



A study of *Quercus* pollen in the Derby area, UK

Julie Corden* & Wendy Millington

Midlands Asthma and Allergy Research Association, 12 Vernon Street, Derby DE1 1FT, UK

(*author for correspondence, fax: +44 1332 362462)

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Abstract

The major allergenic pollen prevalent in the Derby air in May is *Quercus* pollen which has been monitored volumetrically from 1970–1997. *Quercus* pollen levels in Derby are increasing, showing an established long term trend, with 1995 being an exceptionally high year. There is now an earlier start date and a longer seasonal duration. The mean *Quercus* diurnal periodicity for 1991–1997 shows a peak at 15.00 hours.

A detailed study of the 1990–1997 seasons established that a maximum temperature of 20 °C or above, at the usual time of flowering, occasions the start of the *Quercus* pollen season. Average May temperature and drought in the previous June and July are important factors in determining *Quercus* pollen totals. Predictions for the forthcoming seasons were produced which compared favourably with the actual pollen totals.

1. Introduction

Aerobiological monitoring of both pollen and spores has been carried out in Derby for over 28 years enabling long term pollen level studies to be undertaken. In spring, tree pollens of the Fagales order which includes *Quercus*, are a main allergen source in the northern hemisphere, with cross-reactivity occurring between pollen within the same order (Matthieson et al., 1991). The two main *Quercus* species in Derbyshire are *Quercus robur* (English oak), and *Quercus petraea* (Sessile oak). Recent research indicates an increase in hayfever in the UK (Butland et al., 1997), and *Quercus* pollen has been implicated as a significant cause of hayfever symptoms in Britain (Ross et al., 1996). Luscri et al. (1996) showed a 5.7% allergy to *Quercus* pollen in the Rome area, and the study by Farnham (1990) showed a 29% positive skin prick test to *Quercus* pollen, which was second only to *Betula* pollen in New England USA.

Our study of *Quercus* pollen and its long term trends was intended to provide a comprehensive record of *Quercus* pollen presence in Central England,

including its diurnal periodicity as previously there has only been a one year study of *Quercus* pollen in this region, in Chesterfield, Derbyshire (Hyde, 1950). Also Emberlin et al. (1990) suggested an inherent biennial cycle for *Quercus* pollen in London.

It is hoped that our research can be of benefit to allergic patients and their clinicians.

2. Materials and methods

Derby is an industrial city in central England, more than 100 km from any coast. At present a Burkard volumetric pollen/spore trap is sited on the roof of Derby University Mickleover site, 10 m above ground level, in a suburb 100 m above sea level and approximately 4 km S.W. of the city centre. Weather data was provided by a meteorological station 0.5 km from the present trap site. Up to 1989 a Morrow Brown trap (Morrow Brown and Jackson, 1978) was sited on a second storey roof 10 m above ground level in central Derby. However, building developments necessitated the site change to Mickleover in 1990 which

has improved accessibility and maintained optimum sampling height. Statistical analysis of the data set showed that the results could be treated as one population. In 1991 a Burkard volumetric spore trap replaced the Morrow Brown trap. Daily slide or seven day drum traps were used, and mounting and staining techniques followed the methods described by Morrow Brown and Jackson (1978). From 1970–1990 average daily concentrations/m³ were calculated by counting three equidistant microscope fields along the length of the slide and applying the appropriate factor. In 1991 all UK pollen counting centres were standardised, so from that year the daily average pollen counts were calculated by counting 12 equidistant transverse traverses for each 24 hours resulting in the *Quercus* pollen count per cubic metre after factorisation. Two hourly GMT counts were used to establish diurnal periodicity with one transverse traverse of the slide being counted every two hours, and the appropriate factor applied resulting in an hourly count per cubic metre.

Total Derby April–July average *Quercus* pollen concentrations for 28 years were plotted to assess any long term trends. From the seasonal totals the start, end and duration of season were calculated. The method used was that defined as the date by which 2.5% of the total April–July pollen census for the year was trapped, this method has been used successfully with Derby *Betula* pollen data (Emberlin et al., 1997), and the end of season was defined as that day when 97.5% of the total April–July *Quercus* pollen was reached. The duration of the season is the difference between the start and end of the season. The correlation coefficient r for start date and duration was calculated. Trends for seasonal total, start, end, and duration of season were calculated and plotted, and the two hourly diurnal rhythm for *Quercus* pollen was worked out for all days, dry days and days of 20 °C and over.

