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Heat and chill requirements of *Fraxinus* flowering in Galicia (NW Spain)

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Fraxinus pollen data from eight Galician localities (1999–2003), recorded using 7-day Lanzoni VPPS pollen traps, were studied to determine their temporal and spatial distribution. The determination of the chill and heat required to trigger flowering and the start cumulative date were calculated using ten years of pollen data from Ourense. The sum of maximum temperatures from the 55 days before the peak date showed the lowest standard deviation coefficient and the mean quantity of accumulated heat was 741. Temperatures below 0°C and/or rainfall at the beginning of flowering caused a longer period before the peak date was registered. Temperatures recorded in November were very important for chill accumulation and determine the heat requirement needed to trigger *Fraxinus* flowering in Galicia.

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The developmental process that leads to bud dormancy release and thus triggers the onset of growth of temperate zone trees is mainly regulated by temperature. This regulation is such that a period with chilling temperatures followed by a period with forcing temperature induces budburst. These periods of chilling and forcing temperatures are variable according to the specific taxon and geographical area considered. The relationship between both chill and heat requirements has been reported by different authors who consider chilling temperatures accelerate the renewal of growth once dormancy is broken; the more chilling units are cumulated, the less forcing units are subsequently needed for budburst (Myking & Heide 1995, Chuine & Cour 1999). Therefore, temperature is recognized as the main variable to influence the timing of budburst and flowering.

Fraxinus is widespread in Central and Northern Europe. It is an anemophilous tree with a pollen production of around 12,500 pollen grains by anther in the case of *Fraxinus excelsior* L. (Pohl 1937) and between 18,000 and 87,000 in the case of *Fraxinus angustifolia* Vahe (Tormo et al. 1996). The allergological interest in *Fraxinus* pollen stems from its potential cross-reactivity with pollen from other Oleaceae, namely *Olea* pollen (Bousquet et al. 1985, D'Amato 1998, Martínez et al. 1999, Guerra et al. 2000) and 100 pollen grains per cubic meter of air has been cited as threshold level to produce hay fever symptoms in Switzerland (Gehrig & Peeters 2000). The percentage of positive reactions to *Fraxinus* pollen in the population sensitive to a given pollen type is less than 8% in the south of Galicia (Arenas et al. 1996).

In the Mediterranean area of the Iberian Peninsula, *Fraxinus* is, together with *Populus* and *Ulmus*, the most

frequent species found in riverside forests (Costa et al. 1998) and it is also frequent as an ornamental plant (Candau et al. 1994). Despite the fact that most of Galicia belongs to the Euro - Siberian region, southeastern Galicia is usually included in the Mediterranean Biogeographic Region. The confluence of both Euro - Siberian and Mediterranean regions in our territory gives the vegetation a transitional character and the presence of characteristic species from both the Euro - Siberian and Mediterranean area is very frequent. Species broadly distributed around Europe, such as *Alnus glutinosa* (L.) Gaertner together with others of European-meridional or Mediterranean affiliations such as *Populus alba* L., *Celtis australis* L. or *Fraxinus angustifolia* Vahe, form the riverside forests in south-eastern Galicia. Hence, *F. angustifolia* is the most frequent species, although *F. excelsior* L. is also present in a smaller area in the south of the eastern part of Galicia.

Fraxinus, in addition to *Corylus* and *Alnus*, is the first species to flower every year in Galicia. Phenological observations carried out every year revealed huge differences in the behaviour of *Fraxinus* between both years and individuals. Consequently, flowering may start at the end of December when temperature is high, but may then be delayed until the end of January when minimum temperatures below zero are recorded in December and/or early January.

Therefore, and despite the low quantity of pollen recorded at Galician aerobiological monitoring stations, the authors consider that is important to determine the behaviour of *Fraxinus* pollen in this area. Taking into account its early flowering, the chill requirement needed for dormancy release would be satisfied rapidly at the end of autumn. The heat

requirement needed to trigger flowering would then be accumulated, but it is not easy to pinpoint the exact date when this starts. The aim of this study is to determine the chill and heat requirements and the periods when *Fraxinus* trees accumulate heat. This would enable us to compare this region with other European areas and determine the possible effect that climate changes could have on the behaviour of these species.

MATERIAL AND METHODS

The importance of airborne *Fraxinus* pollen in Galicia was analysed using aeropalynological data obtained from five years (1999–2003) in eight Galician localities included in the Spanish Aerobiological Network (REA) (Fig. 1). In the case of the Ourense station, data from 1993 to 2003 were also used to determine the heat requirement needed to trigger *Fraxinus* flowering at this locality (data from 1998–1999 were excluded in the statistical analysis because of the lack of data corresponding to the first fortnight in November). This monitoring station was selected due to the amount of *Fraxinus* pollen recorded and the availability of a longer data series.

