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ORIGINAL RESEARCH

Recent scenario of airborne pollens of Lucknow, India with special reference to intra- and interannual, diurnal, and vertical variation

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Abstract: Biomonitoring of airborne pollen in Lucknow, India was conducted for 2 consecutive years (August 2005–July 2007) with the objective of assessing the recent status of airborne pollen of the city and analyzing the intra- and interannual variations. Determination of total incidence of airborne pollen with subsequent contributions of individual components was carried out by measuring diurnal and vertical gradients. The Pearson correlation test was conducted to analyze pollen counts for 2 successive years. Principal component analysis was also carried out to examine the relative distribution of major pollen samples according to their dominance in the particular environment for 2 consecutive years. A total of 6089 pollen grains were caught in 2005–2006, which included 77 types against 4335 pollen grains comprising 61 types registered in 2006–2007. Two major pollen seasons, ie, spring and autumn, were confirmed. During 2005–2006, the highest airborne pollen concentration was found in February ($154.67/m^3$), while the spring pollen peak was shifted to March ($133.7/m^3$) in the consecutive year. The second pollen peak in both years was in August, which included mostly grass pollen. The highest airborne pollen contributor of 2005–2006 was grass, accounting for 25% of total pollen, while in the subsequent year *Holoptelea* dominated with 47% of total pollen. The diurnal analysis showed that the highest pollen concentration in 2005–2006 was around 2 pm due to abundant flowering of *Morus*, while in 2006–2007, the maximum concentration was reported at 10 am due to *Holoptelea* pollen. Inter-annual species variation in climate was also considered as an important factor involved in inter-annual variation in pollen incidence. In general, a positive correlation was observed with temperature, particularly average temperature. During each period, peak pollen counts occurred when the average temperature fell within the range of 22°C–23°C.

Keywords: airborne pollen, diurnal fluctuation, inter-annual variation, pollen incidence

Introduction

Many different types of pollen are dispersed in the atmosphere. Pollen dispersal patterns in the atmosphere reflect the flowering phenology and pollen productivity of the regional flora. Their atmospheric presence and concentration were strongly influenced by meteorological, biological, and topographical factors.[1,2] Because many airborne pollen are causative factors of several types of allergic disorders in the human population, aerobiological surveys have been carried out in most regions of the developed and developing world in the second half of the last century.[3–9]

A number of aerobiological surveys have already been conducted in many Indian cities, including Lucknow.[10–14] As the composition of the ground vegetation is changing

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due to many anthropogenic causes such as urbanization as well as natural causes such as climate variations, aerospora is becoming altered.[15,16] Hence, new surveys are mandatory to update the knowledge regarding prevailing atmospheric pollen grains.[17] A survey of airborne pollen grains of Lucknow was conducted as early as 1954–1955[18] and subsequent surveys were performed in 1969–1970[19] and 1980–1981.[20] All of these surveys were based on gravitational methods of sampling and therefore presented qualitative data of pollen incidence. A rotorod sampler working on impaction device was used for a one-year survey of aerospora in Lucknow in 1997.[21]

The present survey was conducted to assess both the qualitative and quantitative status of airborne pollen grains in Lucknow using a volumetric sampler. Both diurnal and vertical gradients were used as the sampling was conducted three times daily at three different heights to analyze the periodical and vertical variation of airborne pollen for two consecutive years (August 2005–July 2007) to identify intra- and inter-annual variation of dominant aerial pollen in Lucknow.

Materials and methods
Study area
Airborne pollen monitoring was conducted for two consecutive years (August 1, 2005–July 31, 2007) at the National

Botanical Research Institute, which is situated in the heart of Lucknow (80°59′E, 26°55′N), in the capital city of Uttar Pradesh, India (Figure 1). Lucknow has a warm subtropical climate with cool, dry winters from December to February and dry, hot summers from April to June. The rainy season is from mid-June to mid-September. In winter, the maximum temperature is around 21°C and the minimum is 3°C to 4°C. Fog is quite common from late December to late January. Summers can be quite hot with temperatures rising to the 40°C to 45°C range.

Aerobiological survey: pollen collection, identification, and counting
A daily pollen count was performed during two consecutive years (August 2005–July 2007) using a Burkard volumetric portable air sampler (Burkard Manufacturing, Rickmansworth, Hertfordshire, UK), which operates at a nominal air throughput of ten l/min. Glass slides were labeled and then prepared using a very thin film of a high-quality red-stained glycerin jelly to collect the pollen. The slide was then placed in the Burkard sampler and allowed to run for approximately 15 min each time daily at 10 am, 2 pm, and 5 pm at heights of 0.12 m, 3.048 m, and 9.144 m. The exposed area of the micro-slide was covered with 24 × 24-mm cover glass and analyzed under a light microscope (Olympus CM3 microscope; Olympus, Tokyo, Japan) with the reading method of
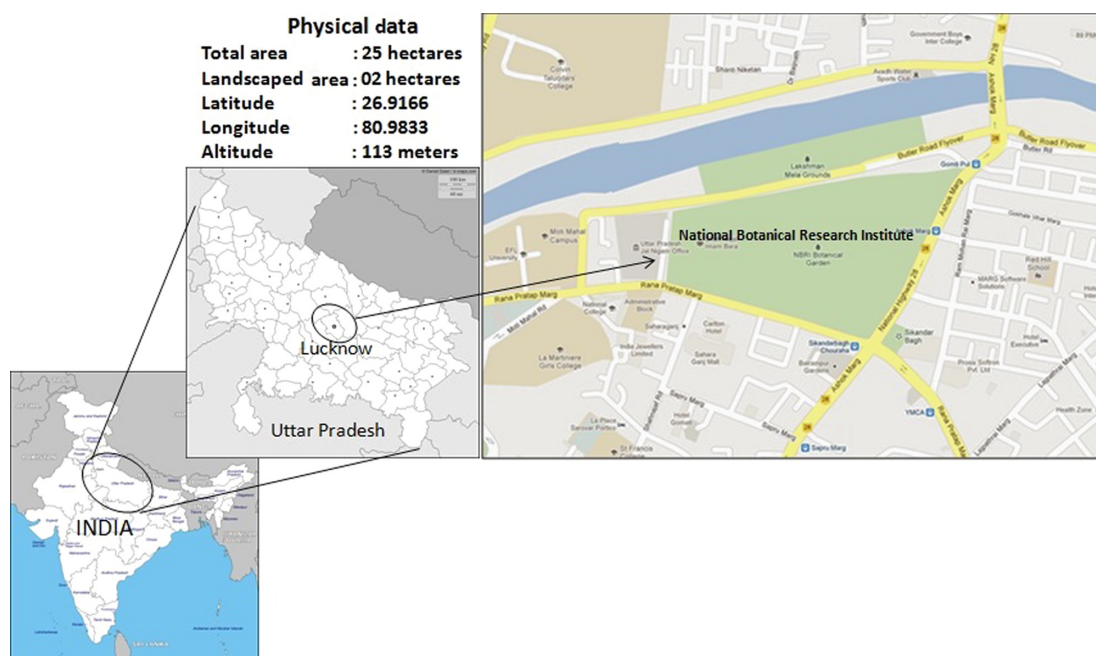

Figure 1 Site of the study (National Botanical Research Institute, Lucknow, India).

parallel smear with tangential microscope fields. With this method, successive tangent fields positioned on four or five lines separated by a space of about 2 mm were examined at 400× magnification (10 × ocular lens and 40 × objective lens).

After counting the pollen grains in one field, the slide was moved to the next tangential field. The pollen grains were then calculated for the entire exposed sample area, and this calculation was the final pollen count. Depending on the number of lines counted and the diameter of each field, pollen concentration per cubic meter was calculated. For reference purposes, acetolyzed pollen grains[22] of identified taxa were prepared. Pollen types were identified to species level (if possible) or at the genus level and grouped by family. Pollen types were identified by comparison with slides from the palynotheca and pollen kits of the Palynology Division, NBRI, Lucknow, India. Bibliographies[22,23] were also consulted for material identification.

Meteorological data

Daily maximum and minimum temperature, rainfall, and relative humidity (RH, %) from August 2005 to July 2007 were obtained from local weather information on the Website of the India Meteorological Department (http://www.mausam.gov.in/WEBIMD/). Simultaneous computing of mean monthly temperature and RH was carried out to find the correlation matrix of the pollen count with the weather variables. For the correlation of pollen incidence with phenological corollary, a study of ground vegetation was conducted.