The Sum 75 method (Driessen et al., 1990) identifies the start of season as that day when the cumulative average daily pollen count reaches 75, and this was calculated when numbers allowed.

To compare seasonal pollen totals with weather data, both *Quercus* pollen and three weather variables were averaged for each year (1990–1997) and then converted to a percentage of mean for each of the eight years. The three weather variables used were current mean May temperature, previous mean June–July temperature, and the previous year's June–July drought code. The drought code was derived from

the inverse of the previous year's percentage of mean June–July rainfall.

Regression analysis was carried out using *Quercus* pollen totals on the three independent weather variables. A multiple regression computer analysis was then carried out taking the percentage mean for *Quercus* pollen totals as the dependent variable and having as the independent variables the percentage of mean current May temperature and the previous year's June–July drought code. From the multiple regression analysis, predicted pollen totals were produced and a plot to compare actual and predicted pollen was obtained.

3. Results

Long term trends of *Quercus* pollen in Derby show increasing pollen levels, even ignoring the exceptionally high year of 1995 (Figure 1). The earlier years (1970–1984) do show alternance but latterly this biennial pattern has been disturbed.

The start of the *Quercus* season whether measured by Sum75 or the 2.5% (Figure 2a) method shows a trend to an earlier date. At the same time the end of season is becoming later resulting in a longer seasonal duration (Figure 2b). Statistical analysis showed a negative correlation between duration and start date, with $r = -0.74$.

The mean diurnal *Quercus* pollen periodicity for 1991–1997 shows the main peak occurring around 15.00 hours (Figure 3). Pollen levels were dramatically increased at temperatures of 20 °C and over.

Quercus pollen and daily maximum temperatures from 1990–1997 (Figures 4a and b) show a variable seasonal pattern. In 1990 and 1995 most of the pollen output occurred during the first week in May when high temperatures were sustained. A late season occurred in 1996 when May was cool and *Quercus* pollen was not released until the last week of the month. In 1991, 1992, and 1994 *Quercus* pollen peaked around the middle of May but in 1993 the quantity of *Quercus* pollen was low. The maximum temperatures show almost as much variability as the pollen, with a maximum temperature of 20 °C or above resulting in a rise in *Quercus* pollen concentrations after April 29.

Multiple Regression analysis using percentage mean *Quercus* pollen totals on percentage mean current May temperatures and the previous June–July drought code revealed multiple $R = 87.6\%$ (Table 1).

