



The relationship between the flowering phenophase and airborne pollen of *Betula* in galicia (N.W. spain)

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Abstract

The aim of this work was to investigate the phenological behaviour of *Betula* in Galicia, NW Spain, and to examine the relationship between the *Betula* pollen curves and the flowering phenophase. Three trees were chosen from each of nine populations of *Betula* located at different altitudes and phytogeographic positions. Phenological observations of the flowering periods of *Betula* were made in each of them. Environmental factors such as frequency of mist, latitudinal and topographic position, proximity of the ocean, degree of solar exposure, and altitude result in phenological differences between the investigated populations. The correlation between the Pollinic Production Index of *Betula* pollen in Galicia and the aerobiological data of the seven monitoring stations showed that the period in which the highest concentrations were registered was almost synchronous with the flowering times at most of the phenological stations studied. Other factors such as transport and reffotation should also be taken into account to provide an adequate interpretation of the aerobiological data of *Betula* pollen in the atmosphere.

Introduction

Phenology, the study of periodical rhythms in biological events including sprouting, flowering and fruit ripening (Font, 1977), has recently received much attention due to its application in climate change studies. Several phenological studies of woody plants in northern temperate regions have showed earlier spring events in recent decades as a response to an increase in temperatures (Menzel, 2000; Sparks et al., 2000; Cenci and Ceschi, 2000). Recently aerobiological data (Emberlin et al., 1997) has also confirmed earlier flowering in birch trees in the U.K. Phenological studies are also useful in other sectors of human activity such as agronomy, where the timing of pesticide and fertiliser application can be related to plant development (Cenci and Ceschi, 2000).

Knowledge of the flowering phenophase of the most important wind pollinated species, allows us to observe the relationship between reproductive phenology and the airborne pollen curves. It also allows us to study the relationship between the release of

pollen from the anthers and its presence in the atmosphere (Latorre and Bianchi, 1998). In this way, phenological studies can be very useful in interpreting aerobiological monitoring data because pollen grain release is linked with flowering phenophase, together with other environmental variables. Meteorological and topographic factors, aerodynamic morphology of the pollen grain and distance of the sampler from the source all contribute to the airborne pollen concentrations in space and time. The pattern shown by pollen curves does not always concur with that of the floral phenophase and sometimes a lack of correlation between maximum flowering and maximum pollen concentration can be observed (Latorre, 1997).

The aim of this study is to understand the phenological behaviour of *Betula* in our area [Galicia (N.W. Spain)]. It also aims to study the relationship between the *Betula* pollen curves for different localities included in the Galician's Aerobiologic Investigation Network (R.I.A.G.) and the flowering phenophase of *Betula* trees located at different altitudes and geographic positions in Galicia.

In this study we chose *Betula* because it is a representative plant of our natural vegetation and it is present throughout the whole region at different altitudes, from almost the sea level to 1500 metres above sea level. Furthermore, *Betula* pollen is a very important aeroallergen commonly found in the air of our cities (Spieksma, 1990; Norris-Hill and Emberlin, 1991; D'Amato and Spieksma, 1992).

Birch is represented in Galicia by *Betula alba* L. (Moreno, 1990). As the dominant tree it forms altimontane oro-Cantabrian acidophilic forests, with a clearly Eurosiberian distribution. They are found above an altitude of 1150 metres being the last tree formations of the altitudinal sequence, with montane thermo-climates and hyper-humid ombro-climates (Izco, 1994). Their limit, although fairly controversial, is situated in the Galician oriental mountain – Ancares and Caurel mountains – (Costa et al., 1990). In this same area, but on siliceous soils and with a greater Mediterranean influence, there are also birch forests in the Galician-Portuguese altimontane layer and the Ourense-Sanabriense and supramediterranean layer.

In Galicia's mountains and foothills we can find non-climatic birches, in place of montane oak groves, which are located on acidic soils and with altitudinal limits between 600 and 1100 metres.

Also, birch may form part of riparian forests, along with *Alnus glutinosa*, *Salix atrocinerea* and *Frangula alnus*.

