

## Article

# Aerobiology of Olive Pollen (*Olea europaea* L.) in the Atmosphere of the Iberian Peninsula

Cláudia Penedos <sup>1,\*</sup>, Guillermo Salamanca <sup>2</sup>, Beatriz Tavares <sup>1,3</sup>, João Fonseca <sup>1,4,5,6</sup>, Pedro Carreiro-Martins <sup>1,7,8</sup>, Rodrigo Rodrigues-Alves <sup>1,9</sup>, Ángel Moral de Gregorio <sup>10,11</sup>, Antonio Valero <sup>11,12</sup> and Manuel Branco Ferreira <sup>1,13,14</sup>

- <sup>1</sup> Sociedade Portuguesa de Alergologia e Imunologia Clínica, 1600-503 Lisboa, Portugal
  - <sup>2</sup> Medical Affairs & Clinical Department, LETI Pharma, 28760 Tres Cantos, Spain
  - <sup>3</sup> Serviço de Imunoalergologia, Centro Hospitalar e Universitário de Coimbra, 3004-561 Coimbra, Portugal
  - <sup>4</sup> Departamento de Medicina da Comunidade, Informação e Decisão em Saúde—MEDCIDS, Faculdade de Medicina, Universidade Porto, 4200-450 Porto, Portugal
  - <sup>5</sup> Centro de Investigação em Tecnologias e Serviços de Saúde—CINTESIS, 4200-450 Porto, Portugal
  - <sup>6</sup> Unidade de Alergia, Instituto & Hospital CUF Porto, 4100-180 Porto, Portugal
  - <sup>7</sup> Serviço de Imunoalergologia, ULS São José, 1169-049 Lisboa, Portugal
  - <sup>8</sup> Comprehensive Health Research Centre (CHRC), LA-REAL, NOVA Medical School, Universidade NOVA de Lisboa, 1169-056 Lisboa, Portugal
  - <sup>9</sup> Hospital do Divino Espírito Santo, 9500-370 Ponta Delgada, Portugal
  - <sup>10</sup> Hospital Universitario de Toledo, 45007 Toledo, Spain
  - <sup>11</sup> Sociedad Española de Alergología e Inmunología Clínica—SEAIC, 28020 Madrid, Spain
  - <sup>12</sup> Servicio de Alergología, Hospital Clínic i Universitari, 08036 Barcelona, Spain
  - <sup>13</sup> Clínica Universitária de Imunoalergologia, Faculdade de Medicina, Universidade de Lisboa, 1300-477 Lisboa, Portugal
  - <sup>14</sup> Serviço de Imunoalergologia, Centro Hospitalar e Universitário Lisboa Norte, 1649-028 Lisboa, Portugal
- \* Correspondence: claudia.penedos91@gmail.com



**Citation:** Penedos, C.; Salamanca, G.; Tavares, B.; Fonseca, J.; Carreiro-Martins, P.; Rodrigues-Alves, R.; Moral de Gregorio, Á.; Valero, A.; Branco Ferreira, M. Aerobiology of Olive Pollen (*Olea europaea* L.) in the Atmosphere of the Iberian Peninsula. *Atmosphere* **2024**, *15*, 1087. <https://doi.org/10.3390/atmos15091087>

Academic Editor: László Makra

Received: 7 June 2024

Revised: 7 August 2024

Accepted: 3 September 2024

Published: 7 September 2024



**Copyright:** © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

**Abstract:** *Olea europaea* L. pollen is one of the main causes of pollinosis and respiratory diseases in the Iberian Peninsula (IP). The aim of this study was to provide a pollen calendar in different regions of the IP, which could help allergists and allergic patients in the management of *Olea europaea* allergic diseases, and to update/complement what has already been reported on olive trees' aeropalynology in this region. Airborne *Olea* pollen dynamics were analyzed over a period of 8 years in a total of 21 localities, 7 in Portugal and 14 in Spain. Airborne pollen monitoring was carried out using the Hirst-type spore trap method and following the recommendations of the Quality Control Working Group of the European Aerobiology Society. The daily pollen count, the annual pollen profile, the Annual Pollen Integral (APIn), the Seasonal Pollen Integral (SPIn) and the Pollen Peak, all expressed in number of pollen grains per cubic metre of air, together with the main pollen season and its characteristics, the Start Day, the End Day and the length of the pollen season, were calculated for each sampling station. Differences in mean *Olea* pollen concentration between odd and even years were also analyzed. On average, the main pollen season (MPS) started in April/May and ended in June, with Pollen Peaks recorded in May, except in Burgos, where it was recorded in June. The longest MPS occurred in Lisbon, Oviedo and Valencia (53 days) and the shortest in Vitoria (25 days). A high daily pollen concentration (i.e., >200 grains/m<sup>3</sup>) was recorded between 1 and 38 days along the year in all sampling stations of the southwest quadrant of the IP and in Jaén. A biannual pattern, characterized by alternating years of high and low pollen production, was found in the southwest of the IP. In conclusion, the study provided a deeper understanding of the pollination behaviour of olive trees in the IP and allowed the establishment of a representative *Olea* pollen calendar for this region. In addition, our results suggest the usefulness of investigating more detailed relationships between annual *Olea* pollen, allergen sensitization and symptoms, both for allergists involved in the study and management of allergic respiratory diseases caused by this species and for the self-management of disease in allergic subjects.

**Keywords:** aerobiology; atmospheric pollen; Iberian Peninsula; *Olea europaea* L.; pollen calendar; respiratory allergy

## 1. Introduction

Olive tree (*Olea europaea* L.) cultivation dates to ancient times in the eastern Mediterranean area and has spread globally in the past two decades [1,2]. Despite ongoing debates about their origins and domestication history, olive trees are recognized today as an emblematic and iconic feature of the Mediterranean landscape [1,3,4] and are a key source of table olives and olive oil—two of the most emblematic foods of the Mediterranean diet [4]. This species has high resistance to extreme weather conditions, such as hot and dry summers and periods of low rainfall [5,6]. These physiological characteristics have allowed the expansion of olive trees throughout the Mediterranean area, spreading westward, reaching the Iberian Peninsula (IP).

The IP is known for its thriving olive growing industry, which holds significant economic, environmental, and cultural importance in this region. Spanish and Portuguese agriculture heavily rely on this sector, which devotes a significant proportion of its land to olive trees and is responsible for a substantial share of the world's olive oil production and consumption [7]. Spain is the world's leading producer of olive oil, with the Andalucía region (southern Spain) accounting for over 60% of the country's agricultural area devoted to olive cultivation [8]. In Portugal, around 32% of the country's agricultural area is dedicated to olive trees, with the Alentejo region (southern Portugal) holding the largest area, comprising nearly half of the country's total olive groves [9].

Olive trees are highly adapted to wind pollination, producing a huge number of flowers [10] and reaching high pollen concentrations in May and June [8,11,12]. The pollen released by the olive trees (*Olea* pollen type) is one of the most abundant airborne pollens of the Mediterranean region and is considered a major cause of pollinosis and respiratory diseases in this area [13–15]. In some regions of southern Spain, olive pollen is the leading cause of seasonal allergic rhinitis and bronchial asthma, with a high sensitization rate among the population [16–20]. Similarly, in Portugal, sensitization to *Olea* pollen also reaches high sensitization rates in the southern cities [21–24].