Statistical analysis

Statistical analysis was performed for the identification of year-wise or seasonal differences in pollen count based on different ground vegetation. Pearson correlation (r-squared value, ie, correlation coefficient) was also calculated using the linear equation $y = mx + b$ in order to establish the correlation between yearly pollen counts. The analysis was performed for $\log_2$-transformed pollen counts data of all the species over two different years (between 12 months of 2 successive years, ie, 2005–2006 and 2006–2007). The unsupervised pattern recognition technique, or principal component analysis (PCA) was conducted using SAS software (v. 9.1.3; SAS Institute, Cary, NC). PCA was performed on the raw pollen count data after centering and auto-scaling of the variables.[24] Through this approach, we were able to determine the variable discriminates between pollen grains

for 14 and 11 major pollen types between 2005–2006 and 2006–2007, respectively.

PCA was also used to derive the first principal components from the data, and used in further analysis to examine the grouping of samples, ie, pollen count from different species, outliers, and to visualize the relative distribution of the major pollen samples according to their dominance in the particular environment. PCA was performed on the
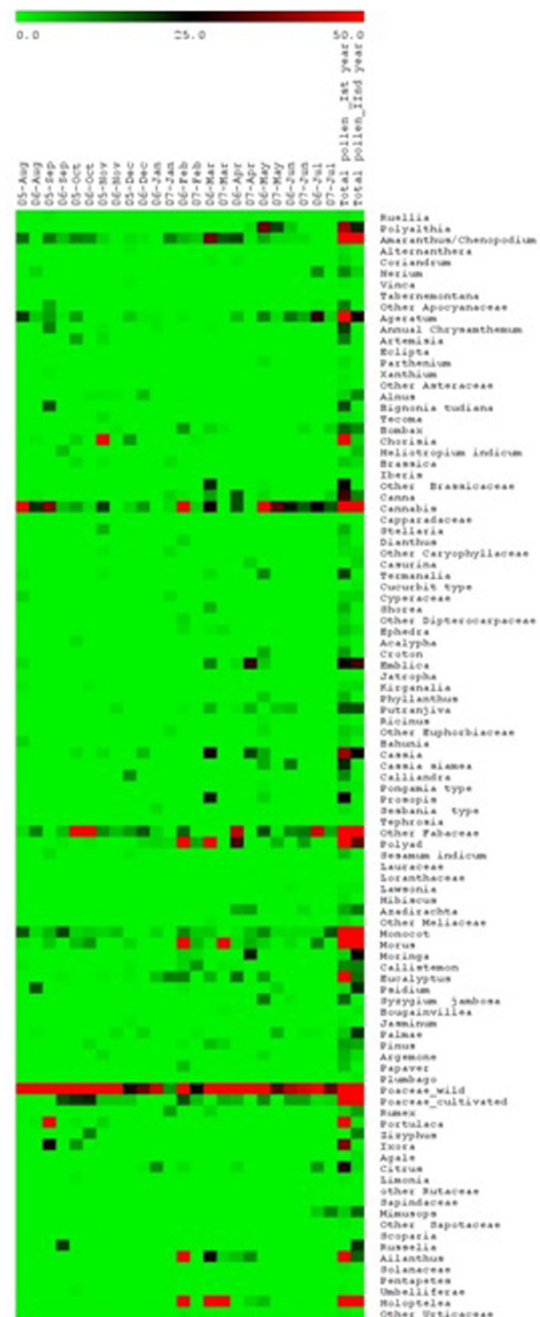

Figure 2 Pollen calendar for monthly incidence of individual airborne types (less, average, peak number) and their annual totals in Lucknow atmosphere for the years 2005–2007.

matrix obtained from the standardized data for pollen counts during the major pollen peaks. The first principal component represented the largest portion of the variability of the original dataset, while the second principal component represents the second largest, and so on.[25]

Results

Pollen sums

Atmospheric pollen monitoring and subsequent microscopic analysis for 2 consecutive years confirmed two main pollen seasons in Lucknow, including spring and autumn; intra- and interannual variations of pollen incidence were also noted (Figure 2 and Supplementary file 1). A total of 6089 pollen grains consisting of 92 types were recorded during 2005–2006. Of 92 pollen types, the pollen of ten plant taxa contributed more than 1% of total airborne pollen, with the rest present at lower frequencies (Figure 3). Grass pollen grains were found to be major pollen contributors during 2005–2006, registering 25% of the total catch followed by *Holoptelea* (20%) and Morus (15%). During 2005–2006, the highest airborne pollen contributor month was February, with a total of 2772 pollen grains and an

airborne pollen concentration of 154.67 pollen grains/m^3, followed by August, with 30.16 pollen grains/m^3 (Figure 4A and C). During 2006–2007, the total pollen catch was 4335 and included 61 pollen types, with the highest pollen peak observed in March (Figure 4B and D) with total of 2525 pollen grains. In contrast to the ten plants contributing more than 1% of total airborne pollen in 2005–2006, during 2006–2007, only seven plants registered more than 1% of total pollen (Figure 3).

Statistical analysis

Pearson correlation test

The correlation coefficient was measured for pollen count data for 12 months in 2 successive years, 2005–2006 and 2006–2007, using the linear equation $y = mx + b$. We observed a nearly linear distribution for these two logarithmic transformed data (ie, $\log_2$ transformation) (Figure 5A and Supplementary file 2). The value was found to be 0.486, which is close to the expected correlation value of approximately 0.5 and follows a nearly linear equation. Further, it could also be inferred that there was no significant correlation (≥ 0.5) between the measured values of total
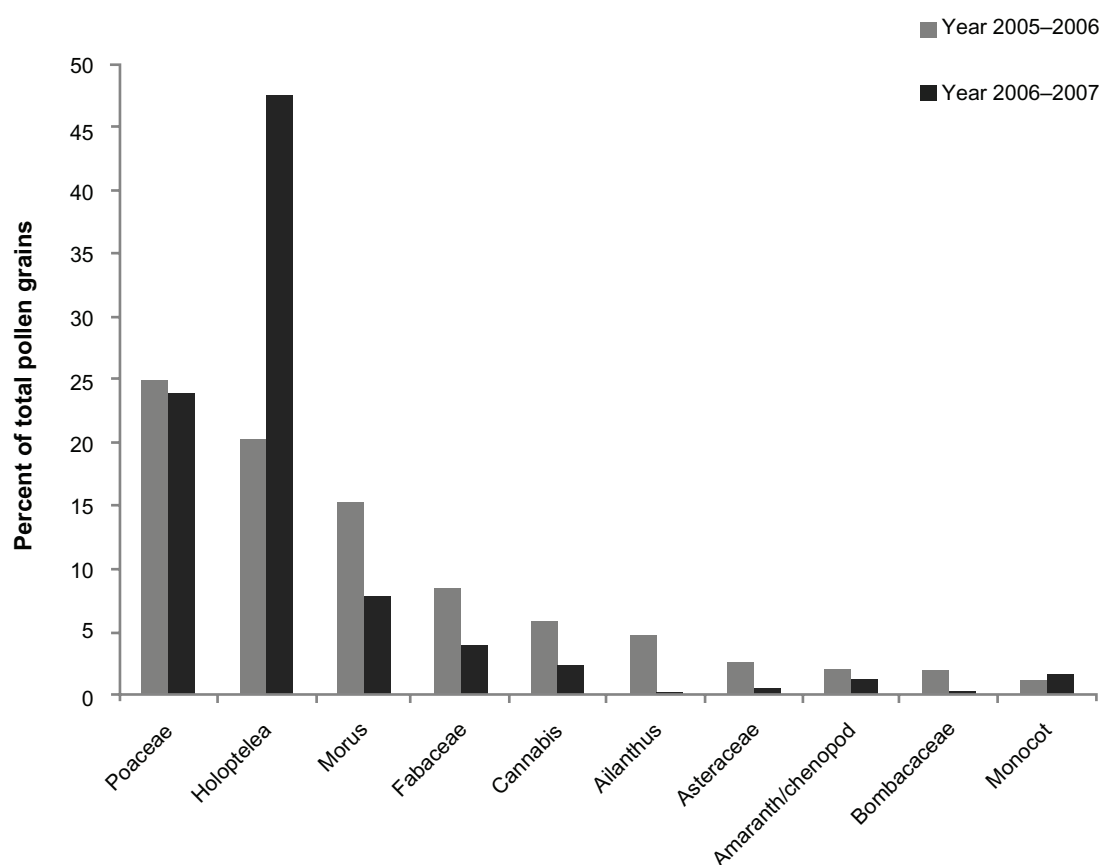