Materials and methods

Phenological survey

To characterise floral phenophase quantitatively, a sampling method was applied during the whole flowering period (from the beginning of March to the end of May of 2000). Nine populations of *Betula* located at different altitude and phytogeographic position were chosen (Figure 1). The Reigosa's population is located in the sudoccidental limit of their distribution area in Galicia (Rigueiro et al., 1983), the Manzaneda and Mogainza's population occupies the higher limit of the forest and the last one forms part of the most important *Betula* forest in Galicia (Costa et al., 1990). In each population a sample of three individuals chosen randomly was used, and in each tree twenty catkins were picked and measured, observed and the number of open anthers were

counted. To characterise flowering phenophase we took into account the percentage of open flowers and the growth of the catkin. The beginning of flowering period was considered when less than 20% of anthers were opened, full flowering when the number of open anthers was between 20 and 50% and the final flowering period when the number of open anthers was higher than 50%. Counting and measuring was carried out at least once a week.

Phenological observations in other localities in Galicia were also made with the aim of checking whether the floral phenophase was correlated with the investigated populations.

Airborne pollen sampling

In eight locations of Galicia, a seven-day volumetric pollen trap (LANZONI VPPS 2000) located approximately 25 metres above ground level was used (Figure 1). The sampling period was from 1st of January to 30th of June 2000. The methodology recommended by the Spanish Network of Aerobiology (R.E.A.) was used to process the samples (Domínguez, 1991).

Statistical analysis

A Spearman correlation test was used to analyse the correlation between flowering and airborne *Betula* pollen. To achieve this we applied the formula:

$$P_{(x)} = (n_1 \times 0) + (n_2 \times 2) + (n_3 \times 4) + (n_4 \times 3) + (n_5 \times 1)$$

$$P_{(x)} = \text{Index of production of } Betula \text{ pollen in Galicia at a given date (x).}$$

$$n_1 = \text{number of trees studied which hadn't started their flowering period at a given date (x).}$$

$$n_2 = \text{number of trees studied which were starting their flowering period at a given date (x).}$$

$$n_3 = \text{number of trees studied which were full flowering period at a given date (x).}$$

$$n_4 = \text{number of trees studied which were in their final flowering period at a given date (x).}$$

$$n_5 = \text{number of trees studied which had finished the flowering period at a given date (x).}$$

Thus, we have considered full flowering as the moment of maximum production of pollen. Therefore, we applied the maximum value as the multiplication factor in the formula; although as there is no pollen