Identifying and measuring pollen types and their concentration in the atmosphere is crucial, particularly in populated urban areas. The information collected from atmospheric monitoring may help in the diagnosis and in the treatment of patients with pollen-related conditions. Consequently, researchers around the globe have been studying atmospheric pollen content in different locations [25–27].

Olive pollen monitoring is essential, as this pollen-type production in the atmosphere varies according to climate, geography and agricultural practise within the same country [8,12,28,29]. Another cause of variation influencing annual olive pollen levels is the “alternation of production”. This phenomenon occurs in some tree species that essentially depend on the competition between the ripening of the fruit and the development of the buds. If trees have not expended many reserves to produce fruits in autumn, the undifferentiated buds will continue developing into flowers during the following spring. However, if nutrients are scarce, then the buds will differentiate into leaves and branches [30].

Beyond their clinical relevance, these aerobiological studies also hold importance for both agricultural and environmental sectors, since *Olea* pollen can be a strong predictor for olive production and the impact of climate change [15,31].

Considering the clinical importance of *Olea* pollen in the IP—being one of the main causes of pollinosis and respiratory diseases—the present study aimed to carry out the first aerobiological study of the region, to provide a pollen calendar including the *Olea* pollen pollinosis symptomatology threshold values [32], to help allergists and allergic patients in the management of *Olea europaea* allergic diseases, and also to update and/or complete the aeropalynological data already reported in this region. To this end, the behaviour of *Olea*

pollen in the atmosphere of the IP was analyzed over a period of eight years, considering the different characteristics and patterns of the main pollen season (MPS) at the 21 sampling stations representative of the different climatic zones of the IP.

## 2. Materials and Methods

### 2.1. Study Area

Atmospheric pollen counts were monitored at 21 sites distributed throughout the IP over a period of eight years (2012–2019), including 7 sampling stations in Portugal, located in (i) Vila Real, Porto and Coimbra in the north-western quadrant of the IP and (ii) Castelo Branco, Lisbon, Évora and Portimão in the south-western quadrant of the IP, and 14 stations in Spain, located in (i) Oviedo and Salamanca in the north-western quadrant of the IP, (ii) Toledo, Badajoz and Seville in the south-western quadrant of the IP, (iii) Vitoria, Burgos, Zaragoza, Lleida, Barcelona and Madrid in the north-eastern quadrant of the IP and (iv) Valencia, Jaén and Almería in the south-eastern quadrant of the IP. (Figure 1). The selected sites have different biogeographical characteristics, covering most of the Mediterranean and Temperate bioclimatic thermotypes found in the IP [33]. The selected sites had altitudes ranging from 4 to 909 m.



**Figure 1.** Map of the Iberian Peninsula (IP) showing the location of the 21 sampling sites in Spain and Portugal. El Cerro de los Ángeles ( $40^{\circ}18'31''$  N,  $3^{\circ}41'04''$  W) was defined as the geographical centre of the IP, allowing the map to be divided into four quadrants: north-west, north-east, south-east and south-west.

El Cerro de los Ángeles ( $40^{\circ}18'31''$  N,  $3^{\circ}41'04''$  W), in Spain, was defined as the geographic centre of the IP, allowing the classification of the IP sampling stations into four quadrants corresponding to the north, south, east and west (Figure 1).

## 2.2. Aerobiological Data

Airborne pollen monitoring was carried out according to the Hirst-type spore trap method [34] and the recommendations of the European Aerobiology Society Working Group on Quality Control [35]. The Hirst-type spore trap method, first developed by J.M. Hirst in 1952, consists of an air admission chamber that led the airflow through a  $14 \times 2$  mm slit. The airflow exiting the slit is directed onto a vertical polyester tape (Melinex) impregnated with an adhesive solution (i.e., petroleum jelly or silicon, from Lanzoni, catalogue number 200400 and 900401, Bologna, Italy), which is moved relative to the slit at a rate of 2 mm/h. The pollen grains are aspirated and retained in the impregnated tape. The pollen traps were mounted on top of buildings (10 to 20 m above ground level) always facing windward, as the whole device was mounted on a weathervane. The drum chamber was allowed to rotate for seven consecutive days. At the end of this period, the Melinex tape containing the pollen sample was removed and replaced with a new one. In the laboratory, the tape was cut into seven segments, each representing a sampling day. The membranes were stained with glycerol–gelatine solution containing basic fuchsin (Lanzoni, catalogue number 200200 and 900200, Bologna, Italy), and the *Olea europaea* pollen grains were identified and quantified under a light microscope at  $400\times$  magnification (Olympus CX41) using the four-longitudinal traverse method.

The daily *Olea* pollen counts were expressed as the number of pollen grains per cubic metre of air ( $\text{grains}/\text{m}^3$ ). This allowed for the obtaining of the annual pollen profiles for each sampling station for each year, and parameters such as the Annual Pollen Integral (APIn), defined as the total sum of olive pollen yearly, and the Seasonal Pollen Integral (SPIn), defined as the sum of *Olea* pollen during the MPS. The Pollen Peak Value (defined as the maximum value recorded during the year) could be calculated ( $\text{grains}/\text{m}^3$ ) and then a mean profile for each site was determined considering the average values of the years of study (2012–2019).

The *Olea* pollen spectrum was determined with the relative frequency of the *Olea* pollen and the Total Atmospheric Pollen collected at each site, thus determining the average values obtained in the years of the study.

The MPS corresponds to the time when a pollen type is present in the atmosphere in significant concentrations at a specific location [36]. In this study, the MPS was determined for each sampling station according to the criteria described by Nilsson and Persson in 1981 [37]. These model profiles allowed for the calculation of new city-specific parameters such as: Start Day (day number/date), End Day (day number/date), Length of the Season (days), SPIn ( $\text{grains}/\text{m}^3$ ), Pollen Peak Value ( $\text{grains}/\text{m}^3$ ), Peak Day (day number/date) and number of days with high risk of exposure to *Olea* pollen ( $>200$   $\text{grains}/\text{m}^3$ ). The number of days on which the average mean daily concentrations exceeded 200 pollen grains/ $\text{m}^3$  was defined by the Spanish Aerobiology Network (i.e., Red Española de Aerobiología, REA) as the *Olea* pollen concentration above which there is high risk of exposure causing symptoms of pollinosis [32]. The mean profiles of MPS parameters were calculated for each sampling station between 2012 and 2019.

The mean pollen profiles calculated allowed obtaining the *Olea* pollen calendar for each sampling station, using a colour scale corresponding to the pollinosis symptomatology thresholds proposed by the REA [32] (Null:  $<1$   $\text{grain}/\text{m}^3$ , Low: 1–50  $\text{grains}/\text{m}^3$ , Moderate: 50–200  $\text{grains}/\text{m}^3$ , High:  $>200$   $\text{grains}/\text{m}^3$ ), of the total average concentration of *Olea* pollen recorded during the study period and across the year and also illustrating some of the MPS parameters (start date, end date and peak date).