Figure 3 Percentage contribution of major pollen types in Lucknow atmosphere from August 2005–July 2006 and August 2006–July 2007.
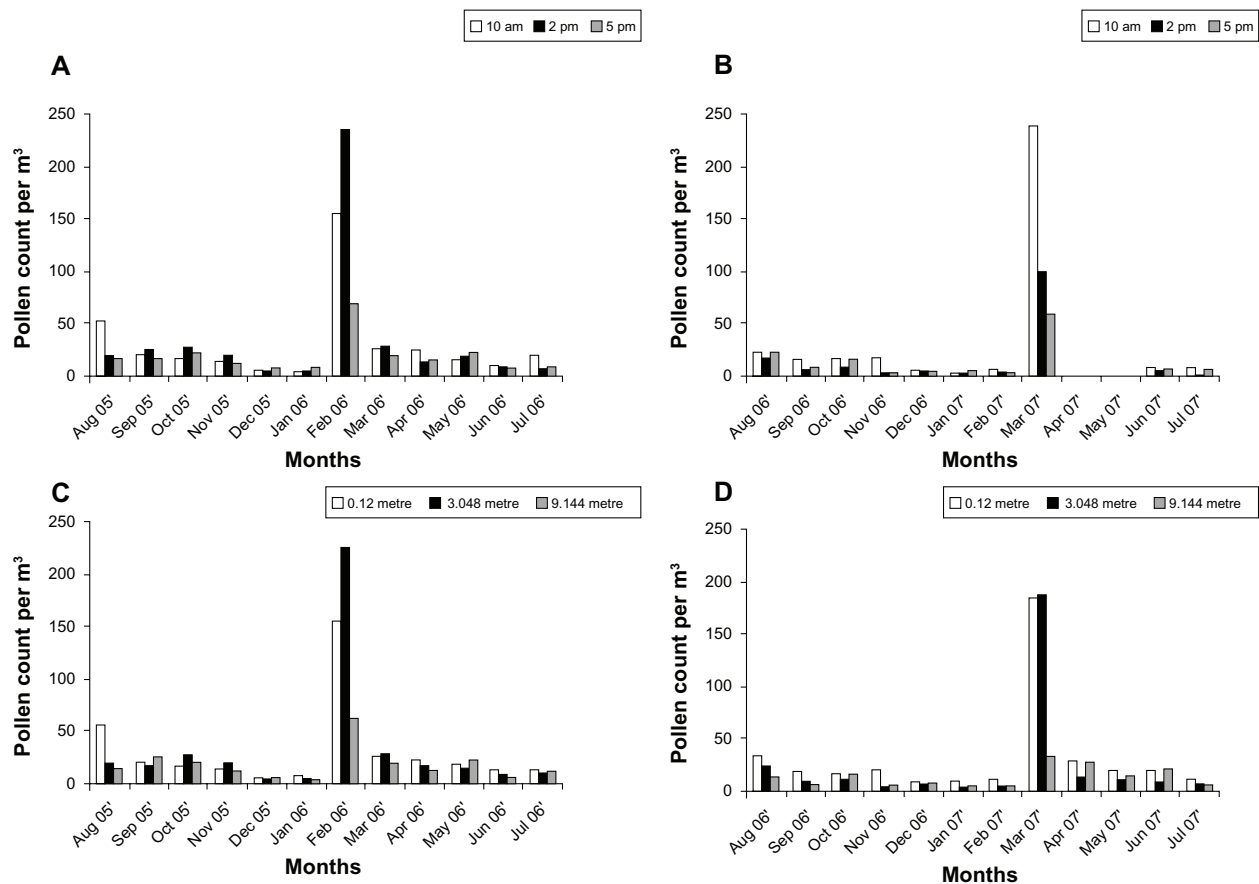
Figure 4 (A) Incidence of airborne pollen in Lucknow atmosphere with respect to diurnal variation (August 2005–July 2006). (B) Incidence of airborne pollen in Lucknow atmosphere with respect to diurnal variation (August 2006–July 2007). (C) Incidence of airborne pollen in Lucknow atmosphere with respect to different heights (August 2005–July 2006). (D) Incidence of airborne pollen in Lucknow atmosphere with respect to different heights (August 2006–July 2007).

pollen counts for 12 months of 2 successive years from 2005–2006 and 2006–2007, whereas correlation between pollen counts of some successive month were found to be significant (Figure 5B; Table 1A and B). The total pollen count was found to be influenced by the average temperature of a particular month, as the maximum pollen count was observed during an average temperature of 22°C ± 0.2°C. The correlation values were nonsignificant for these 2 years with regard to meteorological parameters. The data, however, revealed a positive correlation of relative humidity with pollen load for 2005–2006 only. The increase of one unit of relative humidity increased the pollen load by 0.118 units.

The study also revealed that the pollen peak was shifted from February (2005–2006) (154.67 pollen grains/m³) to March (2006–2007) (133.70 pollen grains/m³) as a result of abundant *Holoptelea* pollen, which contributed as high as 47% of the total airborne pollen of the year (Figure 2). The next most prevalent type was grass (24%).

Principal component analysis

A score plot was made for the first two principal components (PC1 and PC2) to interpret the classification of species according to their pollen grain counts of the 2 consecutive years examined (2005–2006 and 2006–2007) (Supplementary file 3, Sheets 1 and 2). Generally, a separation was observed among pollen grains according to pollen types; however, some samples did overlap. In particular, it was observed for *Ixora* spp. and families Bignoniaceae (2005–2006) (Figure 6A), Bombacaceae, Portulacaceae, and *Ailanthus* spp. overlapped during year 2006–2007 (Figure 6B). The first three PCs accounted for more than 84% of the variation, where PC1 showed 67%, PC2 showed 10%, and PC3 showed 7% of the variation related to the pollen for classification for the 2005–2006 data. However, for classification of the 2006–2007 data, the first three PCs accounted for more than 85% of the variation, where PC1 showed approximately 64%, PC2 showed 11%, and PC3 showed 10% of the variation related to pollen. The eigenvectors for the first three PCs were used to develop

A

$$y = 0.665x - 0.080$$
$$r^2 = 0.486$$

B

Figure 5 (**A**) The correlation coefficient for pollen count data for 12 months in two successive years, 2005–2006 and 2006–2007, using the linear equation y = mx + b. (**B**) Correlation plot in between the total pollen counts (log$_2$ values) in two successive years, 2005–2006 and 2006–2007.
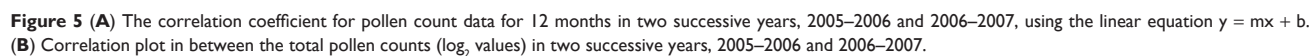
Table 1A Correlation matrix for pollen count data of two successive years (2005–2006)

	Aug 2005	Sep 2005	Oct 2005	Nov 2005	Dec 2005	Jan 2006	Feb 2006	Mar 2006	Apr 2006	May 2006	Jun 2006	Jul 2006
Aug 2005	1	0.8587	0.8895	0.5509	0.8224	0.9456	0.1501	0.6652	0.7889	0.6117	0.8538	0.7056
Sep 2005	0.8587	1	0.7641	0.4876	0.7004	0.7971	0.1287	0.5676	0.6716	0.564	0.7509	0.6142
Oct 2005	0.8895	0.7641	1	0.5425	0.8763	0.8808	0.1423	0.5776	0.8931	0.5751	0.8372	0.855
Nov 2005	0.5509	0.4876	0.5425	1	0.7108	0.5127	0.0673	0.3541	0.4685	0.3916	0.5168	0.4349
Dec 2005	0.8224	0.7004	0.8763	0.7108	1	0.8019	0.1664	0.5201	0.7855	0.5545	0.7939	0.7742
Jan 2006	0.9456	0.7971	0.8808	0.5127	0.8019	1	0.1439	0.648	0.8135	0.5121	0.7788	0.7046
Feb 2006	0.1501	0.1287	0.1423	0.0673	0.1664	0.1439	1	0.4496	0.1388	0.1426	0.1596	0.1736
Mar 2006	0.6652	0.5676	0.5776	0.3541	0.5201	0.648	0.4496	1	0.7173	0.4838	0.5865	0.438
Apr 2006	0.7889	0.6716	0.8931	0.4685	0.7855	0.8135	0.1388	0.7173	1	0.6001	0.7874	0.8131
May 2006	0.6117	0.564	0.5751	0.3916	0.5545	0.5121	0.1426	0.4838	0.6001	1	0.8251	0.6632
Jun 2006	0.8538	0.7509	0.8372	0.5168	0.7939	0.7788	0.1596	0.5865	0.7874	0.8251	1	0.8349
Jul 2006	0.7056	0.6142	0.855	0.4349	0.7742	0.7046	0.1736	0.438	0.8131	0.6632	0.8349	1