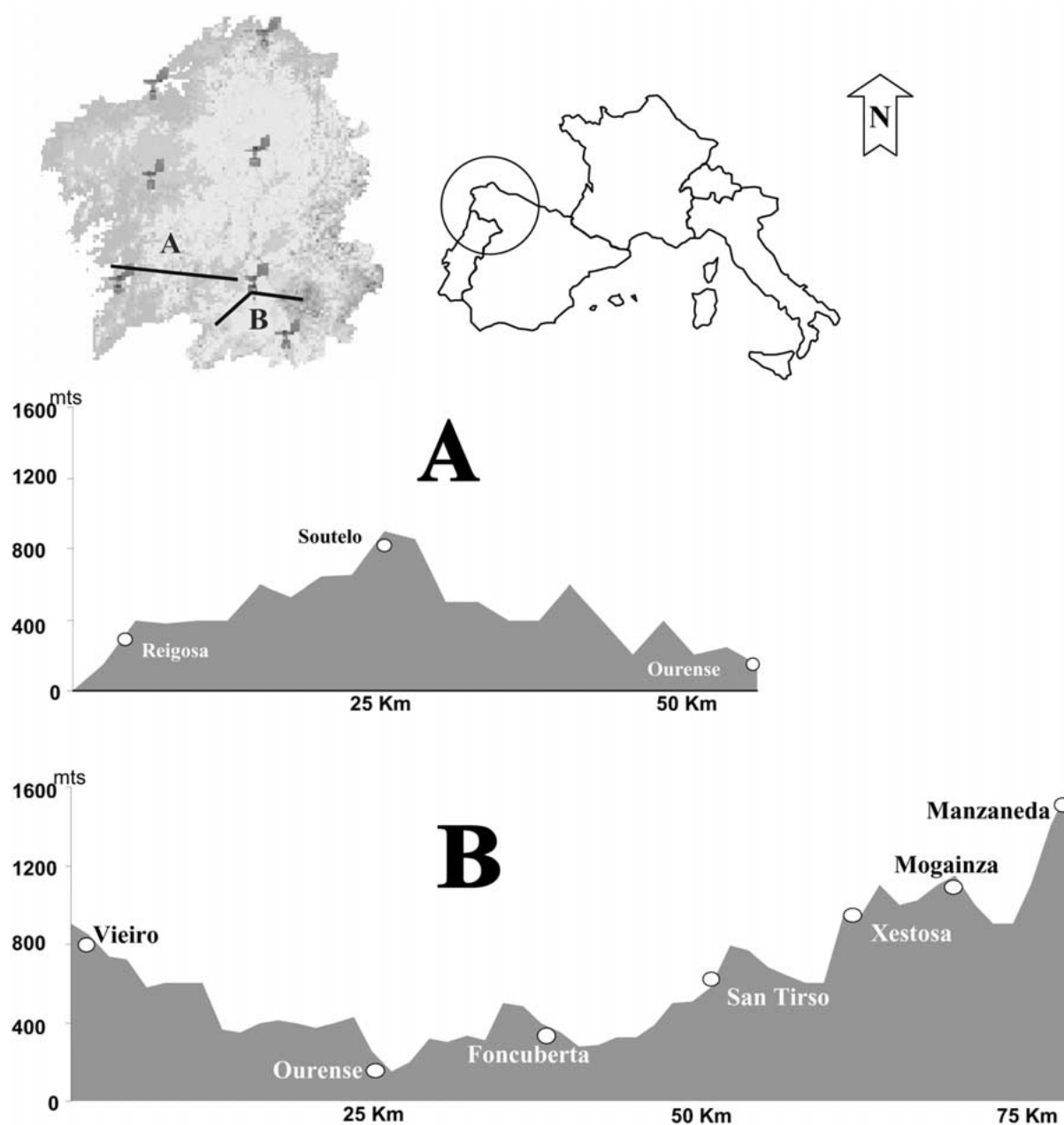


Figure 1. Aerobiological monitoring stations and transects of the phenological observations sites (A and B).

production before the flowering period we applied 0 as the multiplication factor in the 1st term of the formula. Finally we applied 1 as value of the last term in the formula because the flowering was finished and pollen can remain in the air for some time due to the meteorological conditions and other factors including resuspension.

Comparisons between this index and mean daily concentration from each aerobiological station were made.

Meteorological data supplied by the National Meteorological Service were used to analyse the effect of rain and temperature on flowering and the airborne pollen concentration.

