sustainability

MDPI

Article

Multiple Monitoring Stations in Big Cities: First Example of Three Spore Traps in Rome

Annarosa Miraglia [1], Maria Antonia Brighetti [2], Denise De Franco [1], Alessandro Di Menno di Bucchianico [1,3], Francesca Froio [4] and Alessandro Travaglini [2,*]

1 Ph.D. Program in Evolutionary Biology and Ecology, Department of Biology, University of Rome Tor Vergata, 00133 Rome, Italy
2 Department of Biology, University of Rome Tor Vergata, 00133 Rome, Italy
3 ISPRA, Italian Institute for Environmental Protection Research, 00144 Rome, Italy
4 Allergology Centre, San Pietro-Fatebenefratelli Hospital, 00189 Rome, Italy
* Correspondence: alessandro.travaglini@uniroma2.it; Tel.: +39-32-0431-7076

Abstract: (1) Background: Rome is a municipality with an area of 1287 km^2 and presents floristic-vegetational complexity that is reflected in the composition of aerospora, which are responsible for pollinosis. The presence of airborne pollen can be detected by pollen monitoring. The large extent of the city's territory makes it possible to verify possible changes in pollen composition in different sites of the city. With this in mind, a study was conducted to assess the differences in airborne pollen concentration, considering phenological and production indicators at three different sites in the city. (2) Methods: Pollen data of eight taxa were considered, *Alnus* spp., *Castanea sativa* Miller, Cupressaceae-Taxaceae, *Olea europaea* L., Platanaceae, Poaceae, *Quercus* spp., and Urticaceae, during 2020 and 2021, using three monitoring samplers. The airborne pollen concentration and the seasons of the three centers were calculated and compared with each other. (3) Results: The diversity between the three samplers shows a phenological succession in accordance with the microclimatic diversity present in the city. The heterogeneity of the airborne pollen concentration reflects the floristic-vegetational diversity, while qualitative and quantitative parameters indicate a homogeneous flowering trend reflecting the seasonality of the various species. (4) Conclusions: The present work and the Italian geographic context suggest the need for a greater number of sampling points to guarantee a true localization of the data. Having several sampling stations also contributes to the protection of health and green areas, which are difficult to manage, conserve, and maintain.

Keywords: pollen; aerobiology; allergens; pollen trap; urban flora

check for updates

Citation: Miraglia, A.; Brighetti, M.A.; Franco, D.D.; Di Menno di Bucchianico, A.; Froio, F.; Travaglini, A. Multiple Monitoring Stations in Big Cities: First Example of Three Spore Traps in Rome. *Sustainability* **2023**, *15*, 4155. https://doi.org/10.3390/su15054155

Academic Editors: Anna Maria Mercuri, Assunta Florenzano, Eleonora Clò and Gabriel Servera-Vives

Received: 23 December 2022
Revised: 13 February 2023
Accepted: 14 February 2023
Published: 24 February 2023

1. Introduction

Rome is the Italian capital and the seat of the Lazio region in central Italy (Figure 1). Its territory also includes the Vatican City State. Throughout its long history, the city has undergone phases of expansion and reduction, especially on the orographic left bank of the river Tiber.

The original settlement, founded between the Tiber and the Palatine, occupied, year after year, the entire plain, known as the 'Roman countryside', toward the east, as far as the Alban Hills, and the right bank of the river, including important hills such as the Janiculum and Monte Mario (139 m above sea level). As with all large cities in the world after World War II, Rome grew haphazardly, often without clear urban planning or by disregarding the master plan. Within a few decades, it reached its current size of 1287 km^2 [1,2]. The green heritage of Rome's territory consists of 129,000 hectares, of which about 64% is safeguarded and protected; despite the transformations that have taken place in recent decades, Rome still remains a green city, with an endowment of about 14 square meters per inhabitant [3]. Rome is the most populated municipality in the country; its population has risen from 212,000 in 1871 to 2,808,293 [4]. Rome attracts around 20 million tourists and pilgrims every year [5]. In addition, every day more than 350,000 workers arrive in the city for work from all over Lazio and the neighboring regions. Therefore, a large number of people are mainly exposed to pollen released by the plant species present in this area, as well as pollen from long-distance transport [6].

Figure 1. The three sampling areas in Rome: CP, Cipro—Rome Center; SP, Villa San Pietro Hospital—Rome North; TV, University Tor Vergata—Rome South.

It is important to characterize the territory of Rome not only in historical and anthropic terms, but also in terms of vegetation and climate. From an aerobiological point of view, an earlier study was conducted in Rome [7,8], but this multi-center approach represents an important update.

1.1. Climate, Flora, and Vegetation

Rome is located within the Mediterranean Region; however, its climate is also influenced by the innermost sectors of the Temperate Region. From a bioclimatic point of view, it belongs to the mesomediterranean sub-humid type, with mild winters and arid summers (three/four months of aridity). The average annual temperature is 15 °C, and the average annual precipitation is 839 mm [9,10]. The climatic characteristics of the area, the extension, and the landscape complexity of the territory determine the floristic and vegetation complexity. The geology is varied and mainly characterized by clay and sand deposits from the marine Plio-Pleistocene and shale and conglomerates from the middle to upper continental Pleistocene. From 0.5 Mya onwards, two important alkaline-potassic explosive volcanoes began their activity. In the north-western sector is the Sabatini volcanic district. On the south-eastern slope are the Colli Albani. The heterogeneous morphology of the landscape is characterized by gentle hills (from 50 to 139 meters above sea level), valleys, and two main rivers, Tiber and Aniene, with many small tributaries [11].

Due to the biophysical characteristics of the area, the potential natural vegetation consists of oak groves dominated by *Quercus cerris* L. and *Q. frainetto* Ten., with evergreen oak (*Q. ilex* L.) and cork oak (*Q. suber* L.) limited to the slopes [12]; other common woody species are *Acer monspessulanum* L., *A. campestre* L., *Fraxinus ornus* L., *Corylus avellana* L., *Crataegus monogyna* L., *Viburnum tinus* L., *Pistacia lentiscus* L., and trees of *Robinia pseudoacacia* L., *Ailanthus altissima* (Mill) Swingle, and *Ulmus* spp. [9,10,13,14]. The current vegetation is strongly influenced by anthropogenic impact, so most of the vegetation is characterized by anthropogenic communities [14]. Regarding this, extensive literature describes the floristic biodiversity of Rome, with scientific contributions spanning over 70 years of botanical research [13,15–19].

Archaeological areas and monuments have also been studied from a botanical point of view, revealing an important specific flora [20] that needs to be taken into account.

The vegetation complexity described so far is distributed over an important network of urban nature parks of approximately 16,000 hectares, coordinated by Roma Natura, a specific regional agency that manages environmental and landscape protection [10,21]. Urban flora generally has high diversity; this richness depends on the high heterogeneity of the environments, with natural, semi-natural, or artificial habitats; in addition, urban ecosystems can also host alien plant species such as ragweed [22]. The flora of metropolitan Rome contains 1649 entities belonging to 139 families and 677 genera.

The families represented by the largest number of species are Poaceae (182 entities), Asteraceae (175) and Fabaceae (169), followed by Brassicaceae (69), Caryophyllaceae (65), Lamiaceae (63), Apiaceae (58), and Rosaceae (50) [13]. A phytosociological study of Rome's urban woodlands has identified six different syntaxonomic types [17]: (1) *Orno-Quercetum ilicis*, an edaphic-xerophytic variant of the city's potential natural vegetation (deciduous *Quercus* sp. pl. woodlands); (2) *Aquifolium-Fagetum carpinetosum betuli*, in the northern slopes of alluvial valleys; (3) *Q. suber* and *Q. pubescens*, classified in the order *Quercetalia pubescenti-petraeae*; (4) *Quercetum ilicis galloprovinciale suberetosum*; (5) coppice of *Q. cerris* and *Q. frainetto*, belonging to the alliance *Teucrio siculi-Quercion cerridis*; (6) mixed mesophilous woodland of *Q. cerris* and *Ostrya carpinifolia* Scop., which may be considered a transition between the *Doronic-Fagion* alliance and the *Teucrio siculi-Quercion cerridis* alliance. These six types of woody vegetation are all characterized by the great penetration of Mediterranean species belonging to the *Quercetea* and *Quercetalia ilicis* and the Central European species of the *Quercus-Fagetea*.