All the calculated parameters described above (except pollen spectrum), as well as the *Olea* pollen calendar, were obtained using the AeRobiology package [38] for the R<sup>®</sup> software, version 4.0.2.

### 2.3. Statistical Analysis

To analyze the differences in the mean concentration of *Olea* pollen between odd-numbered and even-numbered years, the GNU PSPP® program was used to perform the statistical analysis. For this, parametric methods (Student's t-test and ANOVA) were used in cases in where equality of variances was demonstrated. The non-parametric (Kruskal–Wallis) method was used for those cases with unequal variances. The equality of variances was previously evaluated using the Levene Test.

The annual average (2012–2019) of each parameter studied was obtained. Once this was carried out, new means were calculated for each city, differentiating between odd-numbered and even-numbered years, considering each city's specific annual secondary parameters (Start Day, End Day, SPIn and Pollen Peak Date). Their means were statistically compared as explained above.

The analyses were repeated for every city, excluding the data obtained from the city of Jaén, which on many occasions turned out to be a distorting factor due to the high pollen levels recorded in compared with the rest of the sampling stations.

## 3. Results

### 3.1. *Olea* Pollen Spectrum

*Olea* pollen presence in the Total Atmospheric Pollen collected in each site ranged from 0.3% (Oviedo) to 70.6% (Jaén). *Olea* pollen represented  $\geq 10\%$  of the Total Atmospheric Pollen in sampling stations located in the southwest area of the IP (Coimbra, Castelo Branco, Lisbon, Évora, Portimão, Toledo, Seville, Badajoz) and also in Jaén and Almeria, both located in the southeast region. In the remaining sites the *Olea* pollen spectrum was  $<10\%$  (Table 1).

On average, the highest peak value was registered in Jaén (11,665 grains/m<sup>3</sup>), compared to the lowest peak value which was recorded in Oviedo (24 grains/m<sup>3</sup>) (Table 1).

*Olea* pollen presented between 1 and 38 days with “high” pollen concentration ( $>200$  grains/m<sup>3</sup>) in all sampling stations of the southern quadrants of IP (Almeria, Badajoz, Castelo Branco, Coimbra, Évora, Jaén, Lisbon, Portimão, Seville, Toledo and Valencia) and also a few days in some other sampling stations, such as Barcelona (1 day), Lleida (8 days), Madrid (4 days), Salamanca (1 day) and Vila Real (3 days). On the other hand, Burgos, Oviedo, Porto, Vitória and Zaragoza did not show days with a “high” risk of *Olea* pollen concentration (Table 1).

**Table 1.** Annual Pollen Integral (APIn) of *Olea* pollen and characteristics of *Olea* main pollen season (MPS): Start and End (date and day of the year), Duration (length of the MPS in number of days), Seasonal Pollen Integral (SPIn) (grains/m<sup>3</sup>), number of days at a “high” level (>200 grains/m<sup>3</sup>), Pollen Spectrum (%). Pollen Peak characteristics: Pollen Peak Value (grains/m<sup>3</sup>) and Pollen Peak (date and day of the year). All parameters are averaged values calculated from observations carried out between 2012 and 2019.

Sampling Station	MPS Characteristics						Pollen Peak Characteristics					
	APIn (grains/m <sup>3</sup> )	Start (date)	Start (day)	End (date)	End (day)	Duration (days)	SPIn (grains/m <sup>3</sup> )	Pollen Peak Value (grains/m <sup>3</sup> )	Pollen Peak Date	Pollen Peak Day	No. Days at a “High” Level (>200 grains/m <sup>3</sup> )	Pollen Spectrum (%)
Almería	4176	31/Apr	120	8/Jun	159	40	3844	478	18/May	138	5	44.7
Badajoz	8545	09/May	129	6/Jun	155	27	7809	1357	13/May	133	12	25.6
Barcelona	2208	06/May	126	17/Jun	168	43	2027	244	29/May	149	1	4.1
Burgos	205	11/May	131	28/Jun	179	49	188	52	3/Jun	154	0	1.4
Castelo Branco	11,188	13/May	133	12/Jun	163	31	10,324	1900	22/May	142	11	19.6
Coimbra	3587	08/May	128	11/Jun	162	36	3765	456	24/May	144	6	9.3
Évora	10,287	09/May	129	12/Jun	163	35	9405	1616	15/May	135	13	10.7
Jaén	88,655	09/May	129	9/Jun	160	32	81,164	11,665	15/May	135	38	70.6
Lleida	4794	16/May	136	12/Jun	163	28	4368	627	30/May	150	8	8.8
Lisbon	6184	25/Apr	115	15/Jun	166	53	5633	678	9/May	129	9	13.4
Madrid	3238	14/May	134	20/Jun	171	38	2956	509	28/May	148	4	5.9
Oviedo	72	09/May	129	30/Jun	181	53	67	24	23/May	143	0	0.3
Portimão	12,268	27/Apr	117	5/Jun	156	41	11,152	1229	11/May	131	15	33.2
Porto	950	11/May	131	25/Jun	176	46	873	110	26/May	146	0	3.4
Salamanca	1147	12/May	132	25/Jun	176	45	1059	214	31/May	151	1	5.7
Seville	13,915	26/Apr	116	3/Jun	154	39	12,697	1833	7/May	127	19	37.7
Toledo	11,137	16/May	136	12/Jun	163	28	10,220	1549	26/May	146	13	21.2
Valencia	2754	29/Apr	119	19/Jun	170	53	2504	297	18/May	138	1	7.1
Vila Real	2464	12/May	132	12/Jun	163	33	2262	316	27/May	147	3	6.6
Vitoria	253	09/May	129	2/Jun	153	25	238	76	26/May	146	0	1.2
Zaragoza	1643	08/May	129	15/Jun	167	37	1501	131	27/May	147	0	5.9

### 3.2. APIn, MPS Characteristics, Pollen Peak and High Allergenic Days

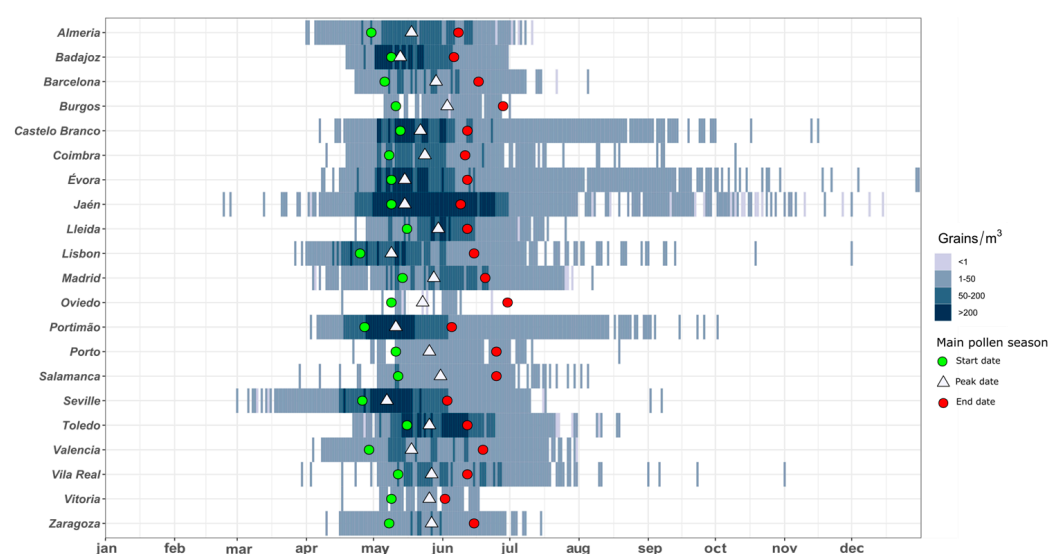
The main features of the APIn and *Olea* MPS are summarized in Table 1. The results show that the APIn and the SPIn, on average, reached the higher values in Jaén (88,655 and 81,164 grains/m<sup>3</sup>, respectively) and lower values in Oviedo (72 and 67 grains/m<sup>3</sup>, respectively) (Table 1).