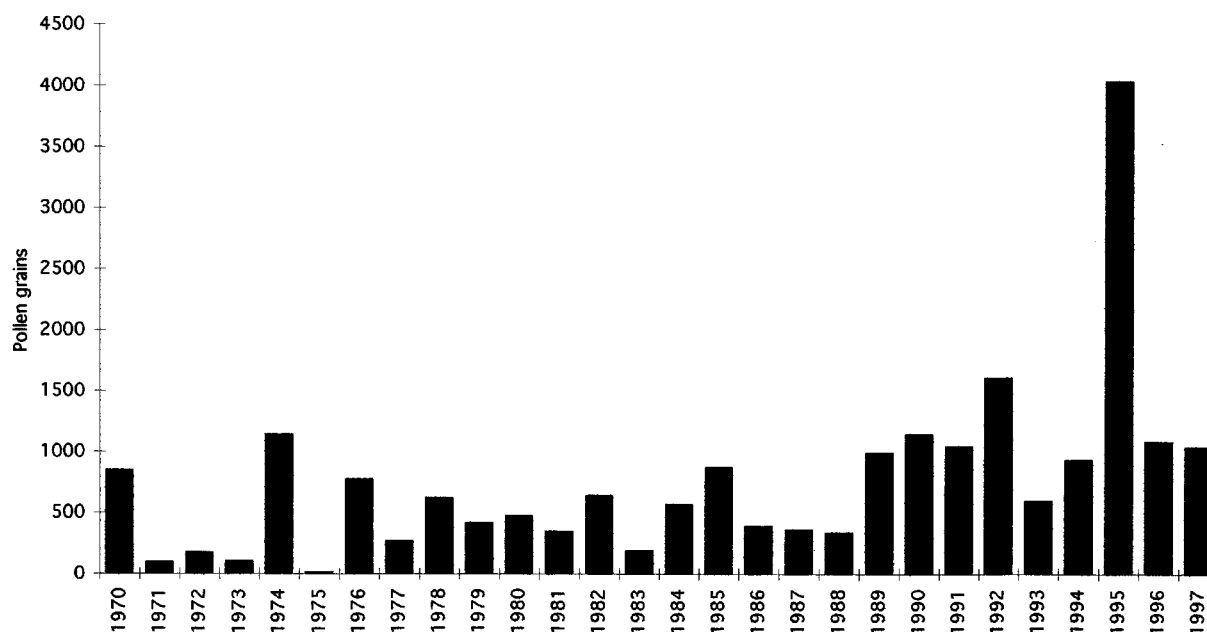


Figure 1. Derby *Quercus* seasonal totals 1970–1997.

Table 1. Data used for multiple regression analysis.

Seasons (descending order of severity)	% of Mean <i>Quercus</i> pollen	% of Mean average daily May temperature	Previous June–July drought code
1995	278.6	119.4	2.0
1992	111.3	116.9	0.7
1990	83.1	109.7	1.2
1996	74.9	80.6	1.6
1991	72.9	92.7	1.0
1997	71.9	96.7	1.6
1994	65.1	87.1	0.8
1993	41.9	97.6	0.6
Multiple $R = 0.875519927$			

Figure 5 shows that the predicted pollen compares favourably with the actual *Quercus* totals. *Quercus* pollen single regression on percentage mean current May temperatures gave multiple $R = 66.4\%$ and on previous June–July drought codes multiple $R = 64.7\%$ but on the previous June–July temperatures multiple $R = 30.5\%$.

4. Discussion

The long term upward trend in Derby *Quercus* pollen seems to be well established, Jäger et al. (1991) also found a weak upward trend for *Quercus* pollen in Brussels. 1995 was an exceptionally high *Quercus* pollen year indicating the possibility of masting, and reminiscent of an exceptionally high *Betula* pollen year in Gothenburg in 1993 (Dahl and Strandhede, 1996). The alternance shown from 1970–1984 for *Quercus* in Derby is for the most part synchronous with that of Brussels, Leiden and Vienna (Jäger et al., 1991). Interestingly the lowest *Quercus* pollen total in both Derby and Leiden was 1975, and in Denmark 1975 was cited as a year of “failed *Quercus* flowering” (Anderson, 1980). The years 1970–1984 show alternance but from 1985, as *Quercus* pollen totals rise, the cycle becomes more variable, three yearly nearly as often as alternate. The start of season for this same period shows a marked trend towards earlier start dates with a slight trend to a later end date, resulting in a longer seasonal duration for *Quercus* pollen. Statistical analysis has shown a negative correlation between start date and duration, so the earlier the start date the longer the duration, as does Emberlin et al. (1993) for *Betula* pollen in London. The rising trend of Derby *Quercus* pollen totals, with earlier start dates, may possibly have been brought about

