (CARE-S), developed using genetically determined factors of plants, such as immunogenicity, morphology, and pollen production. Consequently, the authors do not recommend this species for further planting in public urban green areas.
Platanus spp. pollen triggers allergies in the Mediterranean region: Spain (Alcázar et al.,

2015; Cariñanos et al., 2020) Italy (Bedeschi et al., 2007; Cipriani et al., 2019), Portugal (Loureiro et al., 2005; Ribeiro and Abreu, 2014) and Greece (Gioulekas et al., 2004), as well as in Iran (Sedghy et al., 2017) and China (Jing et al., 2020).

The estimated large amounts of pollen production, 3.3×10^6 pollen grains per inflorescence (Maya-Manzano et al., 2017), indicate *Platanus* as one of the biggest pollen emitters among woody anemophilous species (Damialis et al., 2011).

The current phenological dynamic has been altered by the microclimatic parameters of the environment which led to the earlier onset, longer season and more intense flowering, as well as to large quantities of pollen emitted by a tree (Alcázar et al., 2015; Cariñanos et al., 2020).

A long-term (1982-2015) aerobiological study that took place in Brussels associated the overall increasing trend in daily airborne pollen concentrations and an earlier onset of the flowering period for *Platanus* spp. with the rates of change in the annual cycles of various meteorological variables, air temperature, solar radiation, relative humidity, and precipitation (Bruffaerts et al., 2018).

Over 3,200 inventoried specimens were mapped in the Sofia Municipality Green Areas Registry (ROPKR). The analysis of the dendrological composition of urban street tree plantings in Sofia (Anisimova, 2023) indicated the dominant presence of *Platanus* x *acerifolia* (15.09%) in street landscaping, comprising mainly of young specimens (DBH < 25).

The results from the pilot study of sensitization of patients with pollinosis in Sofia (Nikolov et al., 2021) showed that, at present, the sensitization to pollens of different *Platanus* species is not comparable to that to grass or birch pollen. However, having in mind that mature trees with bigger crown volumes produce substantially more pollen than younger trees, along with other modified environmental factors in the era of climate change, *Platanus* pollination disservices with an impact on human health are expected to increase in the future (Cariñanos et al., 2020).

There is evidence that the allergic response in sensitized patients exposed to high or very high pollen concentrations in the air is very intense and further exacerbated by co-factors, such as particular weather variables or high concentrations of atmospheric pollutants (Oduber et al., 2019; Sauliene et al., 2019; Cariñanos et al., 2021). Weather variables substantially influence pollen concentration, with air temperature, solar radiation and relative humidity being the most significant factors (Rosianu et al., 2022).

The aim of this research was to establish the dynamics of *Platanus* L. pollen concentrations and to assess their relation to meteorological variables, as well as the impact of plane-tree pollen emissions on the air quality in Sofia.

MATERIALS AND METHODS

Study area

The city of Sofia (42.70°N 23.33°E) with an altitude of about 550 m is situated in the western part of Bulgaria, in Sofia Valley, bordering on the south with Vitosha mountain. According to Stanev et al. (1991) the climate of Sofia is continental.

The city of Sofia occupies an area of 492 km^2, with a population of about 1 248 452 citizens (NSI, 2022).

Platanus pollen data

The three species cultivated in the green infrastructure of Sofia are *Platanus orientalis* L., *Platanus occidentalis* L. and *Platanus* x *acerifolia* (Aiton) Willd.

The Durham gravimetric method for aero sedimentation of pollen grains on a film-coated microscope slide was used for obtaining the aerobiological data. The pollen trap was installed at 10 m above the ground. The aerobiological monitoring period started at the beginning of March 2013 and lasted till the end of June 2022. The microscope slide was replaced after 24-hour deposition period and daily airborne pollen counts were conducted. The microscopic identification and counting of pollen grains were performed manually on a 3.24 cm^2 surface of the slide.

Meteorological data

The data series for the hourly values of the studied meteorological variables: air temperatures (°C), relative humidity (%), wind speed (m/s) and wind direction, atmospheric pressure (mbar), solar radiation (W/m^2), for the period 2013-2022 were provided by the Bulgarian Executive Environment Agency (ExEA).

Air pollution data

The data series for the hourly concentrations of PM_{10} for the period 2013-2022 were provided by ExEA.

Statistical analysis

Mean values of the hourly averages for the meteorological variables and mean values of the hourly averages for particulate matter 10 (PM_{10}) concentrations were calculated for 15-day periods. Descriptive statistics for meteorological variables and PM_{10} concentration and coefficients of variation (CV) were calculated.