Table 1B Correlation matrix for pollen count data of two successive years (2006–2007)

	Aug 2006	Sep 2006	Oct 2006	Nov 2006	Dec 2006	Jan 2007	Feb 2007	Mar 2007	Apr 2007	May 2007	Jun 2007	Jul 2007
Aug 2006	1	0.941	0.7949	0.9949	0.8839	0.4253	0.8115	0.0271	0.8036	0.673	0.9009	0.8187
Sep 2006	0.941	1	0.8118	0.9506	0.8406	0.428	0.8445	0.0189	0.7623	0.6379	0.8961	0.8519
Oct 2006	0.7949	0.8118	1	0.8067	0.8898	0.3614	0.7058	0.0249	0.6248	0.5202	0.8655	0.7489
Nov 2006	0.9949	0.9506	0.8067	1	0.8752	0.415	0.8182	0.0285	0.8096	0.6339	0.8915	0.8132
Dec 2006	0.8839	0.8406	0.8898	0.8752	1	0.4007	0.738	0.0102	0.7091	0.7252	0.9313	0.8218
Jan 2007	0.4253	0.428	0.3614	0.415	0.4007	1	0.4441	0.0124	0.315	0.3595	0.4291	0.3601
Feb 2007	0.8115	0.8445	0.7058	0.8182	0.738	0.4441	1	0.0369	0.6919	0.6345	0.8326	0.7412
Mar 2007	0.0271	0.0189	0.0249	0.0285	0.0102	0.0124	0.0369	1	0.0711	0.0024	0.0138	0.006
Apr 2007	0.8036	0.7623	0.6248	0.8096	0.7091	0.315	0.6919	0.0711	1	0.5182	0.7035	0.6459
May 2007	0.673	0.6379	0.5202	0.6339	0.7252	0.3595	0.6345	0.0024	0.5182	1	0.7855	0.7454
Jun 2007	0.9009	0.8961	0.8655	0.8915	0.9313	0.4291	0.8326	0.0138	0.7035	0.7855	1	0.8859
Jul 2007	0.8187	0.8519	0.7489	0.8132	0.8218	0.3601	0.7412	0.006	0.6459	0.7454	0.8859	1
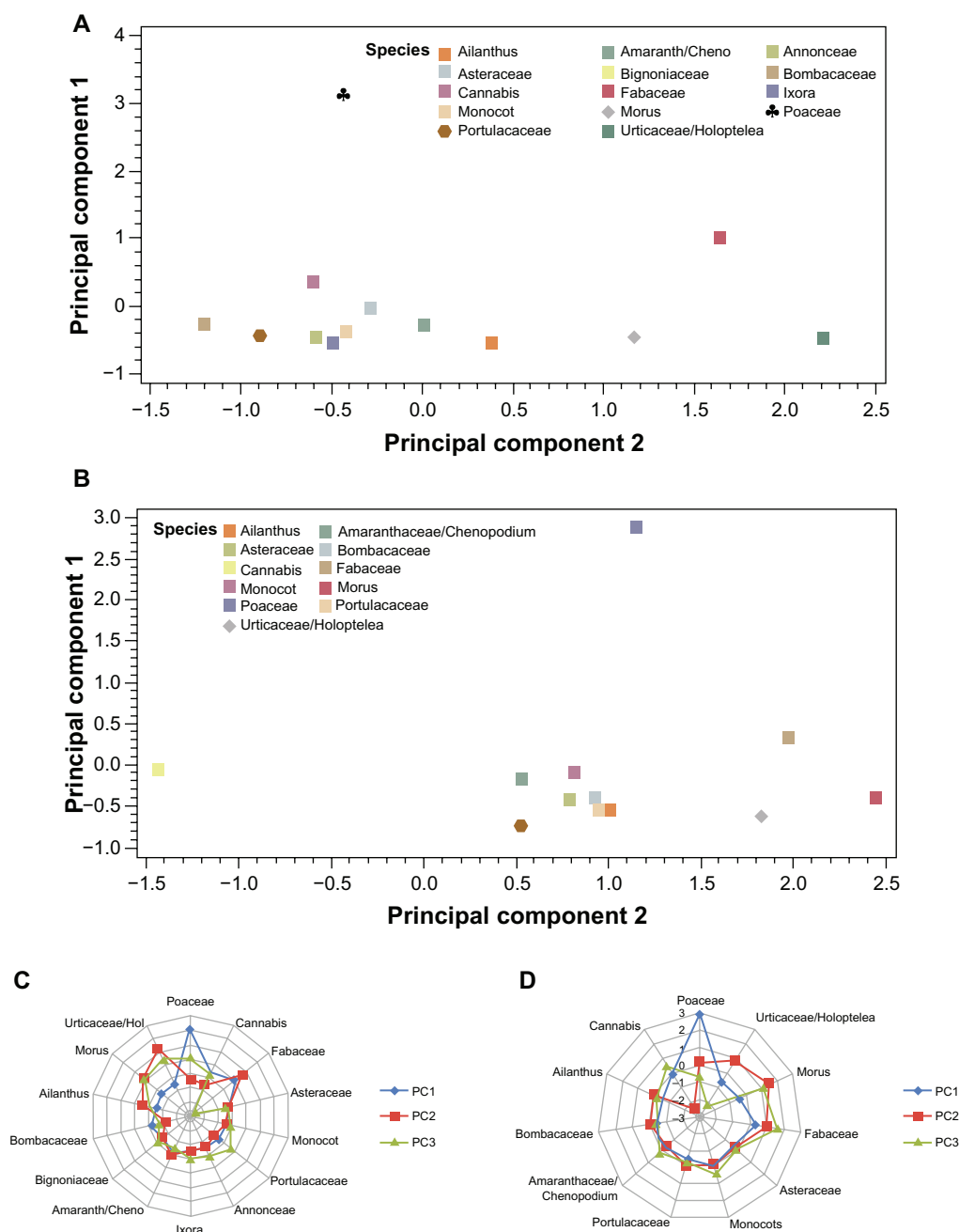
Figure 6 (**A**) PCA analysis for 12 months pollen grains for major 14 species of 2005–2006. (**B**) PCA analysis for 12 months pollen grains for major 11 species 2006–2007. (**C**) Eigenvector for the first three principal components of pollen grains for 14 dominant species in 2005–2006. (**D**) Eigenvector for the first three principal components of pollen grains for 11 dominant species in 2006–2007.
Abbreviations: PCA, principle component analysis.

the PCA plot (radar plot) for both years. The highest eigenvector in PC1 was explained by the high percentage of pollen of Poaceae, in year 2005–2006, while the highest eigenvector in PC2 was explained by the highest percentage of pollen of Urticaceae/*Holoptelea* spp. and Fabaceae, and PC3 was explained by the highest percentage of pollen of Urticaceae/*Holoptelea* spp. and Portulacaceae. However,

no clear separation was observed in the year 2005–2006 (Figure 6C). In 2006–2007, the highest eigenvector in PC1 was explained by the high percentage of pollen of Poaceae, while that in PC2 was explained by the highest percentage of pollen of *Morus* spp. and in PC3 by the highest percentage of pollen of Fabaceae, *Morus* spp. and *Cannabis* spp. (Figure 6D), although no clear separation was observed.

The PCA scores were related to total pollen counts in different months of the year.

Diurnal and vertical variation

Diurnal monitoring of the airborne pollen revealed that during 2005–2006, the concentration of airborne pollen was highest around 2 pm in February 2006 (235.5 pollen grains/m^3) (Figure 4A), while during 2006–2007, the maximum concentration was noted at 10 am in March (240.32 pollen grains/m^3) (Figure 4B). It was found that during the second pollen season, ie, autumn, pollen accumulation was higher at 10 am (53.18 pollen grains/m^3) than in August 2005 (first year) (Figure 4A) than in the afternoon, while it was nearly the same in the morning (23.33 pollen grains/m^3) and afternoon (24.13 pollen grains/m^3) in August 2006 (Figure 4B). The vertical profile indicated that accumulation of pollen was maximum at the 3.048 m height (224.29 pollen grains/m^3) during February 2006 (Figure 4C), while in the consecutive year, nearly the same concentration was noted (184.6 pollen grains/m^3) for (185 pollen grains/m^3) both the 0.12 m height and 3.048 m height (Figure 4D). The data revealed the pollen concentration at 0.12 m was maximum during the second pollen peak of both the years, ie, August 2005 (55.08 pollen grains/m^3) (Figure 4C) and August, 2006 (30.95 pollen grains/m^3) (Figure 4D).