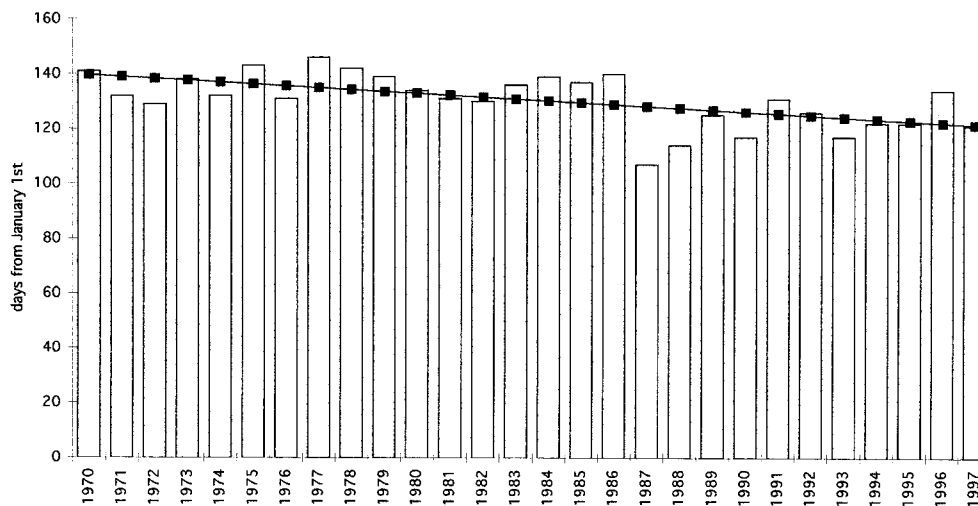


Figure 2a. Trends in *Quercus* start dates 1970–1997 (2.5% method).

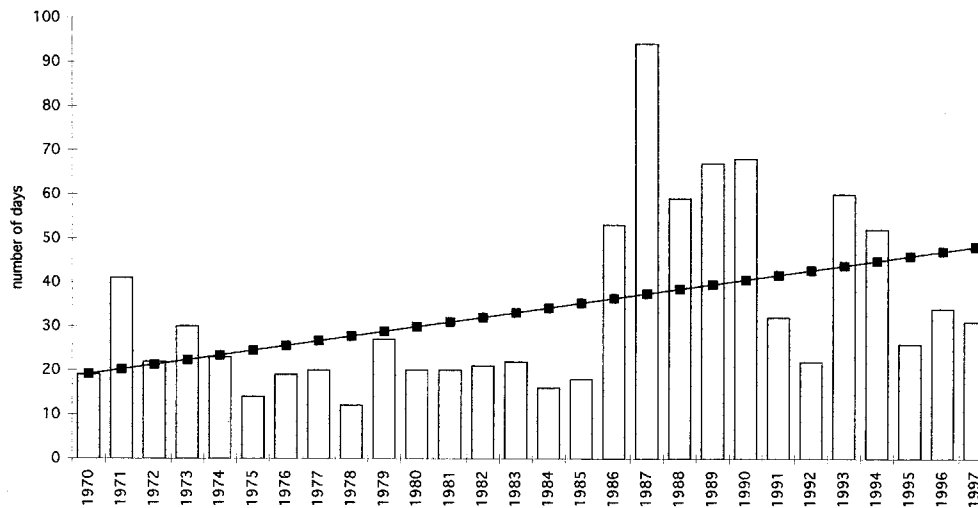


Figure 2b. Trends in the duration of the *Quercus* season 1970–1997.

by warmer weather, as discussed by Emberlin et al. (1997).

The mean diurnal *Quercus* pollen periodicity for 1991–1997 shows a peak at 15.00 hours whereas Käplä (1984) had a peak at noon and in the late afternoon. However, we agree with her that *Quercus* pollen concentrations closely correlate with increased temperatures and with a possible threshold level.

The detailed study of eight seasons 1990–1997 shows that, apart from 1995, the total pollen per season was mostly moderate, with one above average season in 1992 and one below average in 1993. As the *Quercus* 1995 pollen was quite exceptionally high, occurring only once in 28 years, it probably indicates

the importance of weather influences in addition to inherent rhythms. If 1995 is excluded 1992 might have been considered a very high year, and in the long term perspective 1974 also. Variation in acorn production in the USA (Sork et al. 1993) was largely explained by the weather acting in addition to inherent tendencies and we think the same applies to pollen production.

It is initially clear from the seasonal patterns 1990–1997 (Figures 4a and 4b), that *Quercus* pollen release after April 29 is triggered by sustained high daily maximum temperatures, 1995 having temperatures of 22 °C and above from May 2–May 7. In 1996 maximum temperatures did not rise above 20 °C until the end of the month resulting in an exceptionally late