In most of the sampling stations, the *Olea* MPS, on average, mainly spans from late April (Almeria, Lisbon, Portimão, Seville and Valencia) and beginning–mid May (the remaining sampling stations), until the whole of June, with the End Day changing according to the sampling location (e.g., in Vitoria until 2nd June, in Seville to 3rd June, but in Oviedo until 30th June). Regarding the length of the pollen season during the study period, the longest MPS occurred in Lisbon, Oviedo and Valencia (53 days) and the shortest in Vitoria (25 days) (Table 1).

Pollen Peaks, on average, occurred in May in all sampling stations, except in Burgos, in which it occurred on 3rd June. An irregular spatial distribution of *Olea* pollen in the IP was also found, with prominent fluctuations throughout the sites and between the study years.

### 3.3. Pollen Calendar

Figure 2 represents the *Olea* pollen calendar for the IP, considering the study sites, over a whole year. In this study, the first pollen grains were observed at the end of February in Jaén and throughout March in Seville, Lisbon, Salamanca and Vila Real. The last occurrences were recorded in August and September in Seville, Madrid, Portimão, Salamanca, Barcelona, Vila Real and Toledo, with a few scattered pollen grains detected in October in Coimbra, November in Lisbon and Castelo Branco and even December in Évora and Jaén. The MPS characteristics presented in this calendar (start, end and Pollen Peak) varied across the different regions of the IP. The MPS started earlier in the southern and coastal regions (mid-April) and later in the central and northern regions (early-to-mid of May). There is a clear difference in pollen concentration levels (grains/m<sup>3</sup>) in Burgos, Salamanca, Oviedo, Vitória and Porto, in contrast to the other areas of the IP, as these regions present only *Olea* pollen concentrations at “null” (<1 grain/m<sup>3</sup>) or “low” (<50 grains/m<sup>3</sup>) levels. In cities such as Seville, Lisbon, Portimão, Évora, Badajoz, Jaén, Castelo Branco, Lleida and Toledo, the *Olea* pollen concentrations reached the “high” level (>200 grains/m<sup>3</sup>) from April to June (Figure 2) and also registered a greater no. days at a “high” level (>200 grains/m<sup>3</sup>) (Table 1).



**Figure 2.** *Olea* pollen calendar including the start date, end date and Pollen Peak date, and the *Olea* pollinosis symptomatology thresholds proposed by REA (Null: <1 grain/m<sup>3</sup>, Low: 1–50 grains/m<sup>3</sup>, Moderate: 50–200 grains/m<sup>3</sup>, High: >200 grains/m<sup>3</sup>).

### 3.4. Even-Numbered Years vs. Odd-Numbered Years

The comparison of *Olea* pollen concentration between even and odd years showed significant differences ( $p < 0.05$ ) on the MPS End Day for the southwest region of the IP, finishing earlier, on average, during the odd years (30th April) than in the even years (9th May). The SPIn also had significant differences ( $p < 0.05$ ) between even and odd years in the southwest region of the IP, with pollen concentrations values being, on average, much higher in odd years (10,674 grains/m<sup>3</sup>) than in even years (7024 grains/m<sup>3</sup>) (Table 2). This phenomenon of recording alternate years with high and low pollen production was observed in most of the sites studied, but it only presented significant differences in the southwest region (Portimão, Seville, Lisbon, Évora, Castelo Branco, Badajoz, Coimbra, Toledo). Regarding the Peak Day, significant differences ( $p < 0.05$ ) were also found both in the southwest region and in the rest of IP and occurred earlier in odd years than in even years (Table 2).

**Table 2.** Significant Statistical differences ( $p < 0.05$ ) recorded in the variables analyzed: MPS Start Day, MPS End Day, Seasonal Pollen Integral (SPIn) and Peak Day between the odd-numbered years and even-numbered years in sampling stations located in the southwest area in comparison to the rest of the Iberian Peninsula. Data from Jaén were significantly over the scale, and therefore excluded from this statistical analysis, due to their distorting effect.

	Southwest			Rest of Iberian Peninsula		
	Odd Years	Even Years	<i>p</i> -Value	Odd Years	Even Years	<i>p</i> -Value
MPS Start Day (Day Number/Date)	121/30th April	130/9th May	0.075	128/7th May	132/11th May	0.31
MPS End Day (Day Number/Date)	156/4th June	165/13th June	0.02 *	169/17th June	173/21st June	0.483
SPIn (grains/m <sup>3</sup> )	10,674	7024	0.045 *	2036	1604	0.472
Peak Day (Day Number/Date)	131/10th May	141/20th May	0.025 *	144/23rd May	151/30th May	0.049 *

\*  $p < 0.05$ .

## 4. Discussion

The *Olea* pollen spectrum reached its highest values in the southwest region of the IP, which hosts the largest olive tree cultivation areas [8,9,39]. The olive-growing area has been increasing over the last decades in the IP [9,39] and the results obtained in this study indicate a substantial increase in *Olea* pollen presence in the atmosphere over the last 15 to 30 years, regarding findings from previous studies carried out in this region [40–43].

The olive tree produces a large amount of pollen [44] and its pollen grains hold favourable aerodynamic properties, allowing it to be easily transported into the atmosphere [45]. These characteristics, together with the large number of hectares being used for olive tree cultivation, may explain the abundance of *Olea* as one of the dominant pollen types in the atmosphere of Mediterranean countries [46–48].

The largest olive groves are in the south of the IP, particularly in the region of Andalucía (Spain), where the province of Jaén is recognized as the world's leading olive oil producer [49], with a significant percentage of agricultural land use devoted to this crop [39]. Furthermore, Jaén reports that 97% of allergic patients are sensitized to olive tree pollen [18]. In this study, it was observed that Jaén recorded considerably higher *Olea* pollen values in APIn, SPIn, Peak Value, no. of days with "high" allergenic risk and Pollen Spectrum compared to the other sampling stations (Table 1). *Olea* pollen concentration values gradually decreased with increasing latitude in the IP [50,51], with northern sampling stations exhibiting rather less notable values than the southern ones. Lleida seemed to be an exception to this pattern, with a significant area of olive groves [39], and displaying similar behaviour to some of the sampling stations located further south, as it is under the influence of the meso-Mediterranean thermotype, which favours olive growing [52].