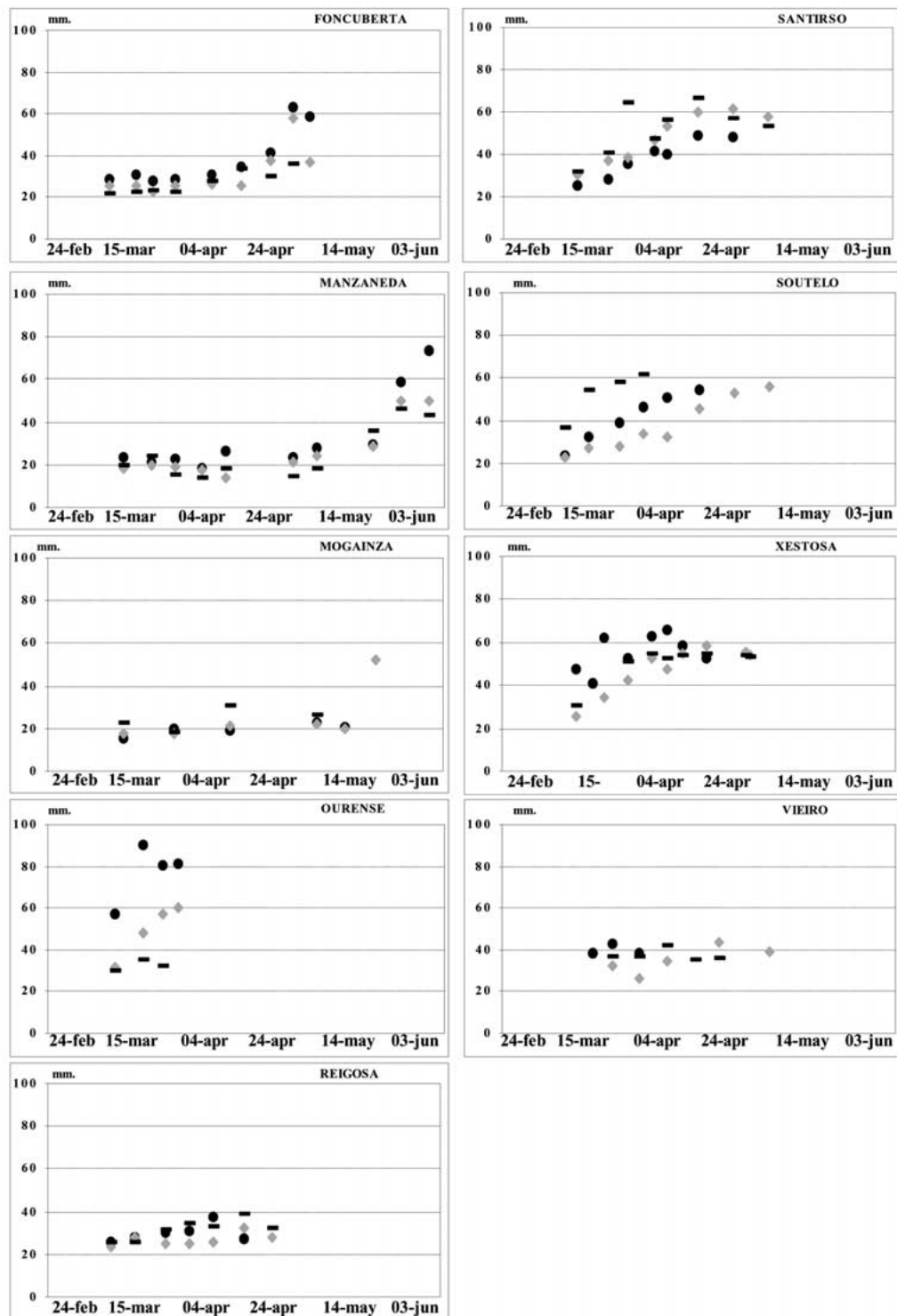


Figure 2. Development of catkin length at the investigated sites (each tree is represented by different symbol).

Table 1. Spearman's correlation coefficients between Pollen Production Index and mean pollen concentrations

	N	R ²	t(N-2)	p-level
A CORUÑA	91	0.409458	4.23403	0.000056
LUGO	91	0.715283	9.65603	0.000000
OURENSE	91	-0.108337	-1.02810	0.306687
SANTIAGO	91	0.406251	4.19427	0.000065
VERÍN	91	0.054931	0.51900	0.605050
VIGO	91	-0.366380	-3.71472	0.000355
VIVEIRO	91	0.572175	6.58174	0.000000
MANZANEDA	91	0.055556	0.52492	0.600941

Results

At the beginning of March, bud break was recorded in the lowest altitude populations (Ourense and Reigosa) and in the highest altitude populations (Manzaneda and Mogainza) during the last week of the same month. Afterwards, growth of the catkins started again, being at its highest level since the prior week to the starting of the flowering until its final phase. The maximum length of the catkins coincided in most of the populations as well as in individual trees in full flower. Figure 2 shows the development of catkin length in each of the three trees of the nine populations investigated. There are significant differences in the flowering period between populations. The earliest floral phenophase was recorded in the middle of March in Ourense (139 m a.s.l.) and the latest was in Manzaneda (1500 m a.s.l.) in the last days of May. Also differences between individual trees in each population were observed (Figure 3).

The development of the daily mean temperature and the daily rainfall are shown in Figure 4. In all the studied localities the temperatures were very high at the beginning of March, falling sharply in the middle of the month and keeping low until the end of April. Rainfall was very heavy during April and continuous from the end of March until the middle of May.

The development of the daily mean pollen concentrations is shown in Figure 5. The cities of Vigo (25 m a.s.l.) and Ourense (110 m a.s.l.), both located to the south of Galicia, were the first to record the airborne *Betula* pollen. In Coruña (20 m a.s.l.) and Viveiro (10 m a.s.l.) both located north of Galicia, the presence of airborne *Betula* pollen occurred later.