Pollen distribution patterns

In both years, spring was the major pollen season due to high incidence of anemophilous trees such as *Holoptelea*, *Ailanthus*, and *Morus*. (Figure 7A–C). It was noticed that February 2006 was the most pollen rich-month due to combined load of *Morus* spp. and *Holoptelea* spp. pollen. However, the lower pollen incidence of *Morus* in February 2007 and profuse flowering in *Holoptelea* spp. in March 2007 resulted in a shift of the pollen peak to March in the consecutive year. Analysis of the data also revealed that abundant flowering in *Morus* spp., which has an afternoon pattern of flowering, resulted in a high concentration of pollen around 2 pm in February 2006 (Figure 4A), while in next year profuse blooming of *Holoptelea* spp. with a morning pattern of anthesis caused a high pollen concentration around 10 am in March 2007 (Figure 4B). The pollen load of autumn (second pollen peak) mainly consisted of grasses (Figure 7D) and herbs, flowering after the rainy season and as most of the grasses
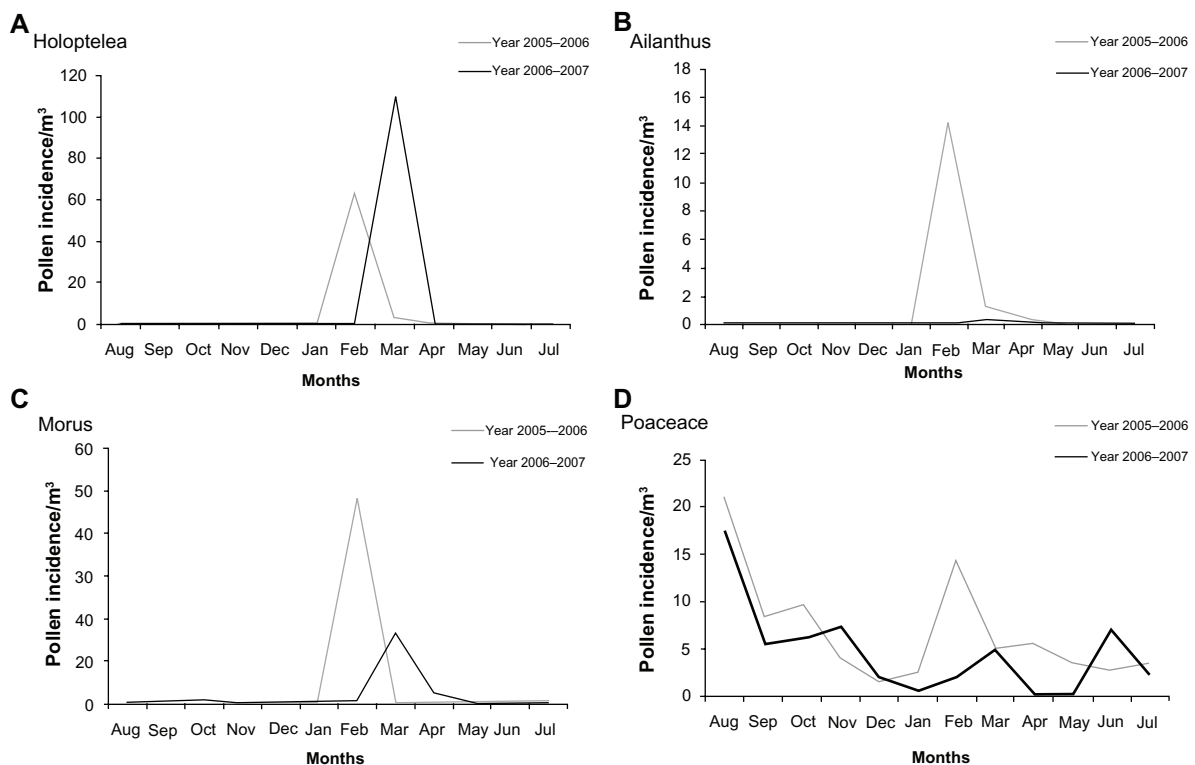
Figure 7 (**A–D**) Incidence of major airborne pollen in Lucknow atmosphere during 2005–2007.
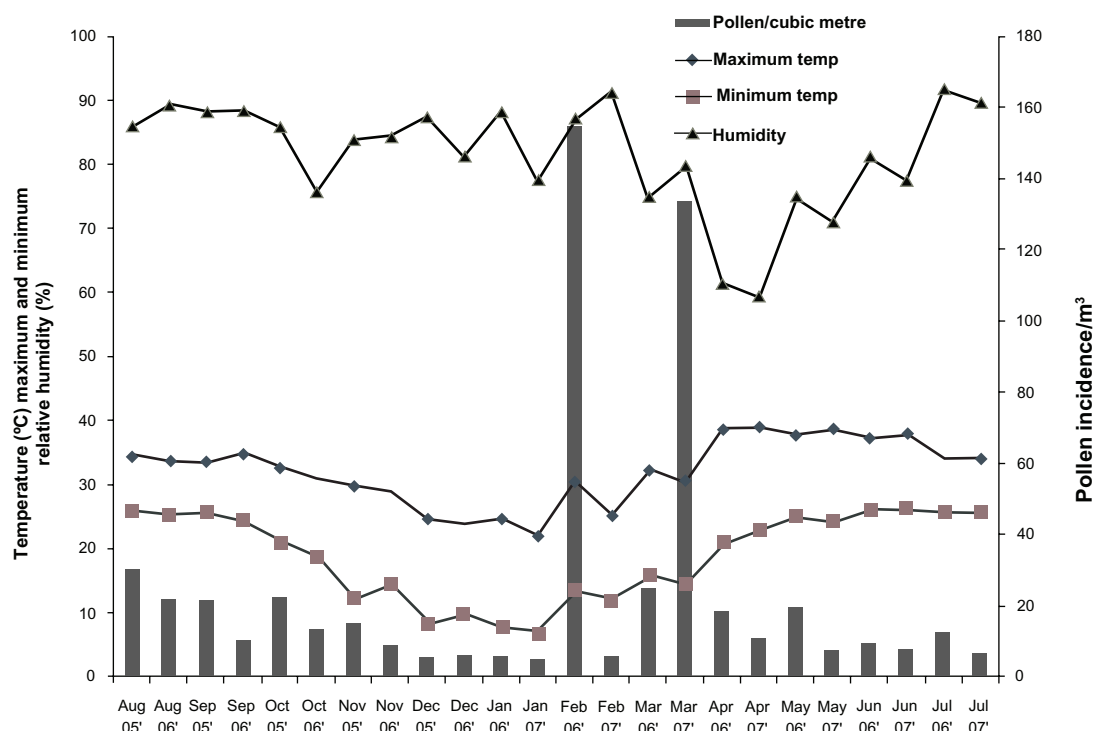
Figure 8 Incidence of airborne pollen in Lucknow atmosphere and prevailing meteorological parameters from August 2005–July 2006 and August 2006–July 2007.

open during forenoon, the pollen concentration reached a maximum at 10 am during both years. The pollen grains of some herbs, however, contributed to afternoon pollen catch (Figure 4A and B). The vertical profile of both years showed a maximum concentration at the ground level, which was a result of accumulation of grass and herb pollen at low levels (Figure 4C and D). The meteorological data indicated many rainy days in February 2007, which may have contributed to the unusually low pollen catch during this month. Atmospheric pollen incidence in the prevailing meteorological conditions, monthly averages of overall temperature, and RH in the study area during the two sampling years (2005–2007) are presented in Figure 8. As shown in the figure, temperature levels were higher in the months between April and July and RH levels were highest in the months of July 2006 and February 2007, where these values were more than 90% compared to the other months of both sampling years.

Discussion

The present study reveals very useful information regarding the current scenario of atmospheric pollen grains of Lucknow, along with diurnal, seasonal and annual variation. The data generated from the two-year volumetric survey

indicated that qualitative and quantitative concentration of aerospora not only differs seasonally or annually, but also differs diurnally and to some extent vertically. This may be influenced by a number of factors, including meteorological parameters. The survey showed that the airborne pollen incidence of Lucknow was greater in the year 2005–2006 for both pollen types and frequencies than in 2006–2007.