Previous studies have concluded that the start, end and peak dates of the MPS occur earlier in the southern regions compared to northern ones [8,11], as well as lower altitudes compared to higher ones [29,51]. This observation sustains the fact that the coastal and southern thermo-Mediterranean sampling stations such as Almeria, Lisbon, Portimão, Valencia and Seville, have an average start of the MPS in late April, compared to the remaining sites, where the MPS only started during May. On the other hand, the last pollen grains of the MPS were recorded at the end of June in Oviedo (sampling station located at the higher latitude) and Burgos (sampling station at the higher altitude), with both sites characterized by a bioclimatic temperate influence. Recio et al. [53] proposed the city of Málaga as an indicator for the onset of *Olea* MPS in the south of the IP, since the Pollen Peak, on average, occurred earlier (8th May) than other cities studied by other authors in this region. Still, accordingly, instead of Málaga, we propose Seville, since it had an even earlier Pollen Peak, occurring on 7th May. According to the findings of this study, we can define Oviedo as an indicator for the *Olea* MPS finish in the IP, with the latest end date (30th June). Although it is already well-established that meteorological parameters have a clear effect on the MPS of *Olea europaea* L., studies have shown that reproductive development is also conditioned by the fulfilment of certain temperature requirements [31], which differ between the several geographical regions and even within the same region (i.e., depending on altitude) [54].

The *Olea* MPS has a short duration (between 25 and 60 days) in most regions, consistent with the findings reported by other authors [12,29,40], since this pollen type comprises by a single species. The MPS in Lisbon, Oviedo and Valencia has a longer duration (53 days), resulting in allergic patients being exposed to this pollen type for an extended period, which increases the risk of more extended pollinosis symptoms [55,56].

The Pollen Peak, on average, occurs throughout the month of May for all sampling stations (excluding Burgos), as previously noticed in the IP [8,12,50,53]. The Pollen Peak dates depend on topographical and climatological conditions [11], which explain the latter Pollen Peak occurrence during June in Burgos, since this sampling station is located at a higher altitude. The Pollen Peak values in Almeria and Jaén have significantly increased since a study conducted in 2003, when they measured at about 150 and 5000 grains/m<sup>3</sup>, respectively [57]. In this study, the average Pollen Peak value recorded for those sampling stations was 478 and 11,665 grains/m<sup>3</sup>, respectively. García-Mozo et al. (2014) [58] have also noticed an increase in *Olea* Pollen Peak Values through the years. This is likely due to the same reason previously discussed, regarding the extremely high increase in olive-growing land in the southern region of the IP [9,39]. These results indicate that the concentrations of *Olea* pollen recorded in this study are higher than those found in previous research, suggesting an increasing allergenic potential for this taxon in the studied area.

In the southwest region of the IP, the pollen concentrations exceed the threshold values of a “high” allergenic risk occurrence (>200 grains/m<sup>3</sup>) for a period ranging from 6 to 38 days, during which *Olea*-sensitized population may develop *Olea* pollen-related symptoms [32]. The results of a study conducted in Toledo between 2003 and 2007 showed an average number of 8 days with “high” allergenic risk [41]. This study shows that this average has now risen to 13 days in Toledo, suggesting an increase in the number of “high” allergenic risk days in this city.

The *Olea* pollen calendar obtained from this study included a wide and representative coverage of the IP (21 sampling stations), which enabled the identification of cities with the highest risk for *Olea* pollen allergic patients and those sensitized, allowing evaluation of the seasonal behaviour of this pollen according to a threshold system, which can measure the percentage of the population susceptible to developing symptoms associated with *Olea* pollen [32]. This calendar is based on an 8-year historical, reliable database (2012–2019). The main findings showed considerable inter-city variability in pollen concentration (grains/m<sup>3</sup>) and MPS features (start, end, and Pollen Peak). This can be attributed to the wide variety of bioclimatic thermotypes and biogeographic areas represented by the sampling stations analyzed in this study. This is the first *Olea* pollen calendar for the

IP using a wide variety of sampling stations in a single figure, to represent the different biogeographic regions. This approach considers pollen based on spatial variability, ensuring that the pollen calendar is accurate and representative of a given area [59].

When we compare the *Olea* pollen calendar in the IP to other areas of the Mediterranean Basin, it is shown that the MPS (start, end and Pollen Peaks) happens slightly later than in Tunisia but sooner than in Italy [51] and south Turkey [60]. Also, the southern regions of the IP present a similar behaviour to the northeast region of Greece [47]. Furthermore, the pollen concentration reached higher values in the south of the IP than in the other countries of the Mediterranean area [51].

The pollen calendar is a valuable tool, providing an updated, clear and illustrative representation summarizing the airborne pollen dynamics (distribution, timing and concentration thresholds) for each specific region throughout the year (on a daily, monthly and annual basis) [61]. This information can be useful both for allergic patients, allowing them to take preventive measures and reduce their exposure to pollen, and for clinicians, to recognize potential triggers and help in the diagnosis/treatment of *Olea* pollen respiratory allergic disease [47].

*Olea europaea* L. exhibits a rotation in flower productivity, leading to biannual pollen production cycles—a year with high pollen production (odd-numbered years), followed by a year with low pollen production (even-numbered years). This pattern of alternate pollen production has already been reported by some authors [11,12,15,46,60] and it is associated with species' biological cycles, as well as weather conditions, particularly seasonal rainfall, which has an important role in the annual production of *Olea* pollen [50]. Conversely, some authors did not notice the biannual pattern in pollen production, as in a study conducted on the north-western region of Morocco [62].

This study noticed a biannual pollen production pattern, with the even-numbered years recording a higher pollen concentration. This pattern only presented significant differences ( $p < 0.05$ ) for the southwest sampling stations of the IP. In addition, significant differences ( $p < 0.05$ ) in southwest sampling stations were also found in the MPS End Day and the Pollen Peak Day, exhibiting these last parameter differences also in the rest of the IP. This situation, regarding the MPS End Day and Pollen Peak Day, needs to be better studied. In future terms, it would be interesting to analyze this biannual pattern with regard to meteorological parameters, since weather conditions greatly influence olive tree flower and pollen production. Additionally, that may be the reason for not observing significant differences revealing the biannual pattern in some regions of the IP.

To analyze the differences between the sampling stations located in the south-western region and the other sampling stations in the IP, we had to exclude Jaén due to this station's influence on the data analysis. As mentioned above, the concentration of *Olea* pollen in Jaén is extremely high compared to any other sampling station (Table 1), resulting in possibly biased results.

## 5. Conclusions

In this study, *Olea europaea* pollen was monitored for eight consecutive years (2012–2019) at 21 sampling sites throughout Spain and Portugal, covering all the different bioclimatic regions of the IP. Our results have provided a deeper understanding of the pollination behaviour of olive trees and allowed us to establish a representative *Olea* pollen calendar for this region. On average, the MPS started in April/May and ended in June, and Pollen Peaks were recorded in May in all sampling sites except in Burgos (north-eastern quadrant of the IP), where they were recorded in June. *Olea* pollen reached 'high' daily pollen concentrations at all sampling sites in the south-western quadrant of the IP and also in Jaén (south-eastern quadrant of the IP). Interestingly, a biannual pattern of pollination was found at sampling sites in the southwest quadrant of the IP, characterized by alternating years of high and low pollen production. Our results suggest the usefulness of investigating more detailed relationships between annual *Olea* pollen, allergen sensitization and symptoms, both for allergists involved in the study and the management of allergic

respiratory diseases caused by this species, including rhinoconjunctivitis and asthma, and for the self-management of disease in allergic subjects.