The total *Betula* pollen during the study period was low (<500 pollen grains) in all the localities

with the exception of Santiago de Compostela (2812 pollen grains). The daily mean pollen concentration was also lower than in previous years. For example, the maximum of 43 pollen grains/m³ found in Ourense was significantly lower than the average of the maximum values between 1993 to 1998 of 130 pollen grains/m³. Similarly, the maximum in Vigo of 27 pollen grains/m³ is low compared to the average maximum values between 1995 to 1998 of 144 pollen grains/m³ (Jato et al., 1999).

The coefficients of Spearman correlation (Table 1) between daily mean pollen concentrations and Pollinic Production Index showed significant values (99% significant level) for Lugo, A Coruña, Santiago and Viveiro and negative for Vigo. Correlation was not significant for Verín and Ourense.

Discussion

Plant development in the temperate zone trees is mainly regulated by temperature (Romberger, 1963). In this way, a period with chilling temperature (variable according to species) followed by a period with temperature above a threshold (also variable according to species) induces flowering and other phenological events (Richardson et al., 1984; Aron, 1983; Faust, 1989; Vegis, 1964). The quantity of heat (Growth Degree Days – GDD) is expressed as the number of hours in which environmental temperature is above a certain threshold temperature (variable not only between species but also in the same species according to environmental conditions). The populations studied in this work are not only located at different altitudes, but there are also other environmental parameters that influence plant development. These parameters include the trees latitudinal position, proximity to the ocean, topographic situation, the degree of solar exposure, soil substratum and the type of vegetation to which they belong. All these variables play a role in the observed phenological differences. Thus, the populations in Soutelo (800 m a.s.l.) and Xestosa (900 m a.s.l.) flower before other populations such as Reigosa (300 m a.s.l.) where we could expect an earlier flowering. Radiation exerts a stronger effect than any other environmental factor on vegetation development (Cenci and Ceschia, 2000), explaining the unexpected delayed development of Reigosa where the narrow valley besides a river leads to a shorter period of sunshine. In contrast the topographic situation of Soutelo and Xestosa ensure a