Non-parametric Spearman's analysis with significant correlations ($p < 0,05$) between aeropalynological data and meteorological and air pollution data were tested in order to identify significant relationships between variables.

RESULTS AND DISCUSSIONS

The analysis of the aeropalynological data for the city of Sofia found a difference in the length of the flowering period over the 10 years of observation (Figure 1). The shortest flowering period was in 2015, in contrast to the longest durations in the following two years (2016 and 2017). In 2016 and 2017, the flowering continued in June and the beginning of July. In general, at the beginning of the studied 10-year period, flowering started in the second half of March, while in 2018 and from 2020 to 2022, it began from the first half of April.

In comparison, the *Platanus* pollen season in Poznan started at the turn of April and May and ended usually in the third decade of May, according to an aerobiological study for the period (2005-2009) (Nowak et al., 2012). The aerobiological study of this taxa in the atmosphere of the city of Granada showed that the pollen season start date took place from the beginning to the end of March, and the pollen season end date took place from mid-April to the end of May, with a peak in mid-March (Cariñanos et al., 2020). *Platanus* L. has been reported to be a good bioindicator of temperature variations in previous studies on the impact of climate change on *Platanus* pollination in different European bioclimatic zones (Tedeschini et al., 2006).

Some authors report similar matches between the pollen peaks and periods with lack of precipitation, low relative humidity, respectively, and increased temperatures (Álvarez-López et al., 2022).

The comparison between the peak of the *Platanus* pollen season and the mean amount of pollen grains for the 10-year data series found matches in 2013, 2015, 2018, 2019, and 2022. In contrast to the aforementioned 5 years, in 2014, 2016, and 2017, the peak in the pollen season was 15 days earlier than the average for the 10-year period. In 2020, two pollen peaks were established, in the first half of April and May, respectively, in the context of gradually rising air temperatures. In 2021, the peak pollen release phase was delayed by 15 days and occurred at the highest mean air temperature values reported for the entire pollen season.

The annual pollen concentrations and the daily pollen peaks vary considerably over the years. The probable causes for these fluctuations could be attributed to the accelerated growth or mortality of trees or different pruning approaches (Cariñanos et al., 2020).

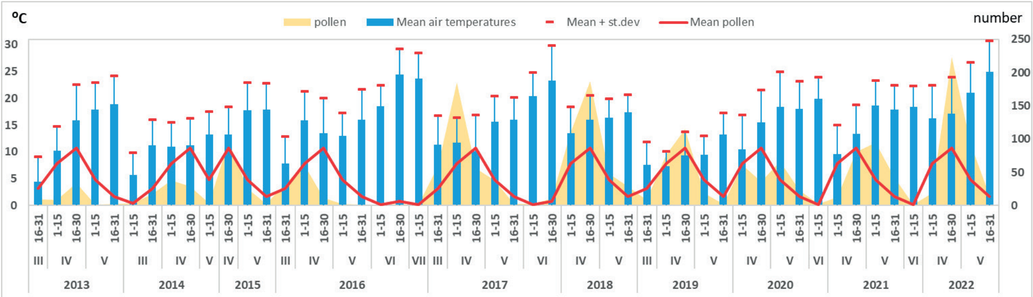

Figure 1. Dynamics of the mean values of the hourly averages of air temperatures and the amount of pollen in the flowering phase over the period 2013-2022

Temperature has been the weather parameter with the greatest impact on the *Platanus* pollen season (Tedeschini et al., 2006; Maya-Manzano et al., 2017).

Within the pollen season, over the 10-year data series, 2014 was found to be the coolest, with a mean temperature in the first half of May of only 13.2°C, in contrast to 2022, which was the warmest for the studied period with a mean temperature of 24.9°C reached in the second half of May (Figure 1).

For the approximately short 60-day flowering period in 2018 and 2022, the maximum amounts of pollen in the air were recorded when temperatures rose in the second half of April. In 2013, 2014, and 2019 the peak was also in the second half of April when temperatures rose and the pollen season was extended to about 75 days. In comparison, the *Platanus* pollen season in Poznan usually lasted for about three weeks for the period (2005-2009) (Nowak et al., 2012), while the average duration in Granada detected for the period 1992–2019 was 44 days, but with fluctuations ranging from 27 days in 2004 to 74 days in 2017 (Cariñanos et al., 2020).