In addition, there are numerous large historic villas in Rome with valuable flora and vegetation. From the villas of important princes and cardinals to the gardens created immediately after the Unification of Italy, there is a great variety of native and exotic species [23]. Imposing urban trees can be found in the most important and large avenues. The floristic-vegetational heterogeneity present is linked to the different levels of anthropization that induce changes in the composition and structure of potential plant communities; suffice it to think of the presence of Poaceae in agricultural areas or Urticaceae in public gardens or along roads [24], or even roadside trees, of which about 120 species have been surveyed, characterized by the predominant genera *Acer* spp. (7378), *Cercis siliquastrum* L. (7594), *Cupressus* spp. (2269), *Hibiscus syriacus* L. (10,649), *Ligustrum* spp. (14,117), *Nerium oleander* L. (5890), *Pinus* spp. (16,507), *Platanus* spp. (17,251), *Populus* spp. (6310), *Prunus* spp. (10,985), *Quercus* spp. (8679), *Robinia* spp. (18,866), *Tilia* spp. (7149), and *Ulmus* spp. (3588) [17,25].

The territory of the city of Rome is characterized by a high level of plant diversity deriving from the great environmental variability, as well as from the prolonged human impact through pastoralism and agriculture that has lasted for millennia with the succession of different populations; furthermore, the moderate presence of ecological corridors allows for a high level of connectivity between the vegetation of the periphery and that present within the city. The complexity of the territory of the city of Rome is associated with the progressive peripheral expansions in which the urban fabric has been modified over time with the addition of road inserts, buildings, parks, and gardens; thus, urban green spaces partly reflect the natural variation of the city's territory and are partly the result of urban planning interventions carried out according to criteria dictated by the aesthetic-ornamental trends of a given historical period [26].

1.2. Pollen Flora and Aerobiological Monitoring Stations

Obviously, this floristic diversity is reflected in an equally varied pollen spectrum for the city of Rome. Indeed, the presence of pollen is mainly linked to local flora and vegetation, but the contribution of long-distance pollen transport is not negligible [27–30]. Thus, pollen concentrations in the atmosphere can vary throughout the year and from one year to the next; this variability in aerospore composition depends on meteorological factors such as temperature, precipitation, wind intensity and direction, long-distance transport, urban area change and transformation, and vegetation changes. The prevailing winds come from the southern quadrant in autumn and from the southwest in summer and spring; in winter, the prevailing winds come from both the south and the north [31].

Biological particles can have detrimental effects on health, with pollen and fungal spores being the most common source of airborne allergens responsible for respiratory and allergic diseases [32–37]; these have also recently been associated with SARS-CoV-2 infection rates [38,39].

Pollen is responsible for allergies (e.g., asthma and rhinitis). Its variations in concentration, allergenicity, dispersion, and transport are linked to various factors such as weather conditions (air temperature, relative humidity, precipitation, wind speed), climate change and related factors such as air pollutants, the characteristic of the vegetation site, seasonality, and urban green management [27,36,40,41].

Aerobiological monitoring is an important tool for avoiding exposure to allergens and thus for preventing allergic symptoms [42]; therefore, since the 1980s, in the most important cities of Italy, Europe, and other continents, it has been possible to know the pollen concentration in the air through aerobiological monitoring activities conducted by monitoring centers. These centers soon built national and international networks; this made it possible to establish minimum requirements for each center and to standardize sampling methods [43–45].

Buters et al. [46] wanted to take inventory of the pollen- and spore-monitoring stations in the world, and it turned out that there were about 900 active pollen-monitoring stations in the world, most of which were in Europe (>500). Today, after three years, some of them are no longer operational; others have been newly installed.

The distribution of the samplers in the world is not homogeneous. Italy, with its 61 stations, is in the top six countries by number of active pollen stations [46,47]. Some cities are densely monitored by several pollen traps (e.g., Seoul, Tokyo, Toronto, Sydney, Madrid, Ourense, Sevilla, Mexico, DC [46], and Rome). In Italy, other big cities, such as Milan, deploy the samplers on the territories of the different adjacent communes. Therefore, only in Rome are there three samplers within the same municipality, because, considering the environmental biodiversity of Rome, we decided to install different samplers in the Rome municipality to verify the eventual difference in airborne pollen concentrations.

1.3. Aim

Knowledge of the pollen concentration at different sites in Rome is very important for allergic persons, and this information, analyzed with pollution data from different monitoring stations belonging to ARPA Lazio (Regional Environmental Protection Agency), could be used to better assess the impact of aerosols on human health [48].

Many studies on the vegetation of the city of Rome highlight a floristic richness [49–52] that is reflected in the diversity of the airborne pollen concentration at a local level [8]; thanks to the positions of the three samplers, it is possible to detect the concentration of airborne pollen and relate the differences, even minimal ones, to the local flora. In virtue of the fact that pollens are considered environmental indicators for the floristic characterization of a territory, this study aims to verify the correspondence between the different phenological phases of the plant species present and the phenological and production indicators of the pollen season.

2. Materials and Methods

Two years of data, from 1 January 2020 to 31 December 2021, were considered, from three monitoring samplers in Rome: University Tor Vergata (TV)—Rome South, Villa San Pietro Hospital (SP)—Rome North, and Cipro (CP)—Rome Center. The three samplers have been active since 1996, 2000, and 2017, respectively (Figure 1). Due to a fire, sampling by SP in North Rome was suspended for a long time; therefore, the usable data for the comparison between the three samplers were reduced to just two years.

The oldest station at Tor Vergata University (TV), operating since 1996, is located on the roof of the Biology Department building of the university, at about 12 m above the ground level (80 m a.s.l., 41°51′13.5″ N, 12°36′14.2″ E); the second (SP), operating since 2000, at San Peter Hospital Fatebenefratelli, near Insugherata Park, at about 15 m above ground level (86 m a.s.l., 41°57′48.6″ N, 12°27′03.2″ E); the last (CP), operating since March 2017, near Vatican City, at 12 m above ground level (31 m a.s.l., 41°54′26.6″ N, 12°26′57.0″ E).

The SP is surrounded by the nature reserve of the Insugherata and Villa Borghese park, with the presence of evergreen scrub with *Quercus ilex*, *Q. pubescens*, *Fraxinus ornus*, *Ligustrum* spp., *Arbutus unedo* L., *Pistacia lentiscus*, *Olea europaea,* and so on; on the sheltered slopes, there are *Quercus robur* L., *Ostrya carpinifolia*, and *Ilex aquifolium* L. In addition, several species belonging to the Cupressaceae are present in private gardens.

The CP is characterized by the presence of important tree-lined avenues consisting of plane trees. Stone pine and ruderal flora are also very important with *Parietaria* spp., Poaceae, and Amaranthaceae, due to their low maintenance. TV is a suburban area with extensive dry meadows; however, the recent planting of trees in new neighborhoods (new headquarters of the Bank of Italy, C.N.R., National Research Council, and Botanical Garden in the last twenty years) and the presence of an important olive grove and the woods of the Alban Hills contribute to the composition of the aerospora [24].