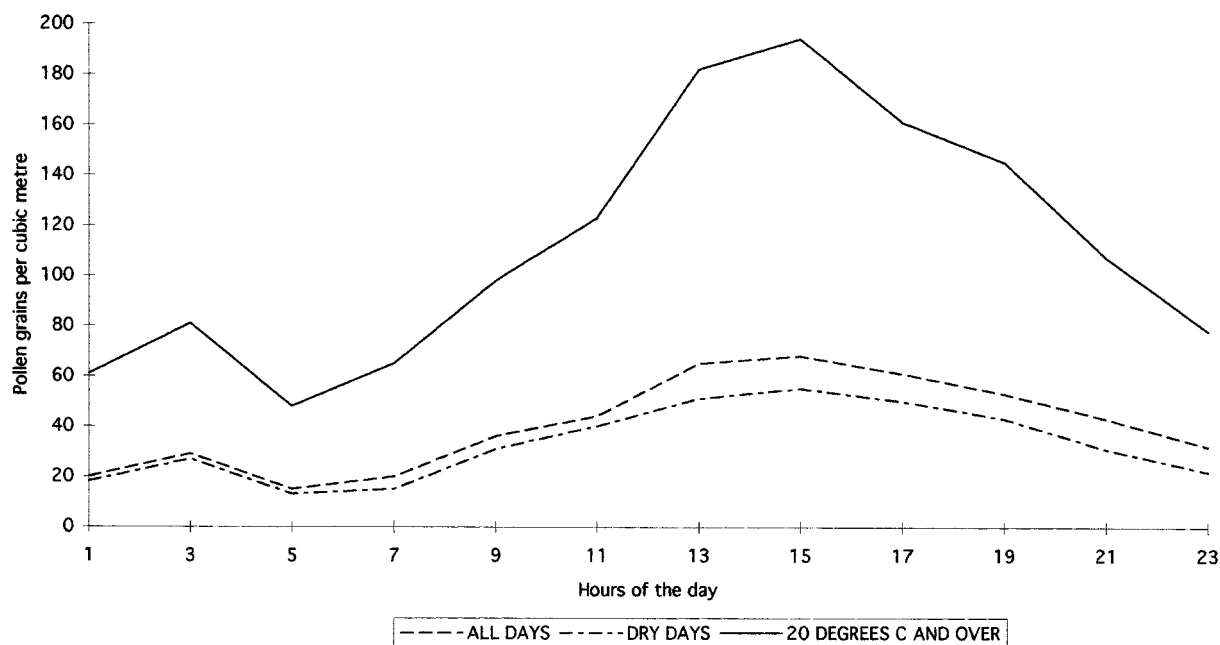


Figure 3. Mean diurnal *Quercus* periodicity 1991–1997.

season with low *Quercus* pollen levels. Conversely the 1997 season had a brief warm spell early in May resulting in an early peak which was not to be sustained due to frost on May 7. In 1993 higher temperatures occurring at the end of April produced a peak on April 30 but subsequent lower temperatures in early May inhibited *Quercus* pollen release. The more usual pattern is that exhibited in 1991–1992 and 1994–1996 when *Quercus* pollen release followed the same graphic curve as maximum temperature. The high temperatures in May 1990 also produced the main but lower *Quercus* pollen peak indicating that other factors should be considered. We therefore looked at previous pollen, previous summer temperatures and rainfall, and rainfall during flowering, and found only previous June and July rainfall was significant and that a very dry June and July in 1994 preceded the high *Quercus* pollen year of 1995. Wind speed and direction were also considered but were not found to be important.

Statistical analysis showed that a combination of drought code (derived from previous June and July rainfall), and average May temperatures at flowering gave a 77% explanation, whereas *Quercus* pollen regressed singly on each of these two factors produced a less adequate explanation. In Pennsylvania Sharp and Sprague (1967) remarked that the good acorn year of 1954 was preceded by very dry conditions the previous summer. A high fruit yield in olive trees

(Lavee, 1989) is said to signal production of flowering inhibitors by the leaves, and drought conditions might be expected to limit this capacity and allow less inhibited flowering with consequent plentiful pollen. Anderson (1980) stated that summer dryness apparently stimulates flower differentiation in *Quercus*. Drought in June and July would be an understandable influence when one considers that it is only during these months of generally high temperatures in the Derby area that water supply is often limiting, and when shoot growth is at its peak. *Quercus* has a second sprouting of leaves by early August “lammas growth”, the last of the season, which could boost the output of flower bud development inhibitors and influence next years pollen levels. We think that the occasional very high *Quercus* pollen year and drought in June and July can both affect the pollen potential for the following year and how much of that potential is expressed depends very much upon the weather, and in particular the temperatures at flowering time. Using both previous years drought code and current May temperatures we have been able to predict the probable *Quercus* pollen total (Figure 5).