Similarly, with a maximum in the first half of April, but with a significant increase in temperatures, was the pollen peak during the longest 4-month long pollen season in 2016. In 2017, the peak of *Platanus* pollen emissions was again in the first half of April, but the temperatures were 4.2°C lower than the mean values during the same period of the previous year.

After relatively lower temperatures in 2014, the flowering period in 2015 started later, in the second half of April, and was shorter with more abundant pollen emissions. The flowering period started the latest in 2022, and its peak coincided with the relatively sharp and steady increase in mean hourly air temperatures in Sofia.

The coefficients of variation (CV) for the mean hourly air temperature values found for the month of March ranged between 42% and 105%, with the largest temperature variation recorded in 2013. The variation of temperatures in the month of April was significantly smaller than March peak values, from 28% in 2018 to 66% in 2017, respectively. The stabilization trend in the fluctuations of mean hourly temperatures was also maintained in the month of May, with the CV fluctuating between 19% for the second half of May 2018 and 38% at the beginning of the month in 2019. Temperature fluctuations in June and July in the studied 10-year period ranged between 19% and 28%, respectively, for 2016 and 2017 in the second half of June.

Relative humidity, which is one of the most important indicators that determine the distribution of *Platanus* pollen (Maya-Manzano et al., 2017), in the present study showed greater fluctuations in the period from 2013 to 2017 (Figure 2).

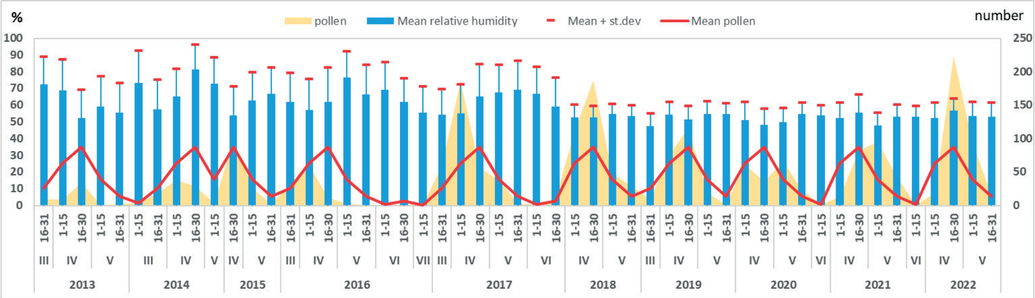

Figure 2. Dynamics of the mean values of the hourly averages of the relative humidity and the amount of pollen during the flowering phase over the period 2013-2022

In most cases, the higher number of pollen grains was associated with a period of lower relative humidity. In the month of March, relative humidity fluctuations varied with a CV between 16% and 31%, and in April between 12% and 33%, respectively. In May, fluctuations above 30% were found only in 2013. For the remaining years from 2014 to 2017, the variation was between 21% and 27%, respectively. For the second 5 years of the studied period, the fluctuations in relative humidity were smaller, between 11% and 17%, respectively. However, the number of identified pollen grains fluctuated widely, between 2 and 95. At the beginning of the studied period, the change in relative humidity in June varied between 23% and 29% while in 2020 and 2021 it was 12%. The atmospheric conditions were also dynamic in June 2016, where the CV of the relative humidity was 28%. A greater number of pollen grains was found at low relative humidity recorded in the period 2013 to 2017, while in the remaining 5-year period the relative humidity fluctuations were weak to insignificant, but the the same correlation was observed again, particularly in 2019 and 2021.

The dynamics of wind speed has a significant influence on the spread of pollen grains, but the observed correlation was ambiguous (Figure 3). In three of the years studied, 2013, 2014 and 2022, respectively, peak pollen amounts were found at relatively lower wind speeds. On the contrary, the highest number of pollen grains was recorded in periods of relatively strong air currents, such as in 2017 and 2020.