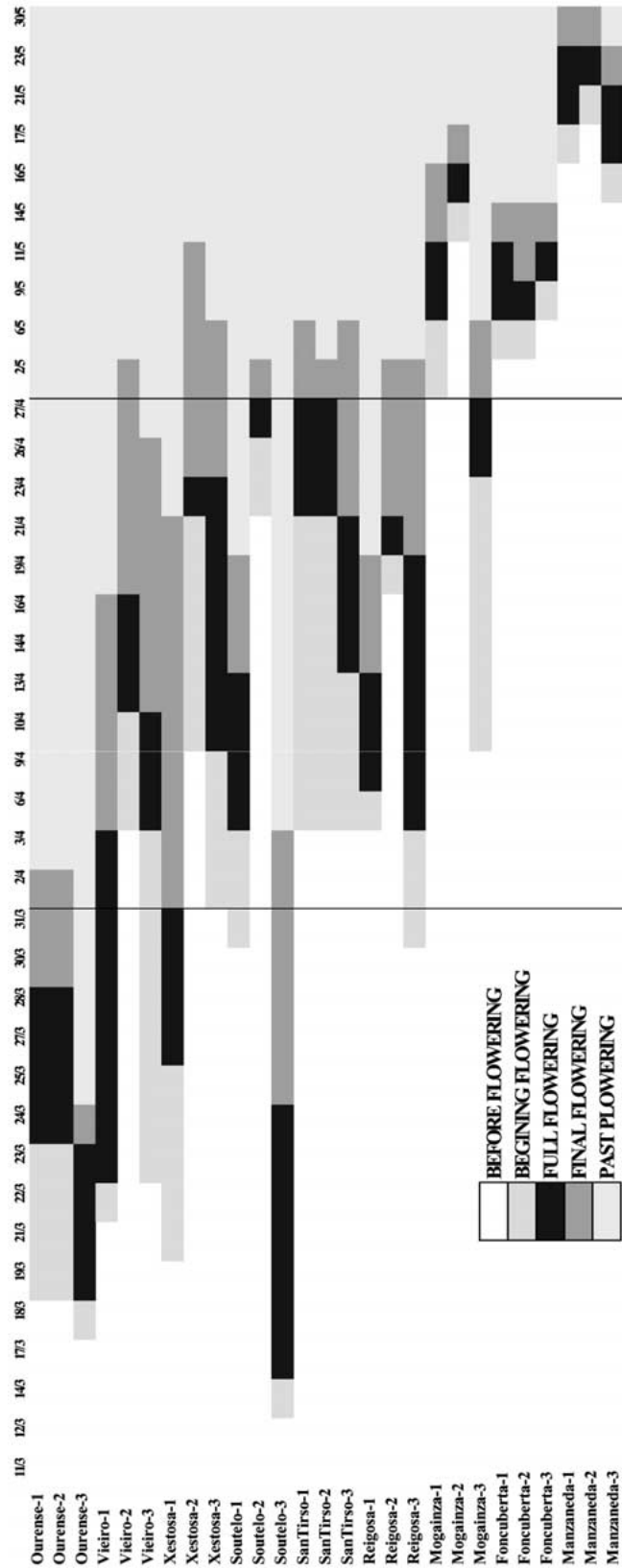


Figure 3. Flowering phenophases of the trees and investigated populations.

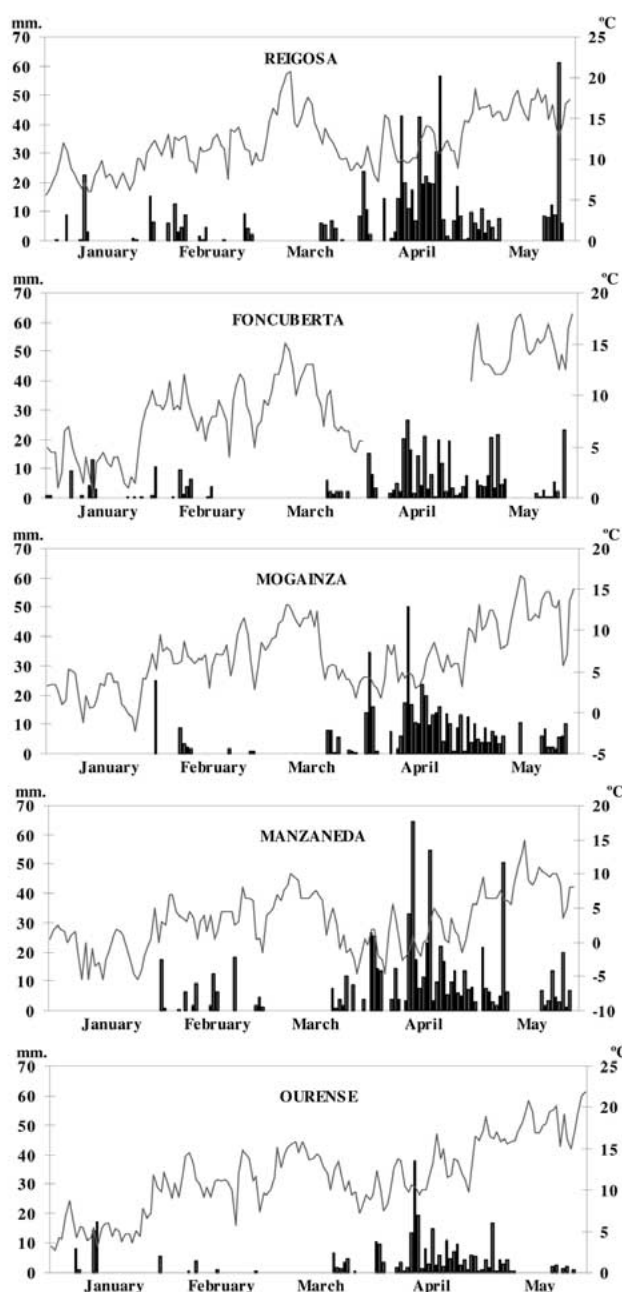


Figure 4. Mean temperature and rainfall from January to May in some of the investigated phenological sites.

greater period of sunshine. On the other hand, a longer dormancy, which has a greater importance in the coastal than in inland regions (Myking, 1997), could delay the flowering phenophase in coastal Reigosa. In some locations other factors will be of great importance, such as the frequency of mist in Ourense which can exacerbate the effects of chilling during winter

(Aron, 1983) and therefore effect the start for computation of accumulated temperature and consequently delaying flowering.