Koenig et al. (1994) thought that no single ecological factor could perhaps account for acorn production in even one taxon of *Quercus*. Similarly, for pollen levels, we find that while an occasional very high or low previous pollen total may also be an indicator,

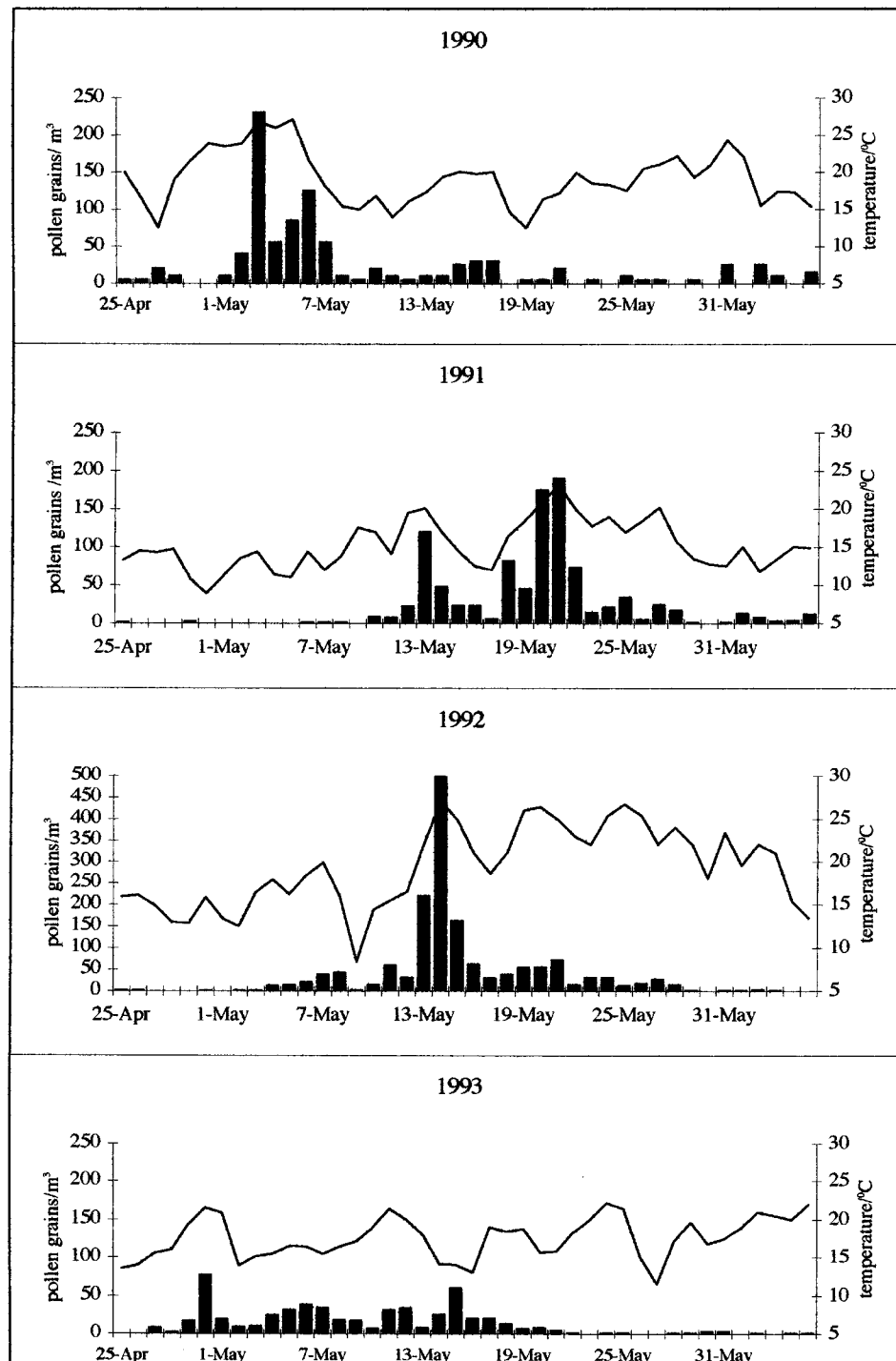


Figure 4a. *Quercus* pollen and daily maximum temperatures 1990–1993.