The sampling methods are in accordance with the UNI 11108/2004 rule and the following update CEN/TS 16868:2019. The sampler consists of different components: a single-stage impactor of particles, a suction pump, an intake orifice, a rotating drum, and a directional wing. The air is captured by a vacuum pump to ensure a constant flow of 10 L/min, corresponding to the average human respiratory capacity, through an orifice of known size (2 × 14 mm), which is continuously oriented against the wind thanks to a directional wing and positioned at a height of at least 1 m above the supporting ground. The air flow is directed on a surface consisting of a transparent plastic Melinex® tape, coated with a 3% polydimethylxiloxanes solution in carbon tetrachloride as the trapping surface. The trapping surface moves at a speed of 2 mm/h on a cylindrical rotating drum that makes a complete round in a week [43,45,53].

At the end of the exposure, the sampling surface (tape) is cut into 48 mm segments representing the daily samplings and prepared for mounting on microscope slides. The tape is treated with glycerine gelatine to adhere perfectly to the slides and stained with a basic fuchsin solution that colors only the pollen grains. Finally, the slides are observed under an optical microscope at 400× magnification using the horizontal continuous strip reading method for pollen characterization. Pollen concentration is expressed as the number of pollen grains/m^3 of air [45,53,54]. The pollen data used refer to the daily concentration, expressed in pollen grains/m^3 [53], of the pollen of botanical, herbaceous, and woody taxa mainly present in the municipal territory, chosen on the basis of abundance and allergenicity.

In this study, eight taxa were considered [55]: two herbaceous—Poaceae (Gramineae) and Urticaceae—and six arboreal—*Alnus*, Cupressaceae-Taxaceae, *Castanea sativa* Miller, *Quercus* spp., *Olea europaea* L., and Platanaceae (*Platanus hispanica* Mill. ex Münchh). The typical vegetation of the Mediterranean area is rich in Urticaceae (*Parietaria* spp. and *Urtica* spp.), Oleaceae, Cupressaceae, Poaceae, Asteraceae (Compositae), and many other allergenic species, with internal variations depending on the region and country [56]. The chosen taxa were the subject of recent multicenter studies on airborne pollen allergy in the Mediterranean environment [42], to which the plane tree (*Platanus*), a species that is very abundant in Rome and characteristic of street trees (especially in the city center), was added.

For each taxon, within each of the three sites, the factors taken into consideration were both phenological indicators—start dates, end dates, duration of the pollen season (number of days)—and production indicators—the intensity of the pollen season (annual pollen integral, APIn), the timing and magnitude of the peak day (the highest average daily pollen concentration during the pollen season), and daily pollen data (daily concentrations p/m^3), using the method of Jäger et al. [57], as well as the pollen season limits, according to which the season [57] begins on the day when the amount of pollen is equal to or greater than 5% of the annual total, provided it is not followed by more than six consecutive days with zero values, and the end of the season is defined as the day when 95% of the annual total has been reached. Data for Cupressaceae-Taxaceae are considered from November of the previous year to October of the current year, as it is a winter-flowering taxon. The 2020–2021 total pollen abundances (APIn) for the three samplers include every taxon, even those not considered in this study. The datasets were constructed by calculating phenological and production indicators for each of the eight taxa considered. The parameters obtained were statistically processed considering the parameters of the three sites. The similarity and diversity of airborne pollen concentration in the two years and at the three sites were analyzed using Pearson's rank correlation statistics. The statistical software IBM-SPSS 25.0 [58] was used for the statistical analysis.

3. Results

During the aerobiological sampling of the three spore traps—TV, SP, and CP—carried out over the two years 2020 and 2021, 731 days for TV (366 days in 2020 and 365 in 2021), 725 days for SP (365 days in 2020 and 360 in 2021), and 700 days for CP (351 days in 2020 and 349 in 2021) were recorded. The unavailable data represent 1.69% or 37 days.

These data show important differences between the three samplers in terms of abundance, but also in terms of distribution between tree and herbaceous taxa, in both 2020 and 2021.

In 2020, the total pollen sampled for TV is 62,417 p/m^3 (grain pollen/air m^3), subdivided into 43,300 p/m^3 arboreal and 18,588 p/m^3 herbaceous; for SP, it is 52,310 p/m^3, subdivided into 40,910 p/m^3 arboreal and 11,419 p/m^3 herbaceous; and finally, for CP, it is 61,450 p/m^3, subdivided into 53,123 p/m^3 arboreal and 8140 p/m^3 herbaceous. In 2021, the total pollen sampled for TV is 25,450 p/m^3, subdivided into 15,112 p/m^3 arboreal and 10,281 p/m^3 herbaceous; for SP, it is 21,818 p/m^3, subdivided into 13,712 p/m^3 arboreal and 8046 p/m^3 herbaceous; finally, for CP, it is 17,475 p/m^3, subdivided into 7398 p/m^3 arboreal and 10,058 p/m^3 herbaceous (Figure 2). The slight discrepancy between the total pollen values and the sum of the pollen of the arboreal and herbaceous taxa is due to the counting of unidentified, broken, or deformed pollen.

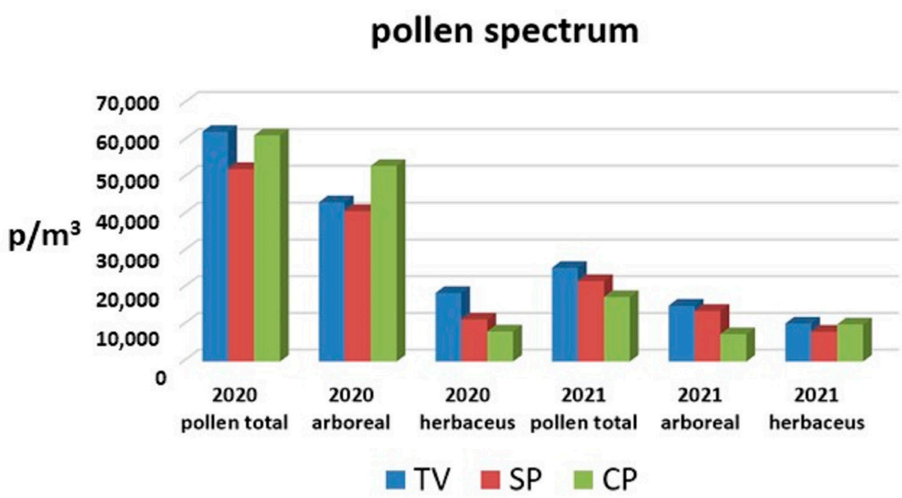

Figure 2. The histogram shows the variability of the floristic composition in three sampling sites (CP, Cipro—Rome Center; SP, Villa San Pietro Hospital—Rome North; TV, University Tor Vergata—Rome South) in the years 2020 and 2021.

As can be seen in Table 1, the taxa chosen for the proposed study account for about 80% of the total airborne pollen in the Rome and are among the main allergenic pollens.

Table 1. Phenological indicators—start dates, end dates, length of the pollen season (number of days)—and indicators of production—the intensity of the pollen season (annual pollen integral, APIn), the timing and magnitude of the peak day (the highest daily average pollen concentration during pollen season), for each taxon, in three sites, in 2020 and 2021.