Pollen sampling was performed using LANZONI VPPS 2000 volumetric traps (Hirst 1952), placed on top of different buildings at a similar height from the ground (between 10 and 20 meters).

Melinex coated with silicon 2% solution was used as a pollen-trapping surface. The exposed tape was cut into seven pieces; these were then mounted on separate glass slides. The pollen grains were counted using the model proposed by the Spanish Aerobiological Network (REA), based on four longitudinal transects along the slides (Dominguez et al. 1992). Daily mean pollen concentrations are expressed as pollen grains/m³ of air.

The meteorological data used were provided by the National Meteorological Institute and obtained by meteorological stations

located near the spore-traps. Mean, minimum and maximum temperatures, rainfall and thermal oscillation range were used.

Taking into account the flowering dates, every annual period comprises two different parts of calendar years. When we refer to an annual period we are referring to both years (i.e. 1998–1999 refers to the pollen for the most part recorded in 1999, but influenced by the meteorological conditions during the final period of 1998).

Start date of the pollen season

Taking into account the low annual total quantity of airborne *Fraxinus* pollen, we selected the start of pollen season by using different criteria including: A) the day on which the prime pollen grains were registered on a continuous basis and for no more than two consecutive days without pollen being detected (Jato et al. 2002); B) the day on which the first *Fraxinus* pollen is collected; C) the first of two consecutive days during which one or more *Fraxinus* pollen grains per cubic metre were registered; D) the day on which the maximum daily mean *Fraxinus* pollen was registered (peak day), because this may be considered as the population's mean flowering date.

Determining the heat requirement

Several methods for determining the heat requirement needed to trigger flowering were tested. Data from ten years (1993–2003) of aerobiological monitoring from Ourense were used. Calculations of chill requirements were performed by taking into account the method of Aron (1983). Calculations of heat requirements were performed using several methods:

- 1) the sum of the daily maximum, mean and minimum temperatures, and the daily thermal oscillation;
- 2) The mean of the daily mean temperatures ($\bar{t}_i$) during the period (Yang et al. 1995): $^{\circ}D = \Sigma(t_i - t_h)/n$, where t_i is the sum of the daily mean temperatures divided by the number of days in the period;
- 3) degree-days were calculated by taking into account daily mean temperatures (Ring et al. 1983): $^{\circ}D = \Sigma(t_{med} - t_h)$, where t_{med} is the daily mean temperature. If $t_{med} < t_h$, then $^{\circ}D$ is equal to 0.
- 4) the criterion proposed by Zalom et al. (1983), based on the following assumptions: if $t_h \geq T_{max}$, then $^{\circ}D$ is equal to 0, if $t_{min} < t_h < t_{max}$, then $^{\circ}D = [(T_{max} - t_h)/2] \times (T_{max} - t_h) / (T_{max} - T_{min})$ and finally if $t_h \leq t_{min}$, then $^{\circ}D = T_{med} - t_h$;
- 5) and lastly, calculation of the heat requirement by taking into account the days when meteorological conditions enabled plant physiological activity, either totally ($t_{min} > t_h$) or partially ($t_{max} > t_h > t_{min}$) (VA-method; Jato et al. 2002). In this case, we considered the heat requirement as a function of the sum of the difference between the daily maximum temperature and the threshold temperatures: $HR = \Sigma(t_{max} - t_h)$. If t_{max} was less than, or equal to, the threshold temperature ($t_{max} < t_h$), the values were set to 0.

Different threshold temperatures from 0°C to 8°C were tested in increments of 0.5°C. The lowest standard deviation and coefficient of variation was used to identify the most adequate threshold temperature in the period and the best date for defining the onset of *Fraxinus* flowering.

All of those indexes used were applied to every 100 days before the start of pollen season and pollen peak dates. Then, the accumulated sum of daily values was calculated starting from the first day before every fixed date (start of pollen season and peak date) and increasing in one-day steps (from 1 to 100 days before every date).

RESULTS

The annual total *Fraxinus* pollen count recorded in every monitoring station and year in Galicia was low (Fig. 2).



Fig. 1. Sampling locations in Galicia.