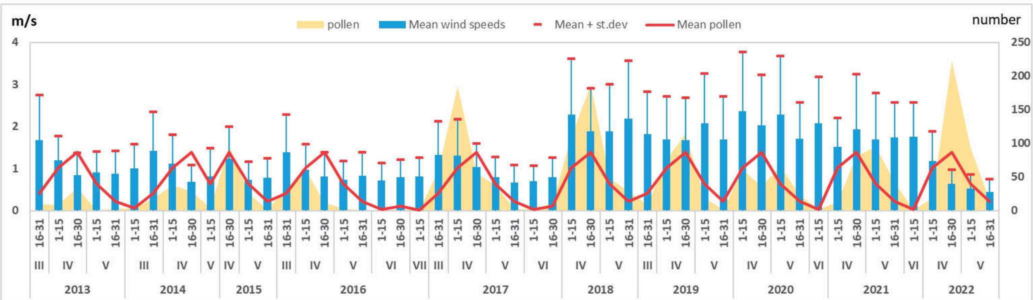

Figure 3. Dynamics of the mean values of the hourly averages of wind speeds and the amount of pollen in the flowering phase over the period 2013-2022

In general, in the period from 2018 to 2021, air currents were characterised by higher speed. At the beginning of the pollen season in March, the variation of the values was large, with a CV between 55 and 66%, respectively. In the second half of April in 2016, fluctuations in the air current speed reached 72%. In the same period of 2021, the wind speed variation was 69%. In the remaining cases, the CV was between 46 and 66%. In the first half of May

2014, wind speed fluctuations were large (CV of 84%), while in May of the other years, the variation was between 48 and 68%. Fluctuations in wind speeds in June and July were between 47 and 58% (Figure 3).

The fluctuations in atmospheric pressure (AP) in Sofia during the studied period were not big (Figure 4).

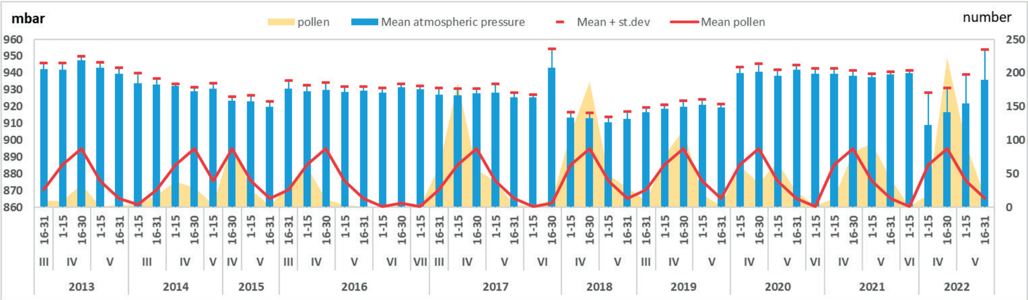

Figure 4. Dynamics of the mean values of the hourly averages of the atmospheric pressure and the amount of pollen in the flowering phase over the period 2013-2022

In March, the values ranged between 0.3 and 0.6%. The dynamics were similar in the following month - April. Only the last year, 2022, was an exception, when the CV was 1.6 and 2.1%, respectively. In May of the same year, the AP varied between 1.9 and 2.0%, but in the other years it was relatively stable with a CV of 0.2 and 0.6%, respectively. The AP was most stable in June and July, ranging between 0.2-0.3%. The only exception was the second half of June 2017, when the AP was higher and the fluctuations were more significant, with a CV of 1.2%. In the said period, the number of pollen grains was 5 times as big as the one obtained for the other years, for which the presence of *Platanus* pollen in the atmosphere of Sofia was reported in June. This could largely be explained with the high AP and the lack of heavy precipitation in that period to clear the atmosphere of pollen grains.

With an increase in solar radiation in spring, *Platanus* flowering intensified. This also occurred in the second half of March in 2014, the first half of April in 2016 and 2017, as well as the second half of April in 2013, 2015, 2018 and 2019 (Figure 5). In 2021, the pollen peak coincided with the increase in solar radiation only in early May, while in 2022, the maximum number of pollen grains was counted in the second half of April, when the solar radiation measured for that particular year was not great. This is largely explained by the higher temperatures and low wind speed during the said period. Slight decreases in the levels of mean solar radiation were found in the first half of April 2019, the second half of the same month in 2014, 2017 and 2022, at the beginning of May 2016, 2018 and 2019 and in the second half of the same month in 2020 and 2021. These decreases can be due to the scattering of solar radiation by particulate atmospheric pollutants, as well as to the absorption of radiation by water vapor in the infrared region of the spectrum, ozone absorption in the ultraviolet region (Tashev et al., 2016).