For the reasons mentioned above to develop our aim of determining which of these factors have greater importance in *Betula* phenology in our area, further studies will be necessary.

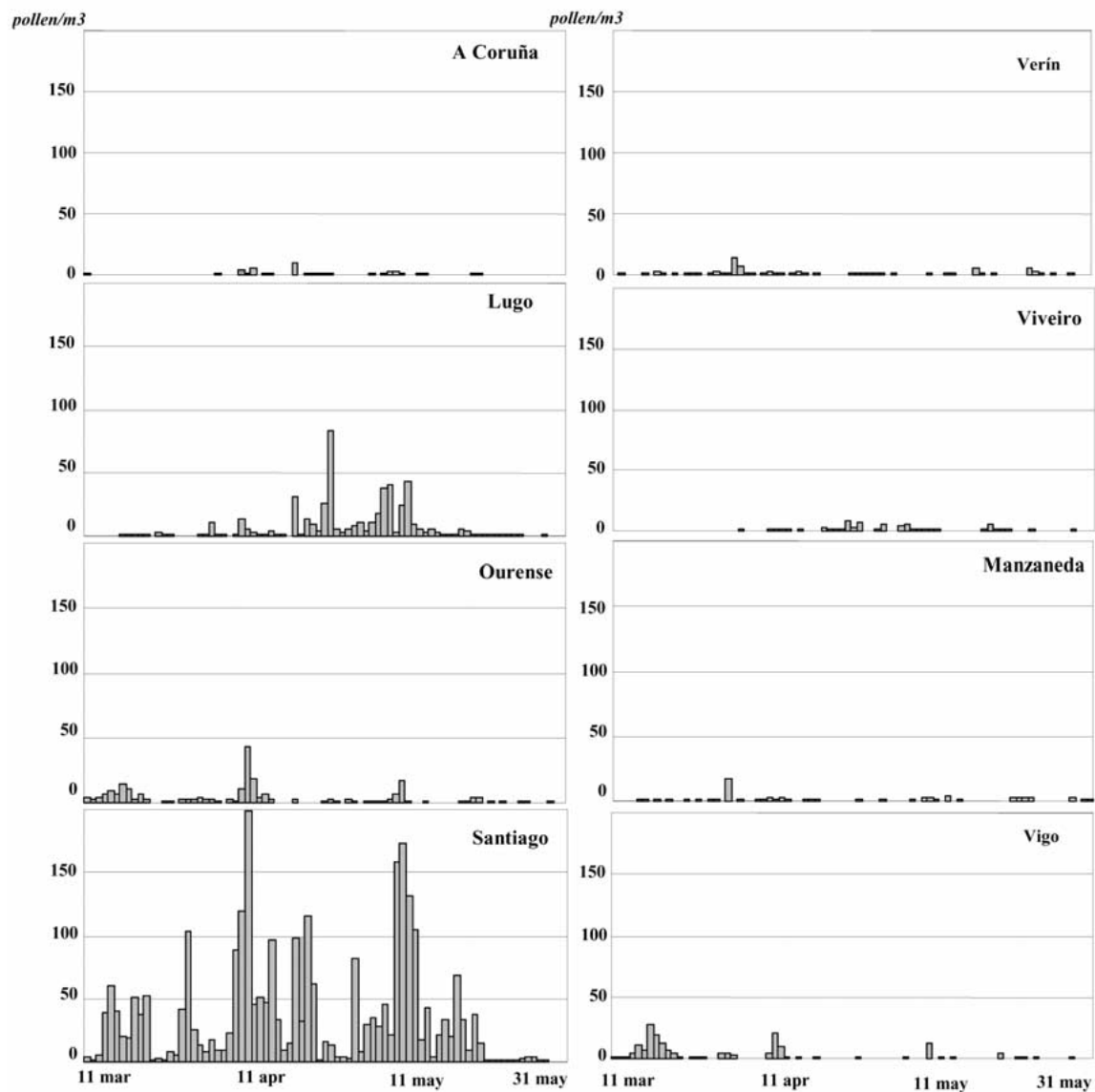


Figure 5. Daily mean *Betula* pollen concentrations at aerobiological monitoring stations from 11th March to 31th May of 2000.