In terms of pollen load, spring was the peak season of both years. While in the first year, February showed the highest pollen incidence, in the next year, the peak shifted to March (Figure 7). Flowering of anemophilous trees created high pollen incidence during spring, many of which were allergenic and significant.[26,27] Variation of total pollen content occurred due to distinct inter–annual species specific fluctuation of pollen incidence.[28] Analysis of the data showed that during spring of 2005–2006, pollen concentration was much higher due to high pollen incidence of a number of tree species, eg, *Morus, Ailanthus* and also many species of family Fabaceae, which starts flowering in February. However, in the subsequent year, the pollen incidence of these species was much lower in February as compared to *Holoptelea* spp. (45%), which flowers mainly in March. Pollen production of certain trees differing from another in a given year may be due to the physiological biorhythm of the particular tree species.

This type of variation in pollen incidence among tree species may influence vertical pollen concentration near the site of the pollen source as has been revealed in the present study. The data shows dominance of pollen grains of *Morus* spp., *Ailanthus* spp., and *Holoptelea* spp. along with the tree species of family Fabaceae, which cumulatively affected maximum pollen concentration at a height of 3.048 m during the spring of 2006.

In the next year (2006–2007), nearly equal pollen concentrations at ground level and a height of 3.048 m were noted; it was found that the pollen of *Holoptelea* appeared at both the levels in large amounts. It was also evident from the study that diurnal variability of pollen concentration is significantly related to the pattern of pollen emission and incidence of major pollen contributor of the season. Yang et al also observed that the diurnal pattern was irregular in some plants which produced a smaller pollen quantity than those which produced large amounts of pollen.[29] Therefore, the afternoon pattern of *Morus* pollen showed the highest concentration at 2 pm in 2006 and the morning pattern of *Holoptelea* showed maximum pollen accumulation at 10 am in the spring of 2007. These findings provide important information for both patients and physicians for managing pollen allergy, as both the taxa have a hazardous effect on susceptible persons.[27] The second pollen season (autumn), was represented mainly by pollen grains of grasses and herbaceous taxa including *Ageratum, Cannabis, Amaranthus* (Amaranth), and *Chenopodium* (Chenopods), which showed more stable airborne incidence in comparison to trees during the two-year survey. Both years' pollen peak was in August, with diurnal periodicity at 10 am in first year and at 10 am and 5 pm in the second year, as some grasses and herbs have late morning or afternoon anthesis.

The relationship between meteorological factors and airborne pollen counts has been studied and discussed by various authors, and interesting interpretations have been made.[30–33] Teranishi et al, formulated an association of total pollen count increase in accordance with an elevated average temperature of the previous year.[34] As in the present case, the total pollen count may be influenced by the average temperature (22°C ± 0.2°C) of a particular month. This is indicated by a shift in the pollen peak for maximum pollen count from February (2005–2006) to March (2006–2007). Alwadie clearly demonstrated that daily mean and maximum temperature, daily temperature fluctuation, and the number of hours of sunshine have a significant positive effect on pollen count.[5] However,

the amount of precipitation and RH negatively influence pollen count. Thus, phenology may not be the only factor influencing the seasonal variation in the total pollen count since this phenomenon is known to be very sensitive to even minor variations in climate, particularly temperature. In the present survey, it was found that the month of July (rainy season) had maximum average RH (91.89%) in 2006, but in 2007, the maximum RH was noted in February (91.29%) due to unusual rain in the early spring, during which a low pollen concentration was observed. Thus, it can be inferred that atmospheric pollen incidence may be negatively correlated with high precipitation and number of rainy days in the month. This fact was also reported by Smart et al, Fehér and Járai-Komlódi, and Alwadie.[5,35,36]

The above study showed that aerospora of any given region is a true depiction of the local vegetation, though it is also significantly influenced by various biotic and abiotic factors. Despite the impact of such factors which emerge with the course of time, it has been noted that the prevalent airborne taxa of a certain region primarily remains the same, with few noticeable variations. Studies from previous aerobiological surveys have shown that the prevailing aerospora of Lucknow is predominated by a few wind-pollinated taxa, though variations in their quantitative load cannot be ruled out.[17,18,20,26] Thus, the results of all aerobiological surveys assist in characterizing the dominant aerospora of the region in question. However, seasonal periodicity provides important information for diagnosing allergenic pollen grains causing allergenic symptoms in susceptible persons. The present survey offers additional information regarding volumetric data, which is more accurate for measuring the quantitative concentration of pollen in atmosphere. The current investigation also provides intricate information regarding diurnal and altitudinal concentration, which would be of great help for the susceptible persons to avoid the hazardous exposure and the physician to give proper treatment. Earlier surveys, however provided only seasonal or month-wise concentrations of airborne pollen.[17,18,20,26] Avoiding allergenic pollen is the best method of taking precaution, but this may not be easy for an active person to confine himself indoors for an entire season. The findings of the present survey provide information about the specific period of the day when the outside atmosphere is loaded with maximum concentrations of particular offending pollens; consideration of this information would make it easier for a person to avoid harmful exposure. The detailed data, providing fluctuation in pollen incidence of different species, may be linked with various factors such as pollen production, comparative dominance

of specific taxa in certain year due to physiological factors, and, of course, various prevailing meteorological conditions which offer prerequisites for in-depth study of environment and ecology.[2]

Conclusion

The study area is the host to a variety of trees, weeds, and grasses that produce copious amounts of pollen grains. Our study found that phenology alone cannot be considered as the sole factor influencing seasonal variation in total pollen count; instead, meteorological factors (temperature and RH), also play a governing role in pollination phenology. Our results showed a positive effect of temperature and negative effect of rain fall, which should be taken into account for a more reliable forecast of both the beginning and main pollen peak emission rate. Early flowering and an average temperature of $22°C \pm 0.2°C$ are factors that positively influence the final yield. A more complete examination of the relationship among meteorological parameters, significant weather events, and year-to-year variation in daily pollen levels was well beyond the scope of this investigation. Further studies are needed to better elucidate the complexities of this relationship and facilitate the development of a predictive model that may enable the forecasting of daily pollen levels, which can be used in allergy prevention centers to predict high-risk periods. The knowledge gained would be invaluable for both the allergy practitioners and the atopic patients.

Acknowledgments

Disclosure

The authors report no conflicts of interest in this work.