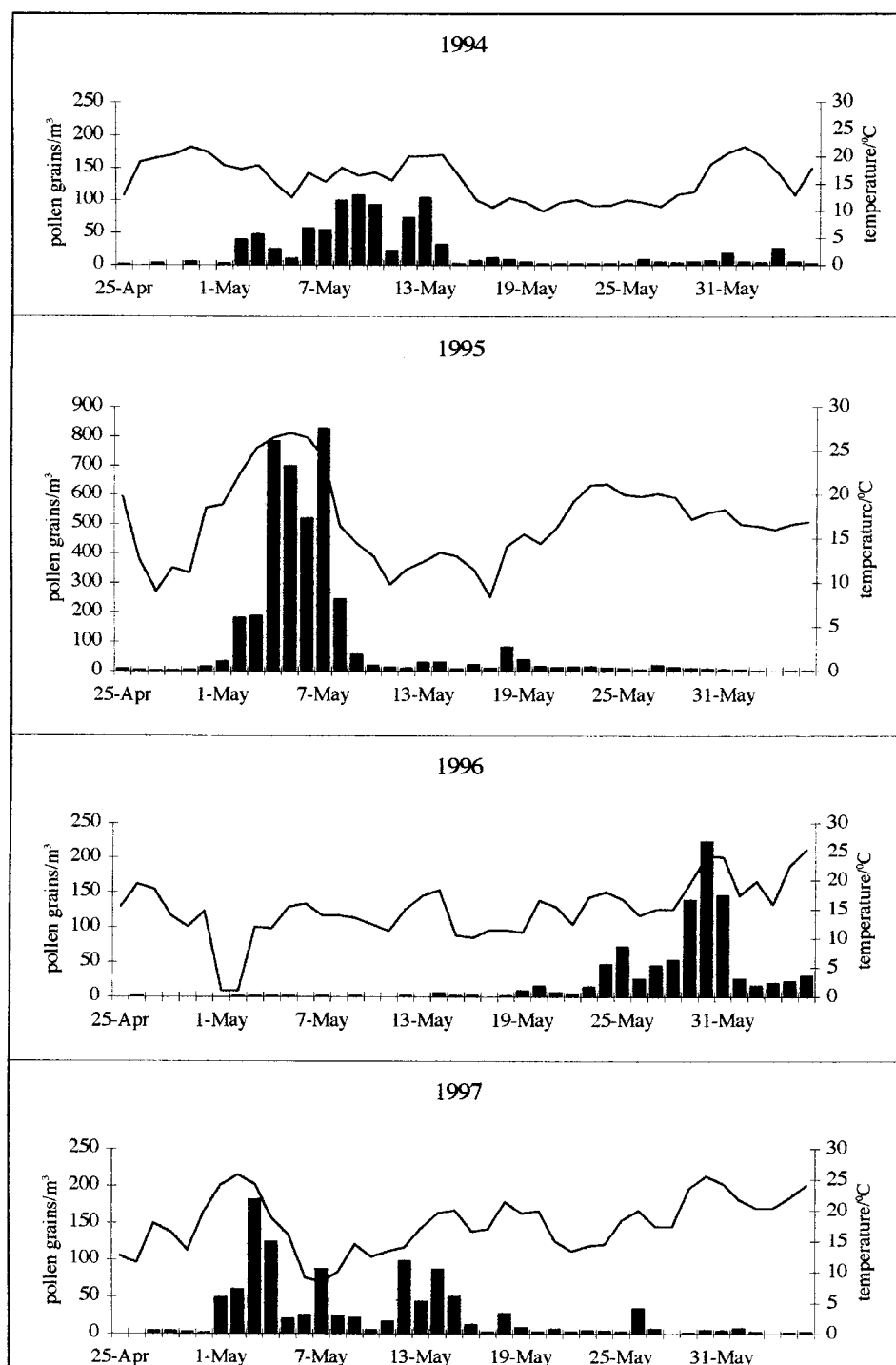


Figure 4b. *Quercus* pollen and daily maximum temperatures from 1994–1997.



Figure 5. Plot of actual compared with predicted *Quercus* pollen for 8 years.

weather seems paramount, with the two most important factors of those tested in the Derby area being drought in the previous summer and ultimately the temperatures in May.