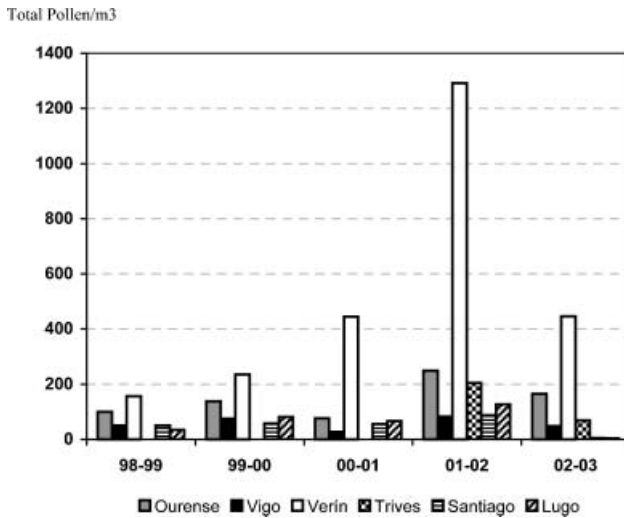


Fig. 2. *Fraxinus* annual total pollen in Galicia (1999–2003). Data from other localities are not shown because of the low values.

Ourense and Verín, monitoring stations located in the south of Galicia, were the areas where the annual total pollen and daily mean pollen concentrations were highest. Every year, Verín, the most meridional monitoring station, registered the highest value, with a maximum annual total pollen in the years analysed of 1291 pollen grains. Ourense registered a maximum annual total count of 249 pollen grains. Other localities registered lower values (almost null in the coastal northern areas), usually between January and March. All stations recorded the maximum annual total pollen in the same year: 2001–2002.

The months in which higher levels were recorded for the localities with higher annual total *Fraxinus* pollen were normally January in the case of Ourense, February in Verín, and February or March in Trives (only data from the last two years are available for this station).

In spite of the low annual total *Fraxinus* pollen, the pollination period lasted for a long period: the first pollen grains usually appeared at the end of December or beginning of January, depending on the station and year,

and ended in late March. The daily maximum concentration was usually recorded in January or February (depending on the year and site), and the peak has been registered in Verín with 223 pollen grains/m³ (12 February 2002). The maximum in Ourense was 37 pollen grains/m³, recorded on 28th January 2002. In a given station, a difference of more than 30 days between the days of maximum daily concentration in the years studied was observed.

In order to determine the influence of meteorological parameters on flowering, different thermal indexes were employed. All of them were applied every year taking into account the different dates calculated using the methods indicated in the Material and Methods section to determine the start of the pollen season and the peak day (Table I).

Firstly, in order to calculate the heat accumulated during the previous period to the start date of the pollen season and the peak date and to determine the date when heat accumulation started, the sum of the daily maximum, mean and minimum temperatures and thermal oscillation were used. The sum of the daily maximum temperatures had the lowest standard deviation for every pollen season start date used and peak day. When the sum of maximum temperatures from the 55 days prior to the peak date was calculated, the lowest standard deviation was obtained. In this case, the standard deviation value was 6.27, obtaining values below 7.0 between the days 29 and 62, increasing thereafter (Fig. 3D).

The values of the standard deviation coefficients were very similar when different pollen season start dates were used. In this case, the values ranged from 8.30, obtained taking into account the 38 days before the date the first *Fraxinus* pollen was captured (*B-criterion*), to 8.63, obtained when considering the 39 days previous to the two consecutive days with *Fraxinus* pollen in the air (*C-criterion*). The values of the coefficients obtained were very similar and less than 9.0 regardless of the criterion used to select the pollen season start date. From that day forward, the coefficient value increased (Fig. 3).

Once we found maximum temperature revealed the lowest coefficients and in order to improve the results obtained, other phenological thermal indexes were employed. Zalom-

Table I. Start of pollen season and peak dates according to the different criteria and pollen concentration values recorded (Pollen m⁻³).

* Not considered in the statistical analysis.