Two months was the maximum difference in the start dates of flowering between populations (Ourense was the earliest and Manzaneda was the latest). Both localities respectively occupy the lowest and highest altitude. This difference is slightly shorter for bud break, where the maximum difference between the earliest (Ourense and Reigosa) and latest (Manzaneda, Mogainza and Foncuberta) populations was only one month. In this case it would be possible that at higher altitude bud break could move forward proportionally to secure rapid growth as soon as the temperature is favourable in spring (Myking, 1997).

The weather during the flowering period was adverse. The sharp fall in temperature at the end of March and the beginning of April occurred just when many trees were about to flower. The sharp fall in temperature together with high rainfall interfered with the necessary dehydration of the tissues to provoke dehiscence of the anthers. Some trees had started opening their anthers during this sharp fall in temperature delaying flowering and extending the overall flowering period (up to one month in some trees). In contrast, populations where the flowering was late (Foncuberta, Mogainza and Manzaneda specially), the

flowering period was very short. In these cases the high temperatures provoked a quick dehydration of the anthers and subsequent release of pollen leading to a flowering period that was reduced to seven days in some trees.

The maximum length of the catkin is normally reached at the beginning of full flowering phenophases. Nevertheless this length is variable not only between trees of different localities but also between trees at the same localities. Previously at the beginning of flowering period a strong lengthening of catkins was observed.

Geographic position, altitude and other factors of the studied localities determined the differences in the beginning of the presence of pollen in the atmosphere. Vigo (45 m a.s.l.) and Ourense (130 m a.s.l.), both located in the south of Galicia, were the cities where *Betula* pollen appeared first. Coruña (20 m a.s.l.) and Viveiro (10 m a.s.l.), both located in the north of Galicia, were the cities where the presence of *Betula* pollen in the atmosphere occurred later. The adverse meteorological conditions during the pollination period resulted in low daily mean pollen concentrations. High rainfall in April contributed to a decrease in the concentration of *Betula* pollen in the atmosphere and is one of the reasons why the total *Betula* pollen in all stations was lower in 2000 than in previous years. Clearly, meteorological conditions affected the obtained results and new observations will be necessary to reinforce the observed trend.

In general, the period in which the highest concentrations were recorded coincides with the period in which most of the phenological stations studied were in flower. Correlation between Pollinic Production Index and daily mean pollen concentration was significant and positive for Coruña, Lugo, Santiago and Viveiro monitoring stations. In contrast it was negative for Vigo, where the highest pollen concentrations were reached at the middle of March, when few trees investigated were flowering. Transport and resuspension are mechanisms that should be taken into account to explain the presence of *Betula* pollen in the atmosphere in some cities. Thus, in Ourense, the highest quantities of *Betula* pollen were registered at the end of the flowering period, followed by smaller recorded quantities until the end of May.

The high concentrations registered in Santiago in the second ten day period of May were obtained when flowering in *Betula* populations located around the pollen trap was finished, and few *Betula* trees were in flowering at that moment in Galicia. The abund-

ance of ornamental *Betula* trees in the proximity of the pollen trap results in the accumulation of catkins on the ground, increasing the likelihood of pollen resuspension in suitable meteorological conditions.

So, the geographical position and altitude are not the only factors that we have to take into account to explain the correlations observed between daily mean pollen concentrations and the Index of production of *Betula* pollen in Galicia. Other factors such as transport and resuspension, as well as different environmental factors are also responsible for the phenological differences observed.

Conclusions

Environmental factors such as frequency of mist, latitudinal and topographic position, proximity of the ocean, degree of solar exposure, and altitude can determine important phenological differences between populations. The adverse conditions registered in this year, particularly the rain in April, undoubtedly affected the concentration of *Betula* pollen in the air and the duration of the pollen season, so further phenological studies should be conducted to allow us a better understanding of the relationship between phenology and aerobiology of *Betula* in Galicia.

The correlation between the Pollinic Production Index of *Betula* pollen in Galicia and the aerobiological data of the monitoring stations showed that the period in which the highest concentrations were registered was almost synchronous with the flowering times at most of the phenological stations studied. Nevertheless other factors such as transport and resuspension are mechanisms that should be taken into account to explain the presence of *Betula* pollen in the atmosphere in some cities.

Phenological studies are a good tool to provide an adequate interpretation of the aerobiological data of *Betula* pollen in the atmosphere and new studies should be carried out.

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