5. Conclusion

Quercus pollen has increased in Derby over the past 28 years even allowing for the natural rhythm of trees, with associated earlier start dates and longer seasonal duration. Seasonal variation is influenced by drought the previous year and current temperatures. The highest *Quercus* pollen levels occurred in mid afternoon.

These results for the English Midlands show how important it is to make *Quercus* pollen allergic patients aware of the earlier start and longer length of season and to ensure that their medication gives them maximum protection in the afternoon.

Our work leads us to the possibility of more accurately predicting the severity of the *Quercus* pollen season.

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References

- Anderson S.T.: 1980, Influence of climatic variation on pollen season severity in wind-pollinated trees and herbs. *Grana* **19**, 47–52.
- Butland B.K., Strachan D.P., Lewis S., Bynner J., Butler N. and Britton J.: 1997, Investigation into the increase in hay fever and eczema at age 16 observed between the 1958 and 1970 British birth cohorts. *BMJ* **315**, 717–721.
- Dahl A. and Strandhede S.-O.: 1996, Predicting the intensity of the birch pollen season. *Aerobiologia* **12**, 97–106.
- Driessen M.N.B.M., Van Herpen R.M.A. and Smithuis L.O.M.J.: 1990, Prediction of the start of the grass pollen season for the southern part of the Netherlands. *Grana* **29**, 79–86.
- Emberlin J.C., Norris-Hill J. and Bryant R.H.: 1990, A calendar for tree pollen in London. *Grana* **29**, 301–309.
- Emberlin J., Savage M. and Woodman R.: 1993, Annual variations in the concentrations of *Betula* pollen in the London area, 1961–1990. *Grana* **32**, 359–363.
- Emberlin J., Mullins J., Corden J., Millington W., Brooke M., Savage M. and Jones S.: 1997, The trend to earlier Birch pollen seasons in the UK: A biotic response to changes in weather conditions? *Grana* **36**, 29–33.
- Farnham J.E.: 1990, New England tree pollen and skin test reactivity. A three year study. *Aerobiologia* **6**, 212–214.
- Hyde H.A.: 1950, Studies in Atmospheric pollen IV. Pollen deposition in Great Britain, 1943. *New Phytol.* **49**, 398–420.
- Jäger S., Spieksma F.Th.M. and Nolard N.: 1991, Fluctuations and trends in airborne concentrations of some abundant pollen types, monitored at Vienna, Leiden and Brussels. *Grana* **30**, 309–312.

- Käplä M.: 1984, Diurnal variation of tree pollen in the air in Finland. *Grana* **23**, 167–176.
- Koenig W.D., Mumme R.L., Carmen W.J. and Stanback M.T.: 1994, Acorn production by oaks in central coast California: variation within and among years. *Ecology* **75**, 99–109.
- Lavee S.: 1989, Involvement of plant growth regulators and endogenous growth substances in the control of alternate bearing. *Acta Hortic.* **239**, 311–323.
- Luscri M.F., Li Bianchi E., Fanti A., Scarnatii C., Cecconi M.E. and Marinelli M.A.: 1996, Tree pollen allergy in Rome. *Allergy* **51**, Suppl.: P389.
- Matthiesen F., Ipsen H. and Løwenstein H.: 1991, In: D'Amato G. (ed.), *Allergenic Pollen and Pollenosis in Europe*. Blackwell Scientific Publications, pp. 36–44.
- Morrow Brown H. and Jackson F.A.: 1978, Aerobiological studies based in Derby.I. A simplified automatic volumetric spore trap. *Clin. Allergy* **8**, 589–597.
- Ross A.M., Corden J.M. and Fleming D.M.: 1996, The role of oak pollen in hayfever consultations in general practice and the factors influencing patients' decisions to consult. *British Journal of General Practice* **46**, 451–455.
- Sharp W.M. and Sprague V.G.: 1967, Flowering and fruiting in the white oaks. Pistillate flowering, acorn development, weather and yields. *Ecology* **48**(2), 243–251.
- Sork V.L., Bramble J. and Sexton O.: 1993, Ecology of mast-fruiting in three species of North American Deciduous Oaks. *Ecology* **74**(2), 528–541.