Study period	Pollen Season Start date (A)	Value	Pollen Season Start date (B)	Value	Pollen Season Start date (C)	Value	Peak Date (D)	Value
1992–1993	Jan 18	20	Jan 7	1	Jan 18	20	Jan 18	20
1993–1994	Jan 3	4	Jan 3	4	Jan 3	4	Jan 15	5
1994–1995	Jan 12	1	Jan 12	1	Jan 12	1	Jan 25	45
1995–1996	Jan 1	8	Jan 1	8	Jan 1	8	Jan 4	31
1996–1997	Jan 9	1	Dec 30	2	Jan 30	2	Jan 6	18
1997–1998	Jan 2	3	Dec 12	2	Dec 20	1	Jan 10	31
1998–1999*	Jan 3	1	Jan 3	1	Jan 5	2	Jan 26	16
1999–2000	Jan 6	2	Dec 29	5	Dec 29	5	Jan 9	17
2000–2001	Dec 10	1	Dec 4	1	Dec 4	1	Feb 11	5
2001–2002	Jan 13	1	Dec 25	1	Jan 13	1	Jan 28	37
2002–2003	Dec 20	1	Dec 20	1	Dec 20	1	Jan 2	15

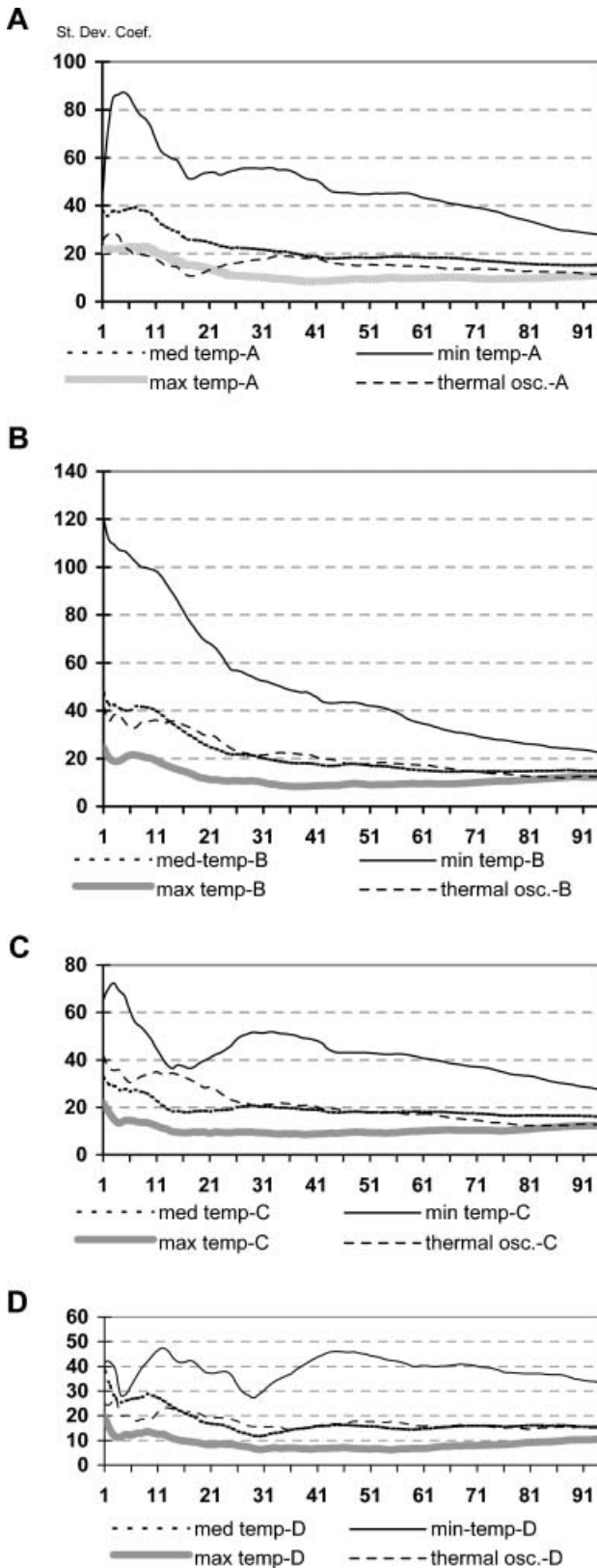


Fig. 3. Standard deviation coefficients of the sum of the daily medium (T_{med}), minimum (T_{min}), and maximum temperatures (T_{max}), and thermal oscillation from 1 to 100 days before the start of pollen season (A – C) and peak date (D).

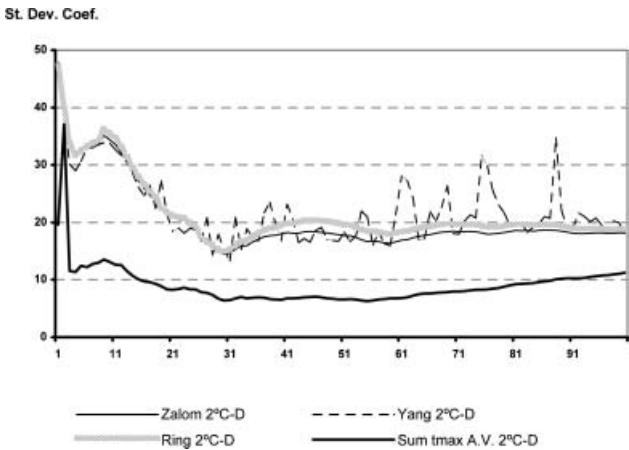


Fig. 4. Standard deviation coefficients of the sum of the Zalom-, Ring-, Yang- and AV- values from 1 to 100 days before the peak date (D). Threshold temperature – 2°C.