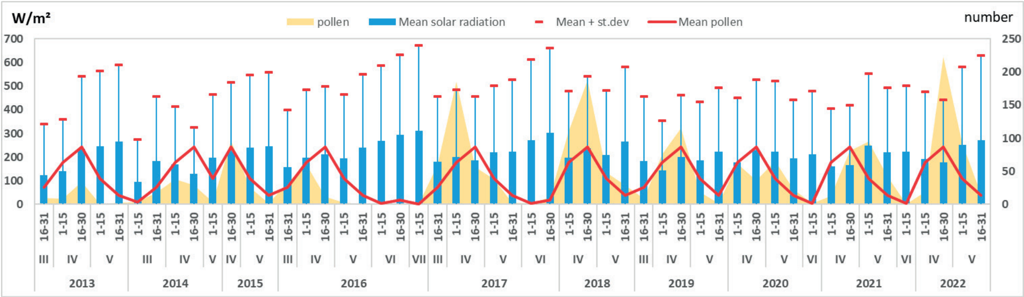

Figure 5. Dynamics of the mean values of the hourly averages of solar radiation and the amount of pollen in the flowering phase over the period 2013-2022

The mean direction of prevailing winds was from WSW (West-Southwest) in March and June to S (South), and in April and May to SSE. The prevailing air currents in the first half of July 2016 were from the SW. Generally, the prevailing winds in 2013 were from S to SW, and in the following 4 years from WSW to S. The prevailing winds in 2021 were from S to SSW. In the first half of May 2018 and 2022, as well as throughout April 2019 and 2020, the recorded winds blew from the SSE direction.

Fluctuations in wind direction are a common phenomenon in the studied area. CV variation in March was between 40% and 55%, in April 32% and 65%, respectively, while in May - 34 to 63%. Fluctuations in wind direction in June and July were also significant, between 37 and 67% respectively. This shows that in the studied period in Sofia Valley, winds the easterly, westerly and even northerly components could often be detected.

Air pollution has been a problem for the city of Sofia for several decades, where the main reason for this is the high concentration of PM_{10} (Doncheva-Boneva et al., 2017). Moreover, *Platanus* pollen may contribute to an increase in PM during the flowering period, consequently aggravating urban air quality (Cariñanos et al., 2020).

The distribution of PM_{10} in the studied *Platanus* flowering period for the last 10 years is shown in Figure 6. The presented maximum mean hourly value was recorded at 1 p.m. on 1 June 2016. It exceeded the previous value by 300 μg/m^3 and was 2.7 times higher than the calculated mean value for the following hour. That fact could hardly be attributed to extreme pollen grain dispersal, even in the immediate vicinity of the Automatic Monitoring Station. During the reporting period, there were other peak concentrations of PM_{10}, which were mainly a result of human activity, not of the pollen season.

The recorded peaks of pollen emissions added to the already polluted atmosphere of the city of Sofia, but their share was relatively small. This trend was more clearly noticeable in 2013, 2014, 2016, 2019, 2020, and 2021. As a whole, in the three years with the maximum number of pollen grains counted (2017, 2018 and 2022) the relative share of pollen in the total amount of particles was greater, as the atmosphere was less polluted with PM_{10}. This showed that with the improvement of air quality in Sofia, the share and importance of tree pollen, and the *Platanus* pollen in particular, will increase.

A significant positive correlation was found between the number of pollen grains and the mean values for the 10-year data series (R = 0.70) on the one hand and wind speed (R = 0.32) on the other. The latter was explained by the fact that stronger wind promoted their further spread, which in turn led to higher pollen levels reported at the aerobiological monitoring station. Conversely, higher values of relative humidity, atmospheric pressure and solar radiation resulted in lower pollen loads. This is also confirmed by the identified negative correlations (Table 1).