2020			Indicator	2021		
TV	SP	CP		TV	SP	CP
			flowering START (day/month)			
3/2	3/2	3/2	*Alnus* spp.	29/1	30/1	5/2
3/2	4/2	4/2	Cupressaceae/Taxaceae	30/1	30/1	6/2
13/6	13/6	13/6	*Castanea sativa* Miller	19/6	13/6	16/6
10/4	31/3	30/3	*Quercus* spp.	6/4	3/4	4/4
24/4	24/4	21/4	Poaceae	29/4	29/4	5/5
24/4	4/5	21/4	*Olea europaea* L.	26/4	16/5	16/5
23/3	19/3	18/3	Platanaceae	21/3	26/3	22/3
4/3	28/2	15/3	Urticaceae	28/2	29/3	22/2
			flowering END (day/month)			
22/3	21/3	22/3	*Alnus* spp.	28/3	24/3	23/3
7/5	4/4	12/4	Cupressaceae/Taxaceae	19/4	24/4	2/4
16/7	21/7	12/7	*Castanea sativa* Miller	12/7	10/8	25/7
30/5	4/6	28/5	*Quercus* spp.	2/6	9/6	29/5
14/7	9/8	8/7	Poaceae	4/7	22/8	15/9
2/6	4/6	3/6	*Olea europaea* L.	7/6	19/6	9/6
21/4	21/4	17/4	Platanaceae	26/4	22/4	10/4
7/7	29/7	3/6	Urticaceae	3/7	25/9	26/9
			flowering LENGTH (number of days)			
49	48	49	*Alnus* spp.	60	55	48
95	61	69	Cupressaceae/Taxaceae	81	86	57
34	39	30	*Castanea sativa* Miller	24	59	40
51	66	60	*Quercus* spp.	58	68	56
82	108	79	Poaceae	67	116	134
40	32	44	*Olea europaea* L.	43	35	25
30	34	31	Platanaceae	37	27	20
126	153	81	Urticaceae	127	181	218
			max (day/month)			
20/3	26/2	20/2	*Alnus* spp.	12/2	13/2	23/2
21/2	26/2	25/2	Cupressaceae/Taxaceae	23/2	11/2	9/2
23/6	8/7	26/6	*Castanea sativa* Miller	20/6	20/6	20/6
15/5	22/5	11/5	*Quercus* spp.	17/5	25/5	18/5
17/5	19/5	13/5	Poaceae	21/5	30/5	25/5
7/5	26/5	25/5	*Olea europaea* L.	23/5	30/5	23/5
23/3	13/4	23/3	Platanaceae	28/3	1/4	29/3
11/4	15/3	23/3	Urticaceae	17/6	30/3	23/5
			max (p/m^3)			
72	70	59	*Alnus* spp.	9	4	3
425	2236	1562	Cupressaceae/Taxaceae	500	563	425
173	35	19	*Castanea sativa* Miller	366	126	146
522	205	405	*Quercus* spp.	279	191	144
291	103	88	Poaceae	179	121	38
669	194	144	*Olea europaea* L.	156	81	49
87	156	1289	Platanaceae	159	81	1076
336	156	207	Urticaceae	258	130	58
			Annual Pollen Index (APIn) (p/m^3)			
893	917	658	*Alnus* spp.	93	50	30
9117	26,717	15,703	Cupressaceae/Taxaceae	4641	6480	4443
1183	531	182	*Castanea sativa* Miller	1415	478	356
7980	2746	4630	*Quercus* spp.	4068	3005	1675
6159	1869	1793	Poaceae	3661	2393	776
5471	1362	1507	*Olea europaea* L.	1599	797	322
997	1144	15,483	Platanaceae	699	812	6975
9560	7365	5215	Urticaceae	4985	4583	1427

The airborne pollen concentration reveals differences in the floristic composition found in the vegetation surrounding the three sampling sites; the most representative airborne pollens are Cupressaceae/Taxaceae for SP (26,717 p/m^3 = 51.0% in 2020 and 6480 p/m^3 = 29.7% in 2021), Platanaceae for CP (15,483 p/m^3 = 25.2% in 2020 and 6975 p/m^3 = 39.9% in 2021), and other taxa than those considered in this study for TV (21,056 p/m^3 = 33.7% in 2020 and 4289 p/m^3 = 16.9 in 2021), as shown in Figure 3, which shows the percentage comparison of pollen data and highlights the floristic differences and the weight of the main taxa present at each site.

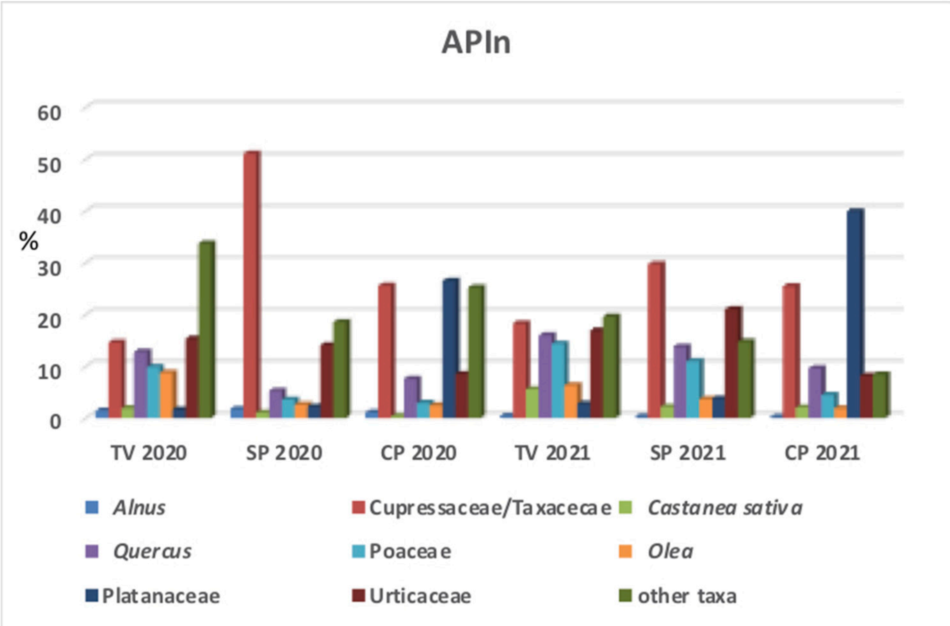

Figure 3. Pollen taxa considered presence in the three sites (CP, Cipro—Rome Center; SP, Villa San Pietro Hospital—Rome North; TV, University Tor Vergata—Rome South) in the years 2020 and 2021. The values are expressed in percentage.

All phenological and production indicator data, shown below, are summarized in Table 1.

Pollen season values show some differences in the two years between the three sites (Table 1); in particular, deviations of more than seven days are found for the following taxa: regarding the start of flowering, in 2020, *Quercus* lags behind by 10 days in TV, *Olea* by 11 days in SP, and Urticaceae by 11 days in CP; in 2021, *Olea* is advanced by 20 days in TV, and Urticaceae is delayed by 29 days in SP; flowering end shows a delay for Cupressaceae/Taxaceae of 25 days in TV, for Poaceae of 26 days in SP, for Urticaceae of 34 days in TV and a further 22 days in SP in 2020; in 2021, there is an advance of 17 days for Cupressaceae/Taxaceae in CP, a delay of 16 days for *Castanea* in SP, a delay of 49 days for Poaceae in SP and an additional 24 days in CP, a delay of 10 days for *Olea* in SP, and an advance of 84 days for Urticaceae in TV.

The end dates of flowering show greater heterogeneity, with clear differences both between the three sites and between the two years considered. For some taxa, the end of flowering is recorded on days up to four weeks apart, up to a limit of 84 days for Urticaceae in the year 2021.

As a result, the overall flowering duration also varies by several weeks, due to the variation in the start and especially the end of flowering.

The situation is the same for the day of the maximum peak, with some variability between taxa from one site to another, reflecting the trend in APIn: the year 2021 appears more homogeneous, whereas in 2020 they occur in most cases within the same week or after 7–10 days, with the maximum difference being 29 days in *Alnus*.

Pearson's correlations can be found in the Tables S2 and S3 in the Supplementary Material.

The Pearson's correlation (* = correlation at the 0.05 two-tailed level and ** = correlation at the 0.01 two-tailed level) between the daily pollen concentrations of the taxa considered at the three sampling sites is significant (Table S2).