Ring-, Yang-, and VA-methods using threshold temperatures from 0°C to 8°C (in 0.5°C steps) were applied. The standard deviation coefficients were higher than those obtained using the sum of daily maximum temperature. The lowest coefficients were obtained in the same way with the peak date and using the VA-method (Jato et al. 2002). In this case, the coefficient decreased despite the low threshold temperature, the lowest being 6.27 obtained by using the 55 days before the peak date and a threshold temperature from 2° to 0°C (Fig. 4).

Coefficients were lower than 7.0 between days 29 and 62 before the peak date. Every index presented the lowest coefficients when threshold temperatures equal to, or below, 2°C were used increasing the value with higher temperatures. When the Zalom- and Ring-methods were applied, the lowest standard deviation coefficients (14.49 and 14.97,

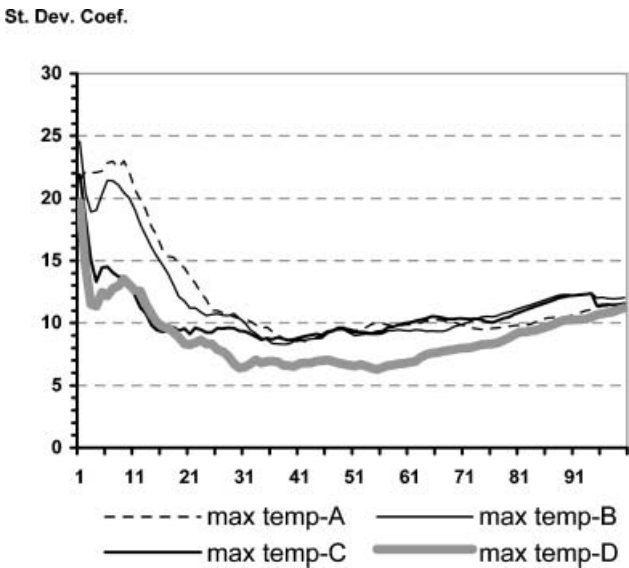


Fig. 5. Standard deviation coefficients of the sums of the daily maximum temperatures (T_{max}) from 1 to 100 days before the start of pollen season (A – C) and peak date (D).

Table II. Average maximum and minimum temperatures (T_{min} and T_{max}) calculated for 62 or 29 days before the peak date during ten years studied.

Chill accumulated during November (--- – negative values); Heat accumulated (as sum of the maximum temperatures) during the 55 days before the peak date; Minimum and maximum values – underlined and in bold respectively.

Study period	Average T_{max} (62)	Average T_{max} (29)	Average T_{min} (62)	Average T_{min} (29)	Chilling November (6.5°C)	Heat 55 days before Peak date
1992–1993	13.50	12.82	5.45	4.44	----	723
1993–1994	13.29	13.59	5.20	6.83	664	717
1994–1995	13.85	12.97	4.53	3.68	651	736
1995–1996	15.42	14.09	6.89	6.91	----	807
1996–1997	12.85	14.35	3.86	3.95	671	714
1997–1998	14.61	13.77	7.33	6.73	----	795
1999–2000	12.95	11.87	3.58	3.74	655	682
2000–2001	13.94	13.77	6.79	6.47	651	753
2001–2002	12.59	13.41	0.1	3.47	634	681
2002–2003	15.43	14.49	7.68	7.14	----	799

respectively) were obtained when the 30 days before the peak date and 2°C as threshold temperature were used. Finally, the results obtained using the Ring-method were extremely irregular, although the same trend was observed. The lowest coefficient (13.36) was obtained using the 30 days before the peak date and a threshold temperature of 2°C (Fig. 4).

Lastly, the same threshold temperatures between 0° and 8°C were applied to the sum of the daily maximum temperature. Once again, the peak date had lower coefficients than when start date was considered. Threshold temperatures equal or below 2°C showed the lowest values. The lowest coefficient (6.21) was obtained when considering the 55 days before the peak date. The coefficient value remained below 7.0 between the days 29 and 62 (Fig. 5).