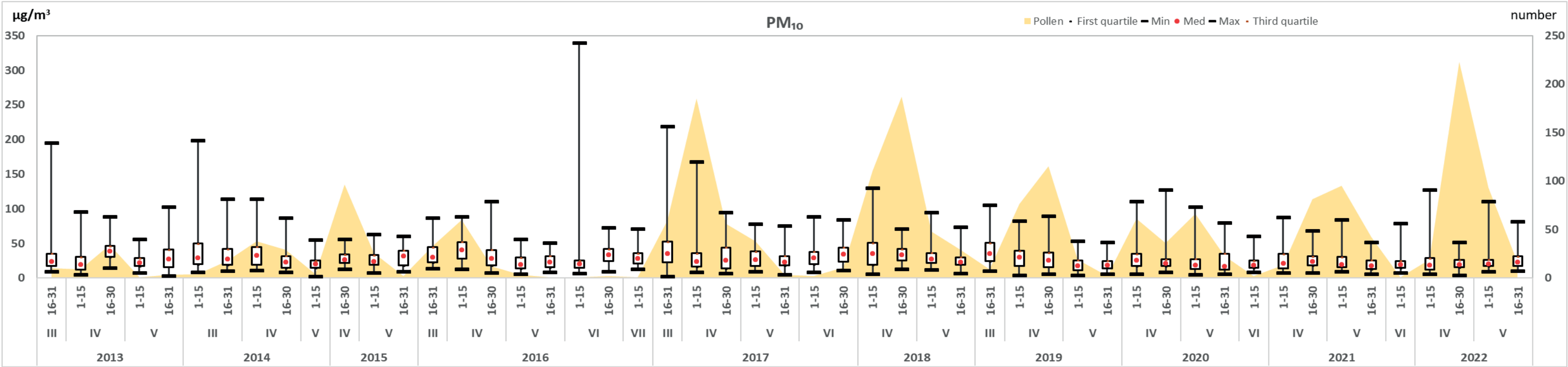

Figure 6. Box-plots of mean values of the hourly averages of PM_{10} contents and the amount of pollen in the flowering phase over the period 2013-2022

Table 1. Spearman Rank Order Correlations (2013 – 2022)

	Mean	AirTem	WS	UMR	Press	GSR	WD	PM_{10}
Pollen	**0.70***	-0.26	**0.32***	**-0.45***	**-0.28***	**-0.29***	-0.20	0.20

AirTem – air temperature (°C); WS – wind speed (m/s); UMR – relative humidity (%); Press - atmospheric pressure (mbar),; GSR – general solar radiation (W/m2); WD – wind direction; PM_{10} (µg/m^3)
* correlations are significant at $p < 0,05$

A significant negative correlation between pollen concentrations and relative humidity was reported (Sánchez-Reyes et al., 2009; Álvarez-López et al., 2022).

Rosianu et al. (2022) found a positive correlation between the concentration of pollen and particulate matter PM_{10}.

CONCLUSIONS

The results of the study showed that the meteorological factors which directly affect the concentrations of airborne pollen were wind speed, relative humidity, atmospheric pressure and solar radiation.

For the time being, the total amount of *Platanus* pollen in Sofia is relatively low. However, in recent years there has been an upward trend. That growth trend is expected to continue due to the degree of maturity of *Platanus* specimens. The use of that species as a dominant element in the urban green infrastructure of Sofia should be reconsidered, not only to improve air quality, but also to enhance urban biodiversity, its resilience and ecosystem services.

In future research, a continuous aerobiological monitoring and a long term and large-scale clinical study on the allergenic potential of each *Platanus* species should be conducted. Designing a *Platanus* pollen calendar and making it publicly available would be a preventive public health measure.

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REFERENCES

Alcázar, P., Galán, C., Torres, C. & Dominguez-Vilches E. (2015). Detection of airborne allergen (Pla a 1) in relation to Platanus pollen in Cordoba, South Spain. *Annals of Agricultural and Environmental Medicine*, 22, 96–101.

Álvarez-López, S., Fernández-González, M., Sánchez Espinosa, K., Amigo, R. & Rodríguez-Rajo, F. (2022). London Plane Tree Pollen and Pla A1 Allergen Concentrations Assessment in Urban Environments. *Forests*, 13, 2089. 1–17.

Anisimova, S. (2023). Analysis of the dendrofloristic composition of urban street tree plantings in Sofia. *Scientific Papers. Series B. Horticulture* [Unpublished manuscript]

Baldachini, C., Castanheiro, A., Maghakyan, N., Sgrigna, G., Verhelst, J., Alonso, R., Amorim, J., Bellan, P., Bojovic, D., Breuste, J., Bühler, O., Cântar, I., Cariñanos, P., Carriero, G., Churkina, G., Dinca, L., Esposito, R., Gawroński, S., Kern, M., Le Thiec, D., Moretti, M., Ningal, T., Rantzoudi, E., Sinjur, I., Stojanova, B., Aničić Urošević, M., Velikova, V., Živojinović, I., Sahakyan, L., Calfapietra, C. & Samson, R. (2017). How does the amount and composition of PM deposited on Platanus acerifolia leaves change across different cities in Europe? *Environ Sci Technol*., 57:1147–1156.

Bedeschi, E., Campari, C., Candela, S., Collini, G., Caranci, N., Frasca, G., Galassi, C., Francesca, G. & Vigotti, M. (2007). Urban air pollution and respiratory emergency visits at pediatric unit, Reggio Emilia, Italy. J. *Toxicol. Environ. Health-Part A: Curr. Issues*, 70(3–4), 261–265.