**Author Contributions:** Conceptualization, C.P., G.S. and M.B.F.; Data curation, C.P., G.S. and M.B.F.; Formal analysis, C.P., G.S. and M.B.F.; Investigation, C.P., G.S., R.R.-A. and M.B.F.; Methodology, C.P. and G.S.; Project administration, M.B.F.; Resources, G.S., B.T., J.F., P.C.-M., Á.M.d.G. and A.V.; Software, C.P. and G.S.; Supervision, B.T., J.F., P.C.-M., R.R.-A., Á.M.d.G., A.V. and M.B.F.; Validation, C.P., G.S., B.T., J.F., P.C.-M., R.R.-A., Á.M.d.G., A.V. and M.B.F.; Visualization, C.P., G.S., B.T., J.F., P.C.-M., R.R.-A., Á.M.d.G., A.V. and M.B.F.; Writing—original draft, C.P.; Writing—review and editing, C.P., G.S., B.T., J.F., P.C.-M., R.R.-A., Á.M.d.G., A.V. and M.B.F. 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:** The data supporting reported results can be requested by contacting the corresponding author.

**Acknowledgments:** The authors would like to thank the Spanish Society of Allergology and Clinical Immunology—SEAIC and to their sampling station collaborators (Juan Jose Zapata Yebenes, Jesus Garcia Menaya, Jordina Belmonte Soler, Pedro Carretero Añibarro, Blanca Saez de San Pedro Morera, Javier Subiza Garrido-Lestache, Francisco Javier Suarez Perez, Maria Asunción García Sanchez, Cristina Ruiz, Pastora Benitez, Gorka Sanz de Ojer and Jesus Pola Pola), the board and staff of the Portuguese Society of Allergology and Clinical Immunology—SPAIC, the Portuguese Aerobiology Network and also their collaborators (Rui Silva, José Plácido, Ana Todo-Bom, Carlos Lozoya, Paula Leiria Pinto and Carlos Nunes). We also would like to thank to Roberto Oliveira, Luis F. García-Fernández, the Medical Affairs and Clinical Department and the Global Publication Team of LETI Pharma for their collaboration in proofreading this article.

**Conflicts of Interest:** The authors declare no conflicts of interest.

## References

1. Kostelenos, G.; Kiritsakis, A. Olive Tree History and Evolution. In *Olives and Olive Oil as Functional Foods: Bioactivity, Chemistry and Processing*, 1st ed.; Wiley: New York, NY, USA, 2017; pp. 1–12. [CrossRef]
2. Talhaoui, N.; Taamalli, A.; Gómez-Caravaca, A.M.; Fernández-Gutiérrez, A.; Segura-Carretero, A. Phenolic Compounds in Olive Leaves: Analytical Determination, Biotic and Abiotic Influence, and Health Benefits. *Food Res. Int.* **2015**, *77*, 92–108. [CrossRef]
3. Besnard, G.; Khadari, B.; Navascués, M.; Fernández-Mazuecos, M.; Bakkali, A.E.; Arrigo, N.; Baali-Cherif, D.; Brunini-Bronzini de Caraffa, V.; Santoni, S.; Vargas, P.; et al. The Complex History of the Olive Tree: From Late Quaternary Diversification of Mediterranean Lineages to Primary Domestication in the Northern Levant. *Proc. R. Soc. B Biol. Sci.* **2013**, *280*, 20122833. [CrossRef] [PubMed]
4. Kaniewski, D.; Van Campo, E.; Boiy, T.; Terral, J.F.; Khadari, B.; Besnard, G. Primary Domestication and Early Uses of the Emblematic Olive Tree: Palaeobotanical, Historical and Molecular Evidence from the Middle East. *Biol. Rev.* **2012**, *87*, 885–899. [CrossRef] [PubMed]
5. Langgut, D.; Cheddadi, R.; Carrión, J.S.; Cavanagh, M.; Colombaroli, D.; Eastwood, W.J.; Greenberg, R.; Litt, T.; Mercuri, A.M.; Miebach, A.; et al. The Origin and Spread of Olive Cultivation in the Mediterranean Basin: The Fossil Pollen Evidence. *Holocene* **2019**, *29*, 902–922. [CrossRef]
6. Morettini, A. *Olivicoltura*; Ramo Editoriale Degli Agricoltori: Rome, Italy, 1950.
7. International Olive Council. Available online: <https://www.internationaloliveoil.org/> (accessed on 9 February 2023).
8. Díaz de la Guardia, C.; Alba, F.; Trigo, M.D.M.; Galán, C.; Ruíz, L.; Sabariego, S. Aerobiological Analysis of *Olea europaea* L. Pollen in Different Localities of Southern Spain: Forecasting Models. *Grana* **2003**, *42*, 234–243. [CrossRef]
9. Instituto Nacional de Estatística (INE) Superfície Das Principais Culturas Agrícolas (Ha) Por Localização Geográfica (Região Agrária) e Espécie; Anual. Available online: [https://www.ine.pt/xportal/xmain?xpgid=ine\\_main&xpid=INE](https://www.ine.pt/xportal/xmain?xpgid=ine_main&xpid=INE) (accessed on 26 September 2019).
10. Molina, R.T.; López, F.G.; Rodríguez, A.M.; Palaciso, I.S. Pollen Production in Anemophilous Trees. *Grana* **1996**, *35*, 38–46. [CrossRef]
11. García-Mozo, H.; Perez-Badía, R.; Galán, C. Aerobiological and Meteorological Factors' Influence on Olive (*Olea europaea* L.) Crop Yield in Castilla-La Mancha (Central Spain). *Aerobiologia* **2008**, *24*, 13–18. [CrossRef]