When considering the different pollen season start dates, the lowest coefficient was obtained when the date on which the first pollen grain was registered was used as the start of pollen season (Fig. 5). Again threshold temperatures below 2°C resulted in the lowest coefficient values (Fig. 5). Below this temperature coefficient values were similar and consequently the results were the same as those obtained without the threshold temperature. The authors observed that every year maximum temperatures below 2°C were not registered during the 100 days before the peak date, and this was the cause because the same standard deviation coefficient was obtained with both methods: the sum of daily maximum temperature-method and the VA-method. It may therefore be considered that 0°C was the threshold temperature that offered the best results.

The mean heat requirement calculated, taking into account the 55 days before the peak date, and using the sum of daily maximum temperature, was 741°C but ranged between 681°C in 2001/2002 and 807°C in 1995/1996 (Table II).

DISCUSSION

Fraxinus pollen concentrations recorded in Galicia are low, with the highest values found at Verín (the southernmost sampler). January or February are usually the months when

both mean pollen concentrations and monthly pollen counts are higher. In the same location but in different years, a delay of more than one month may sometimes be observed between pollen peak dates. This has also been observed in southern Spain by Candau et al. (1994), who attributed the delay to the varying mean temperature in November. Most of the pollen grains registered in Galicia belong to *Fraxinus angustifolia*, which is the main species present in that region. Nevertheless, in the most meridional stations a few pollen grains were captured at the end of the pollen season, mainly in the first fortnight of March. This secondary peak probably corresponds to the pollination of the species *Fraxinus excelsior* (scarcely represented in Galicia), which flowers later.

Low concentrations were also registered in most of the Spanish aerobiological monitoring sites; Girona (NE Spain) is the only city where annual total *Fraxinus* pollen is higher, reaching 3000 pollen grains per year. In Cáceres and Badajoz (Eastern Spain), more than 1000 pollen grains per year are usually recorded. Between 500 and 1000 pollen grains as total annual number are registered in Madrid, Mérida, Sevilla and Oviedo (cf. Rea 1–7, 1995–2002). The other monitoring stations, included in the Spanish Aerobiological Network (REA) record less than 500 pollen grains per year (cf. Rea 1–7, 1995–2002). The month in which the maximum amount of pollen is captured differs depending on the locality; February is always the month in which maximum total pollen is recorded in Girona, whereas in Madrid it occurs in January or February. However, in other localities a great variation was founded, and in some years maximum monthly total pollen count may be detected in December; and in other regions such as Badajoz, it may occur in March.

Higher pollen concentrations and a delay in the start of the pollen season are observed in Switzerland, where March or April was reported to be the pollen season start date (Peeters 2000).

Very different behaviour is also observed in Spain in terms of the synchronization with the flowering of *Betula*, since in Galicia the *Betula* pollen season starts at the end of March or beginning of April. In Switzerland, however, the

start of the pollen seasons of both taxa is usually very close and it takes place at the beginning of April (Peeters 2000, Gehrig & Peeters 2000).

The high variability of the *Fraxinus* pollen season makes it difficult to predict the start of its pollen season, as the flowering of this tree is strongly influenced by the low temperatures that are normal at the time of its pollination period. In Ourense, the annual lowest minimum temperatures are usually recorded in January; however, the highest daily mean *Fraxinus* pollen concentrations are also normally captured in this month. Frost temperatures and precipitation may occur once the first *Fraxinus* pollen grains are present in the air and when this happens the period between the appearance of the first pollen grains and the peak date may be longer. In some years this period may last for as much as 63 days (2000–2001, a year characterised by continuous precipitation) or 36 days (1996–1997, when minimum temperatures below zero were recorded in late December, when the first pollen grains were observed, and the first fortnight in January). The influences of minimum temperature and rainfall on *Fraxinus* pollen season have also been reported by Peeters (2000) and Latorre & Bianchi (1997).

Aerobiological *Fraxinus* pollen data were used to determine the heat requirements needed to trigger flowering and consequently the onset of the pollen season. The accumulated maximum temperatures were calculated taking into account a different number of days before the peak date (29 to 62 days). The use of accumulated maximum temperatures without threshold temperature always yielded the best results, when using both the peak date and the pollen season start dates. The lowest standard deviation coefficients were obtained when the sum of the 55 days or 38 days before the peak date or the start date of pollen season (*B-criterion*) were calculated.