Bruffaerts, N., De Smedt, T., Delcloo, A., Simons, K., Hoebeke, L., Verstraeten, C., Van Nieuwenhuyse, A., Packeu, A., Hendrickx, M. (2018). Comparative long-term trend analysis of daily weather conditions with daily pollen concentrations in Brussels, Belgium. *Int J Biometeorol,* 62: 483–491.

Cariñanos, P., Ruiz-Peñuela, S., Valle, A. & Díaz de la Guardia, C. (2020). Assessing pollination disservices of urban street-trees: The case of London-plane tree (*Platanus* x *hispanica* Mill. ex Münchh). *Science of the Total Environment*, 737 (2020) 139722

Cariñanos, P., Foyo-Moreno, I., Alados, I., Guerrero-Rascado, J., Ruiz-Peñuela, S., Titos, G., Cazorla, A., Alados-Arboledas, L. & Díaz de la Guardia, C. (2021). Bioaerosols in urban environments: Trends and Interactions with pollutants and meteorological variables based on quasi-climatological series. *Journal of Environmental Management*, 282: 111963.

Cariñanos, P., Grilo, F., Pinho, P., Casares-Porcel, M. Branquinho, C., Acil N., Andreucci, M., Anjos, A., Bianco, P., Brini, S., Calaza-Martínez, P., Calvo, E., Carrari, E., Castro, J., Chiesura, A., Correia, O., Gonçalves, A., Gonçalves, P., Mexia, T., Mirabile, M., Paoletti, E., Santos-Reis, M., Semenzato, P. & Vilhar U. (2019). Estimation of the allergenic potential of urban trees and urban parks: towards the healthy design of urban green spaces of the future. *Int. J. Environ. Res. Public Health,* 16.

Cipriani, F, Tripodi, S., Panetta, V., Perna, S., Potapova, E., Dondi, A., Bernardini, R., Caffarelli, C., Casani, A., Cervone, R., Chini, L., Comberiati, P., De Castro, G., Miraglia Del Giudice, M., Dello Iacono, I., Di Rienzo Businco, A., Gallucci, M., Giannetti, A., Mastrorilli, C., Moschese, V., Pelosi, S., Sfika, I., Varin, E., Villella, V., Zicari, A., Brindisi, G., Ricci, G. & Matricardi, P. (2019). Early molecular biomarkers predicting the evolution of allergic rhinitis and its comorbidities: A longitudinal multicenter study of a patient cohort. *Pediatr Allergy Immunol*. 30: 325–334.

Curtis, A., Helmig, D., Baroch, C., Daly, R. & Davis, S. (2014). Biogenic volatile organic compound emissions from nine tree species used in an urban tree-planting program. *Atmos. Environ*., 95, 634–643.

Damialis, A., Fotiou, C., Halley, J. & Vokou, D. (2011). Effects of environmental factors on pollen production in anemophilous woody species. *Trees, Structure and Function*, 25, 253–264.

Doncheva-Boneva, M., Koleva-Lizama, I, Mitkov, S. & Gosteva, L. (2017). Analysis of air temperature and pollutant variations in Sofia. *Forestry Ideas*, 23, 2 (54): 152–159

Fernández-González, D., González-Parrado, Z., Vega-Maray, A., Valencia Barrera, R., Camazón-Izquierdo, B., De Nuntis, P. & Mandrioli, P. (2010). *Platanus* pollen allergen a1: quantification in the atmosphere and influence on a sensitizing population. *Clin. Exp. Allergy* 40 (1), 1701–1708.

Gioulekas, D., Papakosta, D., Damialis, A., Spieksma, F., Giouleka, P. & Patakas, D. (2004). Allergenic pollen records (15 years) and sensitization in patients with respiratory allergy in Thessaloniki, Greece. *Allergy* 59 (2), 174–184.

Jing, X., Lun, X., Fan, C. & Ma, W. (2020). Emission patterns of biogenic volatile organic compounds from dominant forest species in Beijing, China. *J Environ Sci (China),* 95:73–81.

Loureiro, G., Rabaça, M., Blanco, B., Andrade, S., Chieira, C. & Pereira, C. (2005). Aeroallergens sensitization in an allergic paediatric population of Cova da Beira, Portugal. *Allergol Immunopathol (Madr),* 33:192–198.

Magyar, D., Páldy, A., Szigeti, T. & László, O. (2022). A regulation-oriented approach for allergenicity categorization of plants. *Urban Forestry & Urban Greening*, 70, 127530.