12. Ribeiro, H.; Mário, C.; Abreu, I. Airborne Pollen of Olea in Five Regions of Portugal. *Ann. Agric. Environ. Med.* **1982**, *12*, 317–320. [[CrossRef](#)]
13. D’Amato, G.; Lobefalo, G. Allergenic Pollen in the Southern Mediterranean Area. *Allergy Eur. J. Allergy Clin. Immunol.* **1989**, *83*, 116–122. [[CrossRef](#)]
14. Liccardi, G.; D’Amato, M.; D’Amato, G. Oleaceae Pollinosis: A Review. *Allergy Immunol.* **1996**, *111*, 210–217. [[CrossRef](#)]
15. Galán, C.; Vázquez, L.; García-Mozo, H.; Domínguez, E. Forecasting Olive (*Olea europaea*) Crop Yield Based on Pollen Emission. *Field Crop. Res.* **2004**, *86*, 43–51. [[CrossRef](#)]
16. Torrecillas, M.; Gonzalez, J.J.; Palomeque, M.T.; Munoz, C.; Barcelo, J.M.; De la Fuente, J.L.; Chicote, J.M.; Miranda, A. Prevalencia de Sensibilizaciones En Pacientes Con Polinosis de La Provincia de Malaga. *Rev. Esp. Alergol. E Immunol. Clin.* **1998**, *13*, 122–125.
17. Vilches, E.D.; García-Pantaleón, F.I.; Soldevilla, C.G.; Pasadas, F.G.; De La Torre, F.V. Variations in the Concentrations of Airborne Olea Pollen and Associated Pollinosis in Cordoba (Spain): A Study of the 10-Year Period 1982–1991. *J. Investig. Allergol. Clin. Immunol.* **1993**, *3*, 121–129.
18. Garrido-Lestache, F.S.; Pola, J.P.; Brito, F.F.; Moral de Gregorio, A.J. Pólenes de interés en alergología en nuestro medio. *Tratado Alergol.* **2007**, *1*, 425–447.
19. Feo-Brito, F.; Bonilla, P.G.; Rodríguez, R.G.; Torrijos, E.G.; Martínez, F.F.; Fernández-Pachecho, R.; Gallego, A.D. Pólenes Alergénicos En Ciudad Real: Aerobiología e Incidencia Pólenes de Interés En Alergología En Nuestro Medio. Clínica Allergénica Pollens in Ciudad Real: Aerobiology and Clinical Incidence. *Rev. Española Alergol. en Immunol. Clínica* **1998**, *13*, 79–85.
20. Minero, F.J.; Candau, P.; Morales, J.; Tomas, C. Forecasting Olive Crop Production Based on Ten Consecutive Years of Monitoring Airborne Pollen in Andalusia (Southern Spain). *Agric. Ecosyst. Environ.* **1998**, *69*, 201–215. [[CrossRef](#)]
21. Chambel, M.; Paiva, M.; Prates, S.; Loureiro, V.; Pinto, P.L. Polissensibilização a Pólenes Analisada e Reinterpretada à Luz Do Método ImmunoCAP ISAC®. *Rev. Port. Imunoalergologia* **2012**, *20*, 211–219.
22. Mesa, J.A.; Brandao, R.; Lopes, L.; Galan, C. Correlation between Pollen Counts and Symptoms in Two Different Areas of the Iberian Peninsula: Cordoba (Spain) and Evora (Portugal). *J. Investig. Allergol. Clin. Immunol.* **2005**, *15*, 112–116.
23. Tavares, B.; Machado, D.; Loureiro, G.; Cemlyn-Jones, J.; Pereira, C. Sensitization to Profilin in the Central Region of Portugal. *Sci. Total Environ.* **2008**, *407*, 273–278. [[CrossRef](#)]
24. Pereira, C.; Valero, A.; Loureiro, C.; Dávila, I.; Martinez-Cócerca, C.; Murio, C.; Rico, P.; Palomino, R. Sensitisation in Allergic Rhinitis. *Eur. Ann. Allergy Clin. Immunol.* **2006**, *38*, 186–194.
25. Celenk, S.; Canitez, Y.; Bicakci, A.; Sapan, N.; Malyer, H. An Aerobiological Study on Pollen Grains in the Atmosphere of North-West Turkey. *Environ. Monit. Assess.* **2009**, *158*, 365–380. [[CrossRef](#)] [[PubMed](#)]
26. Geller-Bernstein, C.; Portnoy, J.M. The Clinical Utility of Pollen Counts. *Clin. Rev. Allergy Immunol.* **2019**, *57*, 340–349. [[CrossRef](#)]
27. Buters, J.T.; 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**, *8*, 9. [[CrossRef](#)]
28. Singh, A.B.; Mathur, C. An Aerobiological Perspective in Allergy and Asthma. *Asia Pac. Allergy* **2012**, *2*, 210–222. [[CrossRef](#)] [[PubMed](#)]
29. Úbeda, J.R. Estudio de La Fenología Floral Del Olivo (*Olea europaea* L.) y Su Relación Con Las Variables Ambientales. Ph.D. Thesis, University of Castilla-La Mancha, Toledo, Spain, 2014.
30. Macchia, L.; Aliani, M.; Caiaffa, M.F.; Carbonara, A.M.; Gatti, E.; Iacobelli, A.; Strada, S.; Casella, G.; Tursi, A. Monitoring of Atmospheric Conditions and Forecast of Olive Pollen Season. *Experientia* **1987**, *51*, 95–97.
31. Galán, C.; García-Mozo, H.; Vázquez, L.; Ruiz, L.; Díaz de la Guardia, C.; Trigo, M.M. Heat Requirement for the Onset of the *Olea europaea* L. Pollen Season in Several Sites in Andalusia and the Effect of the Expected Future Climate Change. *Int. J. Biometeorol.* **2005**, *49*, 184–188. [[CrossRef](#)]
32. Galán, C.; Cariñanos, P.; Alcázar, P.; Domínguez, E. *Manual de Calidad y Gestión de La Red Española de Aerobiología*; Servicio de Publicaciones de la Universidad de Córdoba: Córdoba, Spain, 2007; ISBN 9788469063545.
33. Rivas-Martinez, S.; Penas, Á.; del Río, S.; Díaz González, T.E.; Rivas-Sáenz, S. Bioclimatology of the Iberian Peninsula and the Balearic Islands. In *The Vegetation of the Iberian Peninsula*; Springer: Berlin/Heidelberg, Germany, 2017; Volume I, pp. 29–80. ISBN 978-3-319-54782-4.
34. Hirst, J.M. An Automatic Volumetric Spore Trap. *Ann. Appl. Biol.* **1952**, *39*, 257–265. [[CrossRef](#)]
35. Galán, C.; Smith, M.; Thibaudon, M.; Frenguelli, G.; Oteros, J.; Gehrig, R.; Berger, U.; Clot, B.; Brandao, R. Pollen Monitoring: Minimum Requirements and Reproducibility of Analysis. *Aerobiologia* **2014**, *30*, 385–395. [[CrossRef](#)]
36. Galán, C.; Ariatti, A.; Bonini, M.; Clot, B.; Crouzy, B.; Dahl, A.; Fernandez-González, D.; Frenguelli, G.; Gehrig, R.; Isard, S.; et al. Recommended Terminology for Aerobiological Studies. *Aerobiologia* **2017**, *33*, 293–295. [[CrossRef](#)]
37. Nilsson, S.; Persson, S. Tree Pollen Spectra in the Stockholm Region (Sweden), 1973–1980. *Grana* **1981**, *20*, 179–182. [[CrossRef](#)]
38. Rojo, J.; Picornell, A.; Oteros, J. AeRobiology: The Computational Tool for Biological Data in the Air. *Methods Ecol. Evol.* **2019**, *10*, 1371–1376. [[CrossRef](#)]
39. Superficies y Producciones de Cultivos-Olivar. Available online: <https://www.mapa.gob.es/es/estadistica/temas/publicaciones/anuario-de-estadistica/> (accessed on 23 February 2022).
40. Minero, F.J.G.; Candau, P.; Morales, J.; Tomas, C. The Pollen Spectrum of Trees and Shrubs in SW Spain (1987–1996). *Grana* **1998**, *37*, 114–120. [[CrossRef](#)]