The highest and lowest values were recorded in 1995–1996 or 2002–2003 and in 1999–2000 or 2001–2002 respectively. When the average maximum and minimum temperatures of the same days were calculated, it was observed the four years above mentioned were also the most extreme in terms of meteorological parameters. Therefore, the average maximum temperature of the 62 days before the peak date reached a maximum value in 2002–2003 and 1995–1996 (Table II); and minimum temperatures below zero were only respectively registered on five days and one day in the same periods. In contrast, the lowest average maximum temperatures of the 29 days before the peak date were recorded in 1999–2000 and minimum temperatures below 0°C were recorded on nine days during the two previous months to the peak date.

As regards average minimum temperatures, the lowest values were recorded in the year 2001–2002, when considering both the 62 and 29 days before the peak date (Table II). Very low minimum temperatures were recorded in November and December 2001, the averages being 2.77 and 1.82, respectively. The peak date in that year was 28th January. Finally, the average minimum temperature considering 29 days before the peak date reached the T-highest value in 2002–2003, the maximum temperatures in December 2002 were very high (average of 14.54°C) and only on one day did the minimum temperature fall below 0°C.

Minimum temperature had a restrictive effect and temperatures over 0°C seem to be necessary in order to release flowering, even if accumulated heat was sufficiently high.

From the results obtained in Ourense, the average date on which heat accumulation began was 25th November; the average accumulated heat value during the previous 55 days to the peak date was 741. The result was tested by using data from 1998–1999 (this year was excluded from the study because the lack in the meteorological data of the first fortnight of November). Exactly 741.70 was obtained as a sum of maximum temperatures between 25th November 1998 and 25th January 1999 (just one day before the peak date). A difference of four days between the expected and observed pollen season start date was obtained when calculating the sum of accumulated maximum temperature on the 38 days before the appearance of the first pollen grains in 1999.

Lastly, cumulated chill during November was calculated every year by means of the Aron-method (Aron 1983). In at least four of the ten years studied, the temperatures recorded in November did not drop enough to allow *Fraxinus* trees to accumulate the chill required below 6.5°C (Table II). In contrast, the highest sum of heat was accumulated in the same years (1995–1996, 2002–2003 and 1997–1998). The years in which the November temperatures enabled the required chill accumulation to be achieved presented the lowest heat accumulation values (1999–2000, 2001–2002). This demonstrated once again that higher cumulated chill results in less heat being necessary for dormancy release, as previously reported by various authors (Myking & Heide 1995, Chuine & Cour 1999, Jato et al. 2000).

The obtained results show a different behaviour among *Fraxinus angustifolia* (the main species in Galicia) and *F. excelsior*. The later presents an early Spring flowering in Switzerland that corresponds together with low *Fraxinus* pollen concentrations detected in the south of Galicia during the month of March. These behaviour differences could be a result of a higher threshold temperature requirement in *Fraxinus excelsior* (Wielgolanski 1974).

Temperature increases during Winter, probably caused by global warming can provoke an early start of the growing season of *Fraxinus angustifolia*. This trend combined with frost events could cause significant frost damage in catkins.

CONCLUSIONS

In spite of the low *Fraxinus* pollen concentrations registered in Galicia, the data corresponding to airborne pollen are a useful tool for demonstrating the importance of meteorological conditions during dormancy to trigger flowering. Accumulated chilling in November determines the heat requirements and the start of pollen season. The maximum temperatures recorded in December are the most important for accumulating the required amount of heat. However, if minimum temperatures fall below 0°C, flowering will be delayed and consequently maximum pollen concentrations will be captured at the end of January or the beginning of February. Possible climatic changes affecting temperatures in November and December will determine changes in the phenology of *Fraxinus* flowering, and expose it to increased risk of frost damage.