References

1. Ziska LH, Epestein PR, Rogers CA. Climate change, aerobiology, and public health in the Northeast United States. *Mitig Adapt Strat Glob Change*. 2008;13(5):607–613.
2. Khanduri VP. Variation in anthesis and pollen production in plants. *American-Eurasian J Agric and Environ Sci*. 2011;11(6):834–839.
3. Frenz DA, Murray LW. An atmospheric pollen survey conducted during the winter in Minneapolis, Minnesota, USA. *Grana*. 1997;36: 245–248.
4. Dvorin DJ, Lee JJ, Belecaneth GA, Goldstein MF, Dunsky EH. A comparative, volumetric survey of airborne pollen in Philadelphia, Pennsylvania (1991–1997) and Cherry Hill, New Jersey (1995–1997). *Ann Allergy Asthma Immunol*. 2001;87(5):394–404.
5. Alwadie HM. Pollen concentration in the atmosphere of Abha City, Saudi Arabia and its relationship with meteorological parameters. *J Appl Sci*. 2008;8:842–847.
6. Liu ZG, Song JJ, Kong XL. A study on pollen allergens in China. *Biomed Environ Sci*. 2010;23(4):319–322.
7. Murray MG, Galan C, Villamil CB. Airborne pollen in Bahia Blanca, Argentina: Seasonal distribution of pollen types. *Aerobiologia*. 2010;26(3):195–207.
8. Çeter T, Pinar NM, Güney K, Yildiz A, Aşcı B, Smith M. A 2-year aeropalynological survey of allergenic pollen in the atmosphere of Kastamonu, Turkey. *Aerobiologia*. 2012;28(3):355–366.
9. Melgar M, Trigo MM, Recio M, Docampo S, García-Sánchez J, Cabezudo B. Atmospheric pollen dynamics in Münster, northwestern Germany: a three-year study (2004–2006). *Aerobiologia*. 2012:1–12.
10. Singh AB, Babu CR. Survey of atmospheric pollen allergens in Delhi: seasonal periodicity. *Annals Allergy*. 1982;48(2):115–122.
11. Mandal J, Chakraborty P, Roy I, Chatterjee S, Gupta-Bhattacharya S. Prevalence of allergenic pollen grains in the aerosol of the city of Calcutta, India: a two year study. *Aerobiologia*. 2008;24(3): 151–164.
12. Sahney M, Chaurasia S. Seasonal variations of airborne pollen in Allahabad, India. *Ann Agric Environ Med*. 2008;15(2):287–293.
13. Shukla S, Shukla RV. A quantitative survey of pollen flora in atmosphere of Korba-Chhattisgarh, India. *Int J Bot*. 2010;6(4):449–455.
14. Nayar TS, Jothish PS. An assessment of the air quality in indoor and outdoor air with reference to fungal spores and pollen grains in four working environments in Kerala, India. *Aerobiologia*. 2012 (DOI 10.1007/s10453-012-9269-8).
15. Ariano R, Canonica GW, Passalacqua G. Possible role of climate changes in variations in pollen seasons and allergic sensitizations during 27 years. *Ann Allergy Asthma Immunol*. 2010;104(3):215–222.
16. Puc M, Bosiacka B. Effects of Meteorological Factors and Air Pollution on Urban Pollen Concentrations. *Pol J of Environ Stud*. 2011;20(3):611–618.
17. Khandelwal A. Aerobiology: Aspects and prospects. *The Paleobotanist*. 2008;57:251–255.
18. Lakhanpal RN, Nair PKK. Survey of atmospheric pollen of Lucknow. *J Sci Indust Res*. 1958;17(e):80–87.
19. Mittre V, Khandelwal A. Airborne pollen grains and fungal spores at Lucknow during 1969–1970. *Paleobotanist*. 1973;22:177–185.
20. Chaturvedi M, Datta K, Nair PKK. A fresh survey of airborne pollen at Lucknow. *J Palynology (G.Thanikaimoni Memorial Volume)*. 1987–1988;23–24:117–143.
21. Khandelwal A. Survey of aerospora by Rotorod Sampler in Lucknow, India: qualitative and quantitative assessment. *Aerobiologia*. 2001;17: 77–83.
22. Erdtman G. Pollen morphology and Plant Taxonomy. Angiosperms. E. J. Brill Publishing, Lieden, The Netherlands; 1983:553.
23. Nair PKK. Pollen morphology of angiosperms. A historical and phylogenetic study. National Botanical Gardens, Lucknow. Scholar Publishing House, India; 1970.
24. Naes T, Isaksson T, Fearn T, Davies T. A user-friendly guide to multivariate calibration and classification. NIR Publications, Chichester, UK; 2002:344.
25. Chao HJ, Schwartz J, Milton DK, Burge HA. Populations and determinants of airborne fungi in large office buildings. *Environ Health Perspect*. 2002;110(8):777–782.
26. Agnihotri MS, Singh AB. Observations in pollinosis in Lucknow with special reference to offending factors. *Aspects Allergy Appl Immunol*. 1971;5:135–140.
27. Singh AB, Kumar P. Common environmental allergens causing respiratory allergy in India. *Indian J Pediatr*. 2002;69(3):245–250.
28. Singh AB, Pandit T, Dahiya P. Changes in airborne pollen concentrations in Delhi, India. *Grana*. 2003;42:168–177.
29. Yang YL, Huang TC, Chen SH. Diurnal variations of airborne pollen and pores in Taipei City, Taiwan. *Taiwania*. 2003;48:168–179.
30. Galán C, Alcázar P, Cariñanos P, García-Mozo, H, Domínguez E. Meteorological factors affecting daily Urticaceae pollen counts in southwest Spain. *Int J Biometeorol*. 2000;43(4):191–195.

31. Gioulekas D, Balafoutis C, Damialis A, Papakosta D, Gioulekas G, Patakas D. Fifteen years' record of airborne allergenic pollen and meteorological parameters in Thessaloniki, Greece. *Int J Biometeorol*. 2004;48(3):128–136.

32. Stennett PJ, Beggs PJ. Pollen in the atmosphere of Sydney, Australia, and relationships with meteorological parameters. *Grana*. 2004;43:209–216.

33. Sousa SIV, Martins FG, Pereira MC, et al. Influence of atmospheric ozone, PM10 and meteorological factors on the concentration of airborne pollen and fungal spores. *Atmos Environ*. 2008;42:7452–7464.

34. Teranishi H, Kenda Y, Katoh T, Kasuya M, Oura E, Taira H. Possible role of climate change in the pollen scatter of Japanese cedar *Cryptomeria japonica* in Japan. *Climate Research*. 2000;14:65–70.

35. Smart JJ, Tuddenham WG, Knox RB. Aerobiology of grass pollen in the city atmosphere of Melbourne: Effects of weather parameters and pollen sources. *Austral J Bot*. 1979;27:333–342.

36. Fehér Z, Járai-Komlódi M. A new weather factor predicting airborne pollen concentration: Péczely's macrosynoptic weather types. *Aerobiologia*. 1998;14:171–177.

Supplementary files

File I

Species	5-Aug	6-Aug	5-Sep	6-Sep	5-Oct	6-Oct	5-Nov	6-Nov	5-Dec	6-Dec	6-Jan	7-Jan	6-Feb
Ruellia	0	0	2	0	0	0	0	0	0	0	0	0	0
Polyalthia	0	0	0	0	0	0	0	0	0	0	0	0	0
Amaranthus/Chenopodium	14	1	13	6	12	11	4	0	3	2	1	12	7
Alternanthera	0	0	0	0	0	0	0	0	2	0	1	0	0
Coriandrum	0	0	0	0	0	0	0	0	0	0	0	0	0
Nerium	0	4	0	0	0	0	0	0	0	0	0	0	0
Vinca	0	0	0	0	0	0	0	0	2	0	0	0	0
Tabernemontana	0	0	0	0	1	0	0	0	0	0	0	0	0
Other Apocyanaceae	0	0	8	0	1	1	1	0	0	0	0	0	0
Ageratum	19	5	9	2	9	1	0	0	5	2	2	0	2
Annual Chrysanthemum	0	0	12	0	0	0	2	0	1	0	2	0	0
Artemisia	0	0	0	0	9	1	3	0	0	0	1	0	0
Eclipta	1	1	0	0	0	0	0	0	0	0	0	0	0
Parthenium	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthium	0	0	2	0	0	0	0	0	0	0	0	0	0
Other Asteraceae	1	0	0	0	0	0	1	1	0	0	0	0	0
Alnus	0	0	0	1	1	2	2	2	1	6	0	0	0
Bignonia tudiana	0	0	17	0	0	0	0	0	0	0	0	0	0
Tecoma	0	0	0	1	0	0	3	0	0	0	0	0	0
Bombax	1	0	0	0	0	0	0	2	0	0	0	0	10
Chorisia	0	2	0	0	4	0	91	0	10	0	0	0	0
Heliotropium indicum	0	0	0	6	0	0	0	0	0	0	0	0	1
Brassica	0	0	0	0	3	0	2	0	0	0	0	3	0
Iberis	0	0	0	0	0	0	0	0	0	1	0	0	0
Other Brassicaceae	0	0	0	0	0	0	0	0	0	1	0	0	0
Canna	0	2	0	0	0	0	0	0	0	0	0	4	2
Cannabis	53	20	39	6	9	3	19	0	4	10	0	3	74
Capparadaceae	0	0	0	0	0	0	0	0	0	0	0	0	0
Stellaria	0	0	0	0	0	0	7	0	0	0	0	0	0
Dianthus	0	0	0	0	0	0	0	0	0	0	0	0	4
Other Caryophyllaceae	0	0	0	0	1	0	2	0	0	0	0	3	0
Casurina	0	0	0	0	0	0	0	0	0	0	0	0	0
Termanalia	2	0	0	0	0	0	2	0	0	0	0	0	0
Cucurbit type	0	0	0	1	1	0	0	0	0	0	0	0	0
Cyperaceae	4	0	0	0	0	0	0	0	0	1	0	3	0
Shorea	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Dipterocarpaceae	0	0	0	0	0	0	0	0	0	0	0	0	4
Ephedra	0	0	0	0	0	0	0	0	0	0	0	0	3
Acalypha	0	0	0	0	3	0	0	0	0	0	0	0	0
Croton	0	0	0	0	0	0	0	0	0	0	0	0	0
Emblica	3	0	0	0	0	0	0	0	0	0	0	0	1
Jatropha	0	0	0	0	1	0	0	0	0	0	0	0	0
Kirganalia	2	0	0	0	0	2	0	0	0	0	0	0	0
Phyllanthus	1	0	0	0	0	0	0	0	0	0	0	0	0
Putranjiva	0	1	0	0	0	0	0	3	0	0	0	0	2
Ricinus	0	0	0	0	0	0	0	0	0	1	0	0	0
Other Euphorbiaceae	0	0	0	0	0	0	1	0	1	0	0	3	0
Bahunia	4	0	0	0	0	0	0	0	0	0	0	0	0
Cassia	0	0	0	0	3	0	3	0	0	6	0	0	0
Cassia siamea	0	0	0	0	0	0	0	0	0	0	0	0	0
Calliandra	0	0	0	0	0	0	0	0	11	0	0	0	0
Pongamia type	0	0	0	0	0	0	0	1	0	0	1	0	0
Prosopis	0	0	0	0	0	0	0	0	0	0	0	0	0
Sesbania type	0	0	0	0	0	0	0	0	0	0	3	0	0