41. Pérez-Badia, R.; Rapp, A.; Morales, C.; Sardinero, S.; Galán, C.; García-Mozo, H. Pollen Spectrum and Risk of Pollen Allergy in Central Spain. *Ann. Agric. Env. Med.* **2010**, *17*, 139–151.
42. Gutiérrez, M.; Sabariego, S.; Cervigón, P. Calendario Polínico de Madrid (Ciudad Universitaria). Periodo 1994–2004. *Lazaroa* **2006**, *27*, 21–27.
43. Caeiro, E. Aerobiologia Do Pólen de Poaceae, *Olea europaea* L. e *Platanus Hispanica* Miller Ex Münchh. e Potenciais Repercussões Na Doença Alérgica Respiratória No Sul de Portugal. Ph.D. Thesis, Évora University, Évora, Portugal, 2013.
44. Ferrara, G.; Camposeo, S.; Palasciano, M.; Godini, A. Production of Total and Stainable Pollen Grains in *Olea europaea* L. *Grana* **2007**, *46*, 85–90. [[CrossRef](#)]
45. Fornaciari, M.; Galan, C.; Mediavilla, A.; Dominquez, E.; Romano, B. Aeropalynological and Phenological Study in Two Different Mediterranean Olive Areas: Cordoba (Spain) and Perugia (Italy). *Plant Biosyst.* **2000**, *134*, 199–204. [[CrossRef](#)]
46. Rojo, J.; Salido, P.; Pérez-Badia, R. Flower and Pollen Production in the ‘Cornicabra’ Olive (*Olea europaea* L.) Cultivar and the Influence of Environmental Factors. *Trees-Struct. Funct.* **2015**, *29*, 1235–1245. [[CrossRef](#)]
47. Katotomichelakis, M.; Nikolaidis, C.; Makris, M.; Zhang, N.; Aggelides, X.; Constantinidis, T.C.; Bachert, C.; Danielides, V. The Clinical Significance of the Pollen Calendar of the Western Thrace/Northeast Greece Region in Allergic Rhinitis. *Int. Forum Allergy Rhinol.* **2015**, *5*, 1156–1163. [[CrossRef](#)]
48. Martínez-Bracero, M.; Alcázar, P.; Díaz de la Guardia, C.; González-Minero, F.J.; Ruiz, L.; Trigo Pérez, M.M.; Galán, C. Pollen Calendars: A Guide to Common Airborne Pollen in Andalusia. *Aerobiologia* **2015**, *31*, 549–557. [[CrossRef](#)]
49. Galán, C.; García-Mozo, H.; Vázquez, L.; Ruiz, L.; Díaz de la Guardia, C.; Domínguez-Vilches, E. Modeling Olive Crop Yield in Andalusia, Spain. *Agron. J.* **2008**, *100*, 98–104. [[CrossRef](#)]
50. Díaz de la Guardia, C.; Galán, C.; Domínguez-Vilches, E.; Alba, F.; Ruiz, L.; Sabariego, S.; Recio Criado, M.; Fernández-González, D.; Méndez, J.; Vendrell, M.; et al. Variations in the Main Pollen Season of *Olea europaea* L. at Selected Sites in the Iberian Peninsula. *Polen* **1999**, *10*, 103–113.
51. Aguilera, F.; Dhiab, A.; Msallem, M.; Orlandi, F.; Bonfiglio, T.; Ruiz-Valenzuela, L.; Galán, C.; Díaz-De la Guardia, C.; Giannelli, A.; del Mar Trigo, M.; et al. Airborne-Pollen Maps for Olive-Growing Areas throughout the Mediterranean Region: Spatio-Temporal Interpretation. *Aerobiologia* **2015**, *31*, 421–434. [[CrossRef](#)]
52. Blumler, M. Three Conflated Definitions of Mediterranean Climates. *Middle States Geogr.* **2005**, *38*, 52–60.
53. Recio, M.; Cabezudo, B.; Trigo, M.M.; Toro, F.J. *Olea europaea* Pollen in the Atmosphere of Málaga (S. Spain) and Its Relationship with Meteorological Parameters. *Grana* **1996**, *35*, 308–313. [[CrossRef](#)]
54. Aguilera, F.; Ruiz Valenzuela, L. Altitudinal Fluctuations in the Olive Pollen Emission: An Approximation from the Olive Groves of the South-East Iberian Peninsula. *Aerobiologia* **2012**, *28*, 403–411. [[CrossRef](#)]
55. Raulf, M.; Buters, J.; Chapman, M.; Cecchi, L.; De Blay, F.; Doekes, G.; Eduard, W.; Heederik, D.; Jeebhay, M.F.; Kespohl, S.; et al. Monitoring of Occupational and Environmental Aeroallergens—EAACI Position Paper: Concerted Action of the EAACI IG Occupational Allergy and Aerobiology & Air Pollution. *Allergy Eur. J. Allergy Clin. Immunol.* **2014**, *69*, 1280–1299. [[CrossRef](#)]
56. Cecchi, L.; D’Amato, G.; Ayres, J.G.; Galan, C.; Forastiere, F.; Forsberg, B.; Gerritsen, J.; Nunes, C.; Behrendt, H.; Akdis, C.; et al. Projections of the Effects of Climate Change on Allergic Asthma: The Contribution of Aerobiology. *Allergy Eur. J. Allergy Clin. Immunol.* **2010**, *65*, 1073–1081. [[CrossRef](#)]
57. Alba, F.; Nieto-Lugilde, D.; Comtois, P.; Díaz de la Guardia, C.; Linares, C.; Ruiz, L. Airborne-Pollen Map for *Olea europaea* L. in Eastern Andalusia (Spain) Using GIS: Estimation Models. *Aerobiologia* **2006**, *22*, 109–118. [[CrossRef](#)]
58. García-Mozo, H.; Yaezel, L.; Oteros, J.; Galán, C. Statistical Approach to the Analysis of Olive Long-Term Pollen Season Trends in Southern Spain. *Sci. Total Environ.* **2014**, *473–474*, 103–109. [[CrossRef](#)]
59. Lo, F.; Bitz, C.M.; Battisti, D.S.; Hess, J.J. Pollen Calendars and Maps of Allergenic Pollen in North America. *Aerobiologia* **2019**, *35*, 613–633. [[CrossRef](#)]
60. Tosunoglu, A.; Altunoglu, M.K.; Bicakci, A.; Kilic, O.; Gonca, T.; Yilmazer, I.; Saatcioglu, G.; Akkaya, A.; Celenk, S.; Canitez, Y.; et al. Atmospheric Pollen Concentrations in Antalya, South Turkey. *Aerobiologia* **2015**, *31*, 99–109. [[CrossRef](#)]
61. Arias, T.; Drago, M.; Soler, J.; Maira, A.; Dahl, V.; Martínez, A.; Hernández, J. *Polinosis: Polen y Alergia*; MRA Creación y Realización: Córdoba, Spain, 2002; ISBN 8488865716.
62. Achmakh, L.; Janati, A.; Boullayali, A.; ElHassani, L.; Bouziane, H. Forecasting Olive (*Olea europaea* L.) Production Using Aerobiological and Meteorological Variables in Tétouan (NW Morocco). *Aerobiologia* **2020**, *36*, 749–759. [[CrossRef](#)]

**Disclaimer/Publisher’s Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.