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REFERENCES

- Arenas, L., González de la Cuesta, C., Tabarès, J. M., Iglesias, I., Jato, V. & Méndez, J. 1996. Sensibilización cutánea a pólenes en pacientes afectados de rinoconjuntivitis-asma en la población de Ourense en el año 1994–1995. – In: 1st Eur. Symp. Aerobiol., Santiago de Compostela 1996. Proc. (ed. Org. Comm.), pp. 93–94. – SC Univ., Santiago de Compostela.
- Aron, R. 1983. Availability of chilling temperatures in California. – Agric. Meteorol. 28: 351–363.
- Bousquet, J. B., Guérin, H., Hewitti, B., Dhivert, F. & Michel, F. B. 1985. Allergy in the Mediterranean area II. Cross allergenicity among Urticaceae pollens (*Parietaria* and *Urtica*). – Clin. Allergy 16: 57–64.
- Candau, P., Gonzalez Minero, F. & Romero, F. 1994. Aeropalynology of *Fraxinus* (Ash) in an urban area of southwestern Spain. – Aerobiologia 10: 47–51.
- Costa, M., Morla, C. & Sainz, H. 1998. Los bosques Ibéricos. – Ed. Planeta, Barcelona.
- Chuine, I. & Cour, P. 1999. Climatic determinants of budburst seasonality in four temperate-zone tree species. – New Phytol. 143: 339–349.
- D'Amato, G. 1998. L'olivo: dal mediterraneo al mondo. – Aria, Ambiente, Salute 3: 36–37.
- Domínguez, E., Galán, C., Villamandos, F. & Infante, F. 1992. Handling and evaluation of the data from the aerobiological sampling. – Monogr. Rea 1: 1–18.
- Gehrig, R. & Peeters, A. G. 2000. Pollen distribution at elevations above 1000 m in Switzerland. – Aerobiologia 16: 69–74.
- Guerra, F., Castro de, C., Alonso, C., Cabeza, N., Luque, D. & Moreno, C. 2000. Incidence of sensitization to *Fraxinus* (t15) in Córdoba (Spain) and its allergological interest. – In: 2nd Eur. Symp. Aerobiol. Vienna 2000. Proc. (ed. Org. Comm.), p. 46. – <http://betula.hno.akh-wien.ac.at/s2000/abstracts.html>.
- Hirst, J. 1952. An automatic volumetric spore-trap. – Ann. Appl. Biol. 36: 257–265.
- Jato, V., Frenguelli, F., Rodríguez, F. J. & Aira, M. J. 2000. Temperature of *Alnus* pollen in Spain and Italy (1994–1998). – Grana 39: 240–245.
- Jato, V., Rodríguez-Rajo, F. J., Méndez, J. & Aira, M. J. 2002. Phenological behaviour of *Quercus* in Ourense (NW Spain) and its relationship with the atmospheric pollen season. – Int. J. Biometeorol. 46: 176–184.
- Latorre, F. & Bianchi, M. M. 1997. Relación entre aeropolen y vegetación arbórea en el Mar del Plata (Argentina). – Polen 8: 43–59.
- Martínez, A., Asturias, J. A., Palacios, R., Sanz, M. L., Sánchez, G., Oehling, A. & Martínez, J. 1999. Identification of a 36-kDa olive-pollen allergen by in vitro and vivo studies. – Allergy 54: 584–592.
- Myking, T. & Heide, O. M. 1995. Dormancy release and chilling requirements of buds of latitudinal ecotypes of *Betula pendula* and *B. pubescens*. – Tree Physiol. 15: 697–704.
- Peeters, A. G. 2000. Frost period and beginning of the ash (*Fraxinus excelsior* L.) pollen season in Basel (Switzerland). – Aerobiologia 16: 353–359.
- Pohl, F. 1937. Die Pollenerzeugung der Windbluetler. Eine vergleichende Untersuchung mit Ausblicken auf die Bestäubung der tierbluetigen Gewaechse und die pollenanalytische Waldgeschichte. – In: Untersuchung zur Morphologie und Biologie des Pollen VI. – Bhf. Bot. Zentralbl. 56A: 365–471.
- Rea (1995–2002) Journal published by the Spanish Aerobiological Network and the Department of Plant Biology of the University of Málaga. – Rea 1–7.
- Ring, B. R., Harris, M. K., Jackman, J. A. & Mesón, J. L. 1983. A Fortran computer program for determining start date and base temperature for degree-day models. – Bull MP-1537. Texas Agric. Exp. St. Texas Univ. System, College Station TX.
- Tormo, R., Muñoz, A., Silva, I. & Gallardo, F. 1996. Pollen production in anemophilous trees. – Grana 35: 38–46.
- Wielgolaski, F. E. & Inouye, D. W. 2003. High latitude climates. – In: Phenology: An integrative environmental science (ed. M.D. Schwartz), pp. 75–194. – Kluwer Acad. Publ., London.
- Yang, S., Logan, J. & Coffey, D. L. 1995. Mathematical formulae for calculating the base temperature for growing degree-days. – Agric. For. Meteorol. 75: 61–74.
- Zalom, F. G., Goodell, P. B., Wilson, L. T., Barnet, W. W. & Bentley, W. J. 1983. Degree-days: the calculation and use of heat units in pest management. – Leaflet 21373. DANR UC, Davis CA.