Maya-Manzano, J., Fernández-Rodriguez, S., Monroy-Colín, A., Silva-Palacios, I., Tormo-Molina, R. & Gonzalo-Garijo A. (2017). Allergenic pollen of ornamental plane trees in a Mediterranean environment and urban planning as a prevention tool. *Urban Forestry and Urban Greening*, 27, 352–362.

McBride, J., (2017). The world's urban forests. History, composition, design, function and management. Future City. vol. 8. Springer, Cham. Switzerland.

Nikolov, G., Tsvetanova, R. & Hristova-Savova, M. (2021). A pilot study of sensitization to plane treepollen in Sofia, Bulgaria. *J of IMAB*, 27(4): 4128-4132.

Nowak, M., Szymanska, A. & Grewling, L. (2012). Allergic risk zones of plane tree pollen (*Platanus* sp.) in Poznan. *Postepy Dermatol Alergol*. 29(3):156-160.

Oduber, F., Calvo, A., Blanco-Alegre, C., Castro, A., Vega-Maray, A., Valencia-Barrera, R., Fernández-González, D. & Fraile, R. (2019). Links between recent trends in airborne pollen concentrations, meteorological parameters and air pollutants. *Agricultural and Forest Meteorology*, 264:16-26.

Pauleit, S., Jones, N., Garcia-Martin, G., Garcia-Valdecantos, J., Rivière, L., Vidal-Beaudet, L., Bodson, M. & Randrup, T. (2002). Tree establishment practice in towns and cities–results from a European survey. *Urban For. Urban Green*. 1 (2), 83–96.

Ribeiro, H. & Abreu, I. (2014). A 10-year survey of allergenic airborne pollen in the city of Porto (Portugal). *Aerobiologia*, 30 (3), 333–344

ROPKR https://ropkr.sofia.bg/public/green/trees/list/ Accessed 15.03.2023

Rosianu, A., Leru, P., Stefan, S., Iorga, G. & Marmureanu L. (2022). Six-year monitoring of atmospheric pollen and major Air pollutant concentrations in relation with Meteorological factors in Bucharest, Romania *Romanian Reports in Physics*, 74, 703.

Sánchez-Reyes, E., Rodríguez de la Cruz, D., Sanchís-Merino, M. & Sánchez-Sánchez, J. (2009). First results of Platanus pollen airborne content in the middle-west of the Iberian Peninsula. *Aerobiologia*, 25, 209–215.

Sauliene, I., Sukiene, L. & Kazlauskiene, V. (2019). The assessment of atmospheric conditions and constituents on allergenic pollen loads in Lithuania. *Journal of Environmental Management*, 250: 109469.

Sedghy, F., Sankian, M., Moghadam, M., Ghasemi, Z., Mahmoudi, M. & Varasteh, A. (2017). Impact of traffic-related air pollution on the expression of *Platanus orientalis* pollen allergens. *Int J Biometeorol.* 61:1–9.

Stanev, S., Kyuchukova, M. & Lingova, S. (1991). Climate of Bulgaria. BAS, Sofia. 499 p. (in Bulgarian).

Tashev, V., Werner, R., Manev, A. & Goranova, M. (2016). Measurement of solar energy falling on the ground for different periods of time using the weather station. Vantage Pro2 Plus. SES 2016. Twelfth Scientific Conference with International Participation. SPACE, ECOLOGY, SAFETY. 2-4 November 2016, Sofia, Bulgaria, 231-239 (in Bulgarian).

Tedeschini, E., Rodríguez-Rajo, F., Caramiello, R., Jato, V. & Frenguelli, G. (2006). The Influence of Climate Changes in *Platanus* spp. pollination in Spain and Italy. *Grana*, 45, 222–229.

Vrinceanu, D., Berghi, O., Cergan, R., Dumitru, M., Ciuluvica, R., Giurcaneanu, C. & Neagos, A. (2021). Urban allergy review: Allergic rhinitis and asthma with plane tree sensitization (Review). *Exp Ther Med*. Mar; 21(3): 275.

Xiaoshan, Z., Yujing, M., Wenzhi, S. & Yahui, Z., (2000). Seasonal variations of isoprene emission from deciduous trees. *Atmos. Environ*. 34, 3027–3032.

NSI. https://www.nsi.bg/bg/content/2975/население-по-области-общини-местоживеене-и-пол Accessed 15.03.2023