The seasonal development of each taxon can be identified by means of phenological indicators, whereby the end, length, and peak day of the pollen season are correlated with a specific taxon. In addition, the start of the pollen season correlates highly significantly with the end and peak day; similarly, the length correlates with the end, and the APIn with the peak day concentration (Table S3).

4. Discussion

Floristic-vegetational diversity is well detected by pollen monitoring, as evidenced by the results in this study (Figure 3): the three samplers are positioned in three very different areas of the city, and there is a heterogeneity of the airborne pollen concentration at different sites and in different years.

The data for all qualitative and quantitative parameters for each species from the three samplers correlate highly significantly ($p < 0.01$), indicating a homogeneous pattern of blooms in the different neighborhoods of the city (Table S2). In fact, in the correlations relative to the production indicators (e.g., Table S3), it is possible to verify how the concentration level in the pollen load over the two years is fairly regular, even though there is a quantitative diversity in the various sampling sites, reflecting the variability of the vegetation within the city, just as the succession of the flowering of the various taxa reflects the seasonality of the various species.

The APIn and maximum peak values (p/m^3) are interesting; they highlight the different characteristic floristic patterns present in the various areas of the city, which differ in terms of landscape, naturalistic, and urban characteristics (Table 1). In the TV area, the herbaceous component is prevalent, which is justified by the fact that the TV sampler is located in an area where more grass and uncultivated areas are present. The greater presence of the herbaceous taxa Poaceae and *Parietaria* and *Urtica* species in the peripheral districts (TV and SP) could be a result of the abandonment of agricultural practices and land consumption [59] and partly of a progressive deterioration in the maintenance of green areas (Figure 1).

The relative contribution of tree species is, in all three cases, greater than that of herbaceous species, and is very different in the three areas: in the TV area, the relative abundance of *Castanea* in both years [60,61] is 10 times higher than that recorded in CP and at least twice as high as that recorded in SP, reflecting the proximity to the Castelli Romani area, whose wooded areas are rich in chestnut trees; on the other hand, SP shows a significantly higher APIn for Cupressaceae-Taxaceae pollens in both years, characterized mainly by species of the Cupressaceae family, used in the 1950s as hedges in tennis and five-a-side football facilities, which are numerous in the SP area; the high APIn values of Platanaceae pollens in the CP area, 10–15 times higher than those in TV and SP, are also the result of the use of *Platanus* for street trees in the city center.

Furthermore, although some agreement is observed in the start of the pollen season for the different taxa, it is evident that not only do the maximum concentrations reached by these taxa vary for the reasons just mentioned, but different trends are observed in both peak and end-of-flowering dates. The flowering delay in Urticaceae can be interpreted considering that the calculation of pollen-flowering season parameters is based on a series of indices [62] that depend on the annual abundance of airborne pollen. Intra-annual fluctuations in pollen production and daily and hourly weather conditions lead to differences in the calculation of phenological parameters, especially in the case of herbaceous species, which have the capacity for successive flowering during the same season. The timing of peak attainment is almost exclusively influenced by weather conditions [41,63], but to conduct a study using weather-climate variables, it would be necessary to consider a longer historical data set. It is also interesting to point out that differences in the duration of the pollen season of the same taxon in the three areas are mostly due to variability in reaching the end of flowering, as in the case of Cupressaceae/Taxaceae, Poaceae, and Urticaceae in 2020 and 2021, and *Castanea sativa* in 2021 (Table 1).

The different distribution of these taxa in and around the Roman territory, therefore, means that an airborne pollen concentration with specific local characteristics is observed in the three areas defined by the three samplers. In fact, from a climatic point of view, the Roman area falls within the Mediterranean region [64] of the mesomediterranean sub-humid type, in which four sub-types can be distinguished: the two peripheral samplers, TV and SP, are found in the sector with the mesomediterranean dry subtype (mean T from 14.6 to 15.2 °C), with low annual rainfall (summer precipitation ranging from 56.9 to 76.6 mm), while CP is located in the sector with the sub-humid thermomediterranean subtype, with higher mean T values (15.7 °C) and summer precipitation (82.2–96.3 mm) [64]. All of this has made it possible to highlight a gradient in the phenological progression of certain taxa, which obviously implies a similar gradient in the attainment of the maximum pollen concentrations relative to these taxa in the different areas.

Moreover, the floristic diversity between the three sites studied is the result not only of the natural variation of the sites but also of urbanization interventions. The SP sampler is located near Monte Mario, which, at 139 meters in height, is the most imposing relief of the hill system known as Farnesina hills and represents a true mosaic of biological diversity due to its environmental characteristics: in the lower areas, there is Mediterranean vegetation, with *Quercus ilex* L., *Quercus suber* L., *Laurus nobilis* L., and *Cistus salvifolius* L., which contrasts with the vegetation in the higher areas, which is typical of sub-mountain conditions, consisting of *Ostrya carpinifolia*, *Acer*, *Fraxinus ornus*, *Corylus avellana*, and *Cornus sanguinea* L.; *Populus* is present in the wetlands.

The TV area has a low component of synanthropic vegetation, being close to two very extensive protected areas, the Castelli Romani park to the east and the Appia Antica park to the west. From a naturalistic point of view, the Appia Antica park represents the most important biological corridor in the city, forming a green wedge that is the environmental link between the peripheral areas and the city center [65]. In this context, the airborne pollen concentration does not show a characteristic predominant taxon but reflects the variety of habitats present (Figure 3).

Site CP presents intermediate conditions between the other two sites in Rome, TV and SP, which are mainly reflected in the phenology of the airborne pollen concentration (Table 1). The climate of urban centers is characterized by the phenomenon known as the 'urban heat island' [66]; this is frequently formed, causing thermal differences between the city areas and suburban or open spaces. Within the city, the intensity of these variations increases from the periphery towards the center and is linked to the density of buildings and the percentage of land covered by vegetation [67–69].

A strong difference in total pollen (APIn) between 2020 and 2021 is evident: this is probably attributable not only to alternating years of loading and unloading of certain taxa, but also to meteorological factors, in particular the value of total annual precipitation: 2021 was a year characterized by abundant precipitation (1050 mm), 257 mm above the average of the last 30 years (793 mm), unlike 2020 with below-average precipitation (604 mm) [70]. It is known that climate and weather have a direct impact on plant phenology, influencing airborne pollen [26,40,42,71–73]. In a recent review of 93 articles, Schramm et al. [74] examined the different effects of precipitation on pollen concentrations and pollen season indicators: increased precipitation can have a short-term effect, potentially causing low pollen concentrations due to the 'wash out' effect, whereas long-term effects of precipitation have a positive correlation with airborne pollen levels. The significance value expressed by the Pearson's correlation of APIn for individual taxa shows the importance of having more sampling stations in large cities, especially if the territory is extensive and has heterogeneous vegetation, as in the case of Rome. However, in terms of percentages and relative abundances, the trends and differences observed between the three areas are confirmed in both 2020 and 2021.

The two-year period of data in this study represents a first description of aerobiological diversity in Rome, but it is a short interval for a complete and meaningful statistical analysis. Despite numerous attempts to automate pollen counting and recognition [75], aerobiological pollen monitoring currently remains a totally manual practice, requiring time and specialized personnel. This is one of the factors that makes it difficult to have multiple sampling sites in apparently homogeneous territories, such as those represented by large cities. Recent studies [6] show the difficulties linked to the spatialization of aerobiological data: data collection uses statistical methods whose estimates are still unreliable due to the complex system of interactions involving pollen-producing plants. In general, statistical models for airborne pollen are difficult to apply because the presence of airborne pollen depends on geographical and meteorological factors mediated by the biological component; moreover, for Italy, the difficulty is increased by the heterogeneity of the geographical characteristics of the territory. The present work and the Italian geographic context suggest the need for a greater number of sampling points to guarantee a true localization of the data.

Furthermore, it is well known that the dynamics that regulate the spread of pollen are influenced in various ways by a series of factors, intrinsic and extrinsic to the plants, which are the source of production. For this reason, in the next few years, having a larger database at our disposal, it would be interesting to investigate the role of meteorological variables and pollutants, verifying whether and to what extent they can influence the phenology of individual taxa in both the release and spread of pollen in the atmosphere.

5. Conclusions

The data highlight the importance of installing multiple aerobiological stations, even within large cities. In these urban environments, greenery is increasingly becoming an element that is as valuable as it is difficult to conserve, plan, and maintain. The presence of parks, gardens, avenues, and squares planted with trees, or in any case equipped with greenery, makes it possible to satisfy an important recreational and social need and to provide a fundamental service to the community, making a city more livable and family friendly. At the same time, however, greenery can be a source of allergic disorders for pollen-sensitive people, and airborne pollen sampling is a useful tool for both prevention and symptom control in allergy sufferers, as the severity of symptoms also depends on pollen exposure [42].

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15054155/s1, Table S2: Pearson's correlation between phenological and production indicators; Table S3: Pearson's correlation between pollen season parameters, sites and taxa.

Author Contributions: Conceptualization, A.M. and A.T.; methodology, M.A.B.; software, M.A.B.; validation, A.M., M.A.B. and A.T.; formal analysis, M.A.B.; investigation, A.M. and D.D.F.; resources, A.M.; data curation, M.A.B.; writing—original draft preparation, A.M.; writing—review and editing, M.A.B.; visualization, F.F.; supervision, A.D.M.d.B.; project administration, A.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: It is our wish to express a particular thanks to Gabrielle Carla Forgione B.A.Hons, University of London UCL, qualified as an interpreter and translator at the Institute of Linguistics.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ravaglioli, A. *Roma anno 2750 ab Urbe Condita*; Tascabili Economici Newton: Rome, Italy, 1997; ISBN 978-88-8183-670-3. (In Italian)
2. Roma Capitale–Ufficio di Statistica. I Numeri di Roma Capitale. Comune di Roma. 31 December 2018. Available online: https://www.comune.roma.it/web-resources/cms/documents/Popolazione_2018_RC_rev.pdf (accessed on 7 December 2022).
3. Roma Capitale Dipartimento Tutela Ambientale e Del Verde–Protezione Civile. Relazione sullo Stato dell'Ambiente Natura e Verde Pubblico 2016. Available online: https://www.comune.roma.it/web-resources/cms/documents/Verde_2016.pdf (accessed on 12 September 2022).
4. ISTAT. 2020. Available online: https://demo.istat.it/strasa2020/index.html (accessed on 28 November 2022).
5. Roma Capitale Dipartimento Trasformazione Digitale U.O. Statistica-Open Data. Il Turismo a Roma Anno 2019. Available online: https://www.comune.roma.it/web-resources/cms/documents/Il_turismo_a_Roma_2019_new.pdf (accessed on 28 November 2022).
6. Vélez-Pereira, A.M.; De Linares, C.; Belmonte, J. Aerobiological modelling II: A review of long-range transport models. *Sci. Total Environ.* **2022**, *845*, 157351. [CrossRef] [PubMed]
7. Caiola, M.G.; Mazzitelli, A.; Capucci, E.; Travaglini, A. Monitoring pollinosis and airborne pollen in a Rome university. *Aerobiologia* **2002**, *18*, 267–275. [CrossRef]
8. Travaglini, A.; Mazzitelli, A. A method to control the spread of allergenic pollen in archaeological and highly frequented areas. *Aerobiologia* **2003**, *19*, 185–190. [CrossRef]
9. Ricotta, C.; Celesti Grapow, L.; Avena, G.; Blasi, C. Topological analysis of the spatial distribution of plant species richness across the city of Rome (Italy) with the echelon approach. *Landsc. Urban Plan.* **2001**, *57*, 69–76. [CrossRef]
10. Blasi, C. Fitoclimatologia del Lazio. *Fitosociologia* **1994**, *27*, 151–175.
11. Amanti, M.; Crescenzo, R.; Marra, F.; Pecci, M.; Piro, M.; Salvi, S.; Vallesi, R. *Memorie Descrittive della Carta Geologica d'Italia*; La geologia di Roma, il centro storico (Geology of Rome. The historic center); Istituto Poligrafico e Zecca dello Stato: Roma, Italy, 1995; Volume 50, ISBN 978-88-240-3970-3.
12. Celesti-Grapow, L.; Fanelli, G. The vanishing landscape of the Campagna Romana. *Landsc. Urban Plan.* **1993**, *24*, 69–76. [CrossRef]
13. Celesti-Grapow, L.; Capotorti, G.; Del Vico, E.; Lattanzi, E.; Tilia, A.; Blasi, C. The vascular flora of Rome. *Plant Biosyst.* **2013**, *147*, 1059–1087. [CrossRef]
14. Fanelli, G.; Tescarollo, P.; Testi, A. Ecological indicators applied to urban and suburban floras. *Ecol. Indic.* **2006**, *6*, 444–457. [CrossRef]
15. Anzalone, B. Flora e vegetazione dei muri di Roma. *Ann. Bot.* **1951**, *23*, 393–497.
16. Anzalone, B.; Iberite, M.; Lattanzi, E. La Flora vascolare del Lazio. *Inf. Bot. Ital.* **2010**, *42*, 187–317.
17. Attorre, F.; Stanisci, A.; Bruno, F. The urban woods of Rome (Italy). *Plant Biosyst.* **1997**, *131*, 113–135. [CrossRef]
18. Celesti-Grapow, L. *Atlante Della Flora di Roma–La Distribuzione delle Piante Spontanee Come Indicatore Ambientale*; Argos Edizioni: Milton Keynes, UK, 1995.
19. Celesti-Grapow, L.; Pyšek, P.; Jarošík, V.; Blasi, C. Determinants of native and alien species richness in the urban flora of Rome. *Divers. Distrib.* **2006**, *12*, 490–501. [CrossRef]
20. Caneva, G.; Pacini, A.; Celesti-Grapow, L.; Ceschin, S. The Colosseum's use and state of abandonment as analyzed through its flora. *Int. Biodeterior. Biodegrad.* **2001**, *51*, 211–219. [CrossRef]
21. Ceschin, S.; Cutini, M.; Caneva, G. Contributo alla conoscenza della vegetazione delle aree archeologiche romane-(Contribution to vegetation knowledge of Roman archaeological areas. *Fitosociologia* **2006**, *43*, 97–139.
22. Celesti-Grapow, L.; Pretto, F.; Carli, E.; Blasi, C. *Flora Vascolare Alloctona e Invasiva delle Regioni d'Italia*; Casa Editrice Università La Sapienza: Roma, Italy, 2010; 208p.
23. Campitelli, A.; Cremona, A. Atlante Storico delle Ville e Giardini di Roma. Jaca Book: Milano, Italy, 2012.
24. Comune di Roma—Dipartimento VI—Politiche della Programmazione e Pianificazione del Territorio Roma Capitale. Relazione Vegetazionale (Documentazione ai Sensi della D.G.R. 18/5/99 n.2649). 1999. Available online: http://www.urbanistica.comune.roma.it/images/uo_urban/prg_vigente/prg_g9b.pdf (accessed on 24 June 2022).
25. The Number in Brackets Indicates the Number of Specimens per Species. Available online: https://www.comune.roma.it/PCR/resources/cms/documents/RSA12natura.pdf (accessed on 18 May 2022).
26. Di Menno di Bucchianico, A.; Brighetti, M.A.; Cattani, G.; Costa, C.; Cusano, M.; De Gironimo, V.; Froio, F.; Gaddi, R.; Pelosi, S.; Sfika, I.; et al. Combined effects of air pollution and allergens in the city of Rome. *Urban For. Urban Green.* **2019**, *37*, 13–23. [CrossRef]
27. Menzel, A.; Ghasemifard, H.; Yuan, Y.; Estrella, N. A first pre-season pollen transport climatology to Bavaria, Germany. *Front. Allergy* **2021**, *2*, 627–863. [CrossRef] [PubMed]
28. de Weger, L.A.; Pashley, C.H.; Šikoparija, B.; Skjøth, C.A.; Kasprzyk, I.; Grewling, Ł.; Thibaudon, M.; Magyar, D.; Smith, M. The long distance transport of airborne Ambrosia pollen to the UK and the Netherlands from Central and south Europe. *Int. J. Biometeorol.* **2016**, *60*, 1829–1839. [CrossRef] [PubMed]
29. Cecchi, L.; Morabito, M.; Domeneghetti, M.P.; Crisci, A.; Onorari, M.; Orlandini, S. Long distance transport of ragweed pollen as a potential cause of allergy in central Italy. *Ann. Allergy Asthma Immunol.* **2006**, *96*, 86–91. [CrossRef]
30. Damialis, A.; Gioulekas, D.; Lazopoulou, C.; Balafoutis, C.; Vokou, D. Transport of airborne pollen into the city of Thessaloniki: The effects of wind direction, speed and persistence. *Int. J. Biometeorol.* **2005**, *49*, 139–145. [CrossRef]

31. Travaglini, A.; Canini, A.; Grilli Caiola, M. Project of the "Tor Vergata" University (Rome) botanic garden: Description of the site. *Museol. Sci.* **1992**, *9*, 329–345.
32. EAACI-European Academy of Allergy and Clinical Immunology. *Global Atlas of Asthma*; Akdis, C.A., Agache, I., Eds.; European Academy of Allergy and Clinical Immunology: Florence, Italy, 2013.
33. EAACI-European Academy of Allergy and Clinical Immunology. *Global Atlas of Allergy*; Akdis, C.A., Agache, I., Eds.; European Academy of Allergy and Clinical Immunology: Florence, Italy, 2014.
34. EAACI-European Academy of Allergy and Clinical Immunology. *White Paper on Research, Innovation and Quality Care*; Agache, I., Akdis, C.A., Chivato, T., Hellings, P., Hoffman-Sommergruber, K., Jutel, M., Lauerma, A., Papadopoulos, N., Schmid-Grendelmeier, P., Schmidt-Weber, C., Eds.; European Academy of Allergy and Clinical Immunology: Florence, Italy, 2018.
35. WAO-World Allergy Organization. *White Book on Allergy: Update 2013*; Pawankar, R., Canonica, G.W., Holgate, S.T., Lockey, R.F., Blaiss, M.S., Eds.; World Allergy Organization: Milwaukee, WI, USA, 2013.
36. Xie, W.; Li, Y.; Bai, W.; Hou, J.; Ma, T.; Zeng, X.; Zhang, L.; An, T. The source and transport of bioaerosols in the air: A review. *Front. Environ. Sci. Eng.* **2021**, *15*, 44. [CrossRef] [PubMed]
37. Joubert, A.I.; Geppert, M.; Johnson, L.; Mills-Goodlet, R.; Michelini, S.; Korotchenko, E.; Duschl, A.; Weiss, R.; Horejs-Höck, J.; Himly, M. Mechanisms of particles in sensitization, effector function and therapy of allergic disease. *Front. Immunol.* **2020**, *11*, 1334. [CrossRef] [PubMed]
38. Damialis, A.; Gilles, S.; Sofiev, M.; Sofiev, V.; Kolek, F.; Bayr, D.; Plaza, M.P.; Leier-Wirtz, V.; Kaschuba, S.; Ziska, L.H.; et al. Higher airborne pollen concentrations correlated with increased SARS-CoV-2 infection rates, as evidenced from 31 countries across the globe. *Proc. Natl. Acad. Sci. USA* **2021**, *18*, e2019034118. [CrossRef]
39. Awaya, A.; Kuroiwa, Y. The relationship between annual airborne pollen levels and occurrence of all cancers, and lung, stomach, colorectal, pancreatic and breast cancers: A retrospective study from the National Registry Database of cancer incidence in Japan, 1975–2015. *Int. J. Environ. Res. Public Health* **2020**, *17*, 3950. [CrossRef]
40. Ziello, C.; Sparks, T.H.; Estrella, N.; Belmonte, J.; Bergmann, K.C.; Bucher, E.; Brighetti, M.A.; Damialis, A.; Detandt, M.; Galan, C.; et al. Changes to airborne pollen counts across Europe. *PLoS ONE* **2012**, *7*, e34076. [CrossRef]
41. Bruffaerts, N.; De Smedt, T.; Delcloo, A.; Simons, K.; Hoebeke, L.; Verstraeten, C.; Van Nieuwenhuyse, A.; Packeu, A.; Hendrickx, M. Comparative long-term trend analysis of daily weather conditions with daily pollen concentrations in Brussels, Belgium. *Int. J. Biometeorol.* **2018**, *62*, 483–491. [CrossRef]
42. Hoffmann, T.M.; Travaglini, A.; Brighetti, M.A.; Acar Şahin, A.; Arasi, S.; Bregu, B.; Caeiro, E.; Caglayan Sozmen, S.; Charpin, D.; Delgado, L.; et al. Cumulative Pollen Concentration Curves for Pollen Allergy Diagnosis. *J. Investig. Allergol. Clin. Immunol.* **2021**, *31*, 340–343. [CrossRef]
43. *UNI 11108:2004*; Air Quality. Method for Sampling and Counting of Airborne Pollen Grains and Fungal Spores; UNI, Italian National Unification: Milano, Italy, 2004; p. 8.
44. Galán Soldevilla, C.; Cariñanos González, P.; Alcázar Teno, P.; Domínguez Vilches, E. Spanish Aerobiology Network (REA): Management and Quality Manual. *Serv. Publ. Univ. Córdoba.* **2007**, *184*, 1–300.
45. *CEN/TS 16868:2019*; Ambient Air—Sampling and Analysis of Airborne Pollen Grains and Fungal Spores for Allergy Networks—Volumetric Hirst Method; UNI, Italian National Unification: Milano, Italy, 2019.
46. Buters, J.T.M.; Antunes, C.; Galveias, A.; Bergmann, K.C.; Thibaudon, M.; Galán, C.; Schmidt-Weber, C.; Oteros, J. Pollen and spore monitoring in the world. *Clin. Transl. Allergy.* **2018**, *4*, 9. [CrossRef] [PubMed]
47. Pollnet-Snpa. 2020. Available online: https://www.arpae.it/it/notizie/lo-stato-dei-principali-pollini-allergenici-in-italia-nel-2020 (accessed on 24 June 2022).
48. Cariñanos, P.; Casares-Porcel, M.; Díaz de la Guardia, C.; Aira, M.J.; Belmonte, J.; Boi, M.; Elvira-Rendueles, B.; De Linares, C.; Fernández-Rodriguez, S.; Maya-Manzano, J.M.; et al. Assessing allergenicity in urban parks: A nature-based solution to reduce the impact on public health. *Environ. Res.* **2017**, *155*, 219–227. [CrossRef]
49. Blasi, C.; Filibeck, G.; Frondoni, R.; Rosati, L.; Smiraglia, D. The map of the vegetation series of Italy. *Fitosociologia* **2004**, *41* (Suppl. 1), 21–25.
50. Blasi, C.; Dowgiallo, G.; Follieri, M.; Lucchese, F.; Magri, D.; Pignatti, S.; Sadori, L. La vegetazione naturale potenziale dell'area romana. *Atti Acc. Naz. Lincei* **1995**, *115*, 423–457.
51. Fanelli, G. *Analisi Fitosociologica dell'Area Metropolitana di Roma*; Braun-Blanquetia: Camerino, Italy, 2002; Volume 27, 269p.
52. Blasi, C.; Di Pietro, R.; Filibeck, G.; Filesi, L.; Ercole, S.; Rosati, L. *Le Serie di Vegetazione della Regione Lazio. La Vegetazione d'Italia*; Palombi & Partner Srl: Roma, Italy, 2010; pp. 281–309.
53. Mandrioli, P.; Comtois, P.; Domınguez-Vilches, E.; Galan-Soldevilla, C.; Syzdek, L.D.; Isard, S.A. Sampling: Principles and techniques. In *Methods in Aerobiology*; Mandrioli, P., Comtois, P., Levizzani, V., Eds.; Pitagora Editrice: Bologna, Italy, 1998.
54. Galan, C.; Ariatti, A.; Bonini, M.; Clot, B.; Crouzy, B.; Dahl, A.; Fernandez-Gonzalez, D.; Frenguelli, G.; Gehrig, R.; Isard, S.; et al. Recommended terminology for aerobiological studies. *Aerobiologia* **2017**, *33*, 293–295. [CrossRef]
55. Hoffmann, T.M.; Acar Şahin, A.; Aggelidis, X.; Arasi, S.; Barbalace, A.; Bourgoin, A.; Bregu, B.; Brighetti, M.A.; Caeiro, E.; Sozmen, S.C.; et al. "Whole" vs. "fragmented" approach to EAACI pollen season definitions: A multicenter study in six Southern European cities. *Allergy* **2020**, *75*, 1659–1671. [CrossRef]
56. D'Amato, G.; Lobefalo, G. Allergenic pollens in the southern Mediterranean area. *J. Allergy Clin. Immunol.* **1989**, *83*, 116–122. [CrossRef] [PubMed]

57. Jäger, S.; Nilsson, S.; Berggren, B.; Pessi, A.; Helander, M.; Ramfjord, H. Trends of some airborne tree pollen in the Nordic countries and Austria, 1980–1993. *Grana* **1996**, *35*, 171–178. [CrossRef]
58. IBM Corp. *Released 2017. IBM SPSS Statistics for Windows, Version 25.0*; IBM Corp: Armonk, NY, USA.
59. Munafò, M. (Ed.) *Consumo di Suolo, Dinamiche Territoriali e Servizi Ecosistemici*; Report SNPA 32/22; Report SNPA: 2022; ISBN 978-88-448-1124-2. Available online: https://www.snpambiente.it/2022/07/26/consumo-di-suolo-dinamiche-territoriali-e-servizi-ecosistemici-edizione-2022/ (accessed on 18 March 2022).
60. Fusaro, L.; Marando, F.; Sebastiani, A.; Capotorti, G.; Blasi, C.; Copiz, R.; Manes, F. Mapping and assessment of PM_{10} and O_3 removal by woody vegetation at urban and regional level. *Remote Sens.* **2017**, *9*, 791. [CrossRef]
61. Travaglini, A.; Ravaziol, D.; Caiola, M.G. A meteorological station and a pollen trap at the botanical garden and arboretum of the university of Rome Tor Vergata. *Aerobiologia* **2000**, *16*, 303–307. [CrossRef]
62. Jato, V.; Rodriguez-Rajo, F.J.; Alcázar, P.; De Nuntiies, P.; Galán, C.; Mandrioli, P. May the definition of pollen season influence aerobiological results? *Aerobiologia* **2006**, *22*, 13–25. [CrossRef]
63. Stepalska, D.; Myszkowska, D.; Piotrowicz, K.; Kasprzyk, I. The phenological phases of flowering and pollen seasons of spring flowering tree taxa against a background of meteorological conditions in Krako'w, Poland. *Acta Agrobot.* **2016**, *65*, 1678. [CrossRef]
64. Blasi, C.; Michetti, L. La Carta del Fitoclima d'Italia (scala 1:250.000). In *International Symposium of Biodiversity and Phytosociology: 106*; University of Ancona: Ancona, Italy, 2003.
65. Roma Capitale-Dipartimento Tutela Ambientale e del Verde. Relazione sullo Stato dell'Ambiente, Natura e Verde Pubblico. 2012. Available online: https://www.comune.roma.it/PCR/resources/cms/documents/RSA12natura.pdf (accessed on 18 March 2022).
66. Colacino, M.; Lavagnini, A. Evidence of the urban heat island in Rome by climatological analyses. *Arch. Meteorol. Geophys. Bioclimatol. Ser. B* **1982**, *31*, 87–97. [CrossRef]
67. Brighetti, M.A.; De Franco, D.; Di Cosmo, C.; Di Menno di Bucchianico, A.; Froio, F.; Miraglia, A.; Moselli, D.; Travaglini, A. Aerobiological Biodiversity in the Metropolitan City of Rome. *Int. J. Environ. Sci. Nat. Res.* **2022**, *30*, 556283. [CrossRef]
68. Donato, F.D.; Scortichini, M.; Parliari, D.; Kontos, S.; Papastergios, G.; Kelessis, A.; Tzoumaka, P.; Argentini, S.; Casasanta, G.; Deliyannis, A.; et al. *Urban Heat Islands and Heat Health Warning Systems in Mediterranean Cities. Results from the Life ASTI Project*; ISEE Conference Abstracts; Environmental Health Perspectives: Durham, NC, USA, 2021. [CrossRef]
69. Keppas, S.C.; Papadogiannaki, S.; Parliari, D.; Kontos, S.; Poupkou, A.; Tzoumaka, P.; Kelessis, A.; Zanis, P.; Casasanta, G.; de'Donato, F.; et al. Future Climate Change Impact on Urban Heat Island in Two Mediterranean Cities Based on High-Resolution Regional Climate Simulations. *Atmosphere* **2021**, *12*, 884. [CrossRef]
70. Esposito, S. Un'analisi dell'Andamento Pluviometrico sul Territorio Nazionale nell'Anno Appena Concluso. PianetaPSR Numero 110 Febbraio 2022. CREA AA. 2022. Available online: http://www.pianetapsr.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/2679 (accessed on 16 March 2022).
71. Cristofolini, F.; Anelli, P.; Billi, B.M.; Bocchi, C.; Borney, M.F.; Bucher, E.; Cassoni, F.; Coli, S.; De Gironimo, V.; Gottardini, E.; et al. Temporal trends in airborne pollen seasonality: Evidence from the Italian POLLnet network data. *Aerobiologia* **2020**, *36*, 63–70. [CrossRef]
72. Mercuri, A.M.; Torri, P.; Fornaciari, R.; Florenzano, A. Plant Responses to Climate Change: The Case Study of Betulaceae and Poaceae Pollen Seasons (Northern Italy, Vignola, Emilia-Romagna). *Plants* **2016**, *5*, 42. [CrossRef]
73. Mercuri, A.M.; Torri, P.; Casini, E.; Olmi, L. Climate warming and the decline of Taxus airborne pollen in urban pollen rain (Emilia Romagna, northern Italy). *Plant Biol.* **2013**, *15* (Suppl. 1), 70–82. [CrossRef]
74. Schramm, P.J.; Brown, C.L.; Saha, S.; Conlon, K.C.; Manangan, A.P.; Bell, J.E.; Hess, J.J. A systematic review of the effects of temperature and precipitation on pollen concentrations and season timing, and implications for human health. *Int. J. Biometeorol.* **2021**, *65*, 1615–1628. [CrossRef]
75. Jiang, C.; Wang, W.; Du, L.; Huang, G.; McConaghy, C.; Fineman, S.; Liu, Y. Field Evaluation of an Automated Pollen Sensor. *Int. J. Environ. Res. Public Health* **2022**, *19*, 6444. [CrossRef]