7-Feb	6-Mar	7-Mar	6-Apr	7-Apr	6-May	7-May	6-Jun	7-Jun	6-Jul	7-Jul	Total pollen _Ist year	Total pollen_2nd year
0	0	0	0	0	0	0	0	0	0	0	2	0
0	0	0	0	3	36	18	5	0	0	0	41	21
5	37	16	18	2	8	3	3	3	1	0	121	61
0	0	0	0	0	0	0	0	0	0	0	3	0
0	2	0	2	0	0	0	0	0	0	0	4	0
0	0	0	0	0	0	0	0	0	11	0	11	4
0	0	0	0	0	0	0	0	0	0	0	2	0
0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	2	0	12	1
0	0	1	6	1	12	3	13	8	30	4	107	27
0	2	0	0	0	0	0	0	0	0	0	19	0
0	0	0	0	0	0	0	0	0	0	0	13	1
0	0	0	0	0	0	0	0	0	0	0	1	1
0	0	0	0	0	3	0	0	0	0	0	3	0
0	0	0	0	0	0	0	0	0	0	0	2	0
0	0	0	0	0	0	0	0	0	0	0	2	1
0	0	0	0	0	0	0	0	0	0	0	4	11
0	0	0	0	0	0	0	0	0	0	0	17	0
0	0	1	0	0	0	0	0	0	0	0	3	2
0	4	2	0	0	0	0	0	3	0	4	15	11
2	0	0	0	0	0	0	1	0	0	0	106	4
0	0	0	0	0	0	0	0	0	0	0	1	6
0	0	0	0	0	0	0	0	0	0	0	5	3
0	0	0	0	0	0	0	0	0	0	0	0	1
0	21	0	0	0	2	0	1	0	0	0	24	1
0	9	0	17	1	3	0	0	0	0	4	31	11
4	27	0	17	0	68	35	23	16	25	16	358	113
0	1	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	0	7	0
0	0	0	0	0	0	0	0	0	0	0	4	0
0	0	0	0	0	0	0	0	0	0	0	3	3
0	0	0	0	4	1	0	0	0	0	0	1	4
0	3	0	0	0	11	0	0	1	0	0	18	1
0	0	0	0	0	0	1	0	0	0	0	1	2
0	0	0	0	0	0	0	0	0	0	0	4	4
0	7	0	0	0	0	0	0	0	0	0	7	0
0	0	0	0	0	0	0	0	0	0	0	4	0
0	2	3	0	0	1	0	0	0	0	0	6	3
0	0	0	0	0	0	0	0	0	0	0	3	0
0	0	0	0	1	8	0	1	0	0	0	9	1
0	12	0	3	31	5	1	0	0	0	0	24	32
0	0	0	0	0	0	1	0	0	0	0	1	1
0	0	0	0	0	1	0	0	1	0	0	3	3
0	0	0	0	0	5	0	1	0	0	0	7	0
0	7	1	2	7	0	5	6	0	0	0	17	17
0	0	0	0	0	2	0	0	0	0	0	2	1
0	0	0	0	0	3	0	0	0	0	0	5	3
0	0	0	0	0	0	0	0	0	0	0	4	0
0	27	1	0	18	8	0	0	0	0	0	41	25
0	0	0	0	0	8	0	13	0	0	0	21	0
0	0	0	0	0	0	0	0	0	0	0	11	0
0	0	1	0	0	2	0	0	0	0	0	3	2
0	22	0	0	0	4	0	0	0	0	0	26	0
0	0	0	0	0	0	0	0	0	0	0	3	0

(Continued)

File 1 (*Continued*)

Species	5-Aug	6-Aug	5-Sep	6-Sep	5-Oct	6-Oct	5-Nov	6-Nov	5-Dec	6-Dec	6-Jan	7-Jan	6-Feb
Tephrosia	1	0	0	0	0	0	0	0	0	0	0	0	0
Other Fabaceae	3	12	0	6	71	56	11	6	10	16	4	0	15
Polyad	0	0	0	2	0	2	0	0	0	3	4	3	62
Sesamum indicum	0	0	3	0	0	0	1	0	2	0	0	0	0
Lauraceae	1	0	0	0	0	0	0	0	0	0	0	0	0
Loranthaceae	0	0	0	0	1	0	0	0	0	0	0	0	0
Lawsonia	0	0	0	0	0	0	0	0	0	0	0	0	0
Hibiscus	0	0	0	0	1	0	0	0	0	0	0	0	0
Azadirachta	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Meliaceae	0	0	0	0	0	0	0	0	0	0	0	0	0
Monocot	16	3	7	18	4	5	4	6	1	0	4	0	11
Morus	2	0	5	1	6	10	1	1	4	0	1	0	875
Moringa	0	0	0	0	0	0	0	0	0	0	0	0	4
Callistemon	2	0	0	0	0	0	0	0	2	0	0	0	4
Eucalyptus	0	0	0	2	0	0	2	0	2	0	6	12	12
Psidium	0	17	0	0	1	0	0	0	0	0	0	0	2
Syzygium jambosa	0	0	0	0	0	0	0	0	0	0	0	0	0
Bougainvillea	0	0	0	0	0	0	0	0	0	0	0	0	0
Jasminum	0	0	0	0	0	0	0	0	2	0	0	0	0
Palmae	0	2	0	0	0	0	0	3	0	4	0	0	0
Pinus	0	0	1	1	0	3	0	0	0	0	0	0	2
Argemone	1	0	0	1	0	0	3	0	0	0	0	0	0
Papaver	0	0	0	0	0	0	0	0	0	0	0	0	6
Plumbago	0	0	0	1	0	0	0	0	0	0	0	0	0
Poaceae_wild	395	330	157	89	147	78	61	141	28	36	46	10	242
Poaceae_cultivated	0	1	0	17	20	21	5	5	5	0	1	0	17
Rumex	0	0	0	0	0	0	0	0	0	0	0	9	0
Portulaca	0	2	87	0	2	0	4	0	0	0	0	0	0
Zizyphus	0	0	0	0	0	12	0	0	0	0	0	0	0
Ixora	1	0	27	0	10	0	0	0	1	0	0	0	0
Agale	0	0	0	0	0	0	0	0	0	1	0	0	0
Citrus	0	0	1	0	0	0	0	0	0	2	11	0	3
Limonia	0	0	0	0	2	0	0	0	0	0	0	0	0
Other Rutaceae	0	0	0	0	0	0	0	0	0	0	0	0	0
Sapindaceae	0	0	0	1	0	0	0	0	0	0	0	0	0
Mimusops	0	0	0	1	0	1	0	0	0	0	0	0	0
Other Sapotaceae	0	0	0	0	0	0	0	0	0	0	0	0	0
Scoparia	0	0	0	0	0	0	0	0	0	0	0	0	0
Russelia	0	0	0	19	1	0	0	0	0	0	0	0	0
Ailanthus	0	0	0	0	0	0	0	0	0	0	0	0	256
Solanaceae	0	0	0	1	0	0	1	0	0	0	1	0	0
Pentapetes	0	0	0	0	1	0	0	0	0	0	0	0	0
Umbelliferae	0	0	0	0	2	0	0	0	0	0	0	0	0
Holoptelea	0	0	0	0	0	0	0	0	0	0	0	0	1149
Other Urticaceae	0	0	0	0	0	0	0	0	0	0	0	0	2

7-Feb	6-Mar	7-Mar	6-Apr	7-Apr	6-May	7-May	6-Jun	7-Jun	6-Jul	7-Jul	Total pollen _1st year	Total pollen_2nd year
0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	1	45	0	17	2	11	13	47	8	234	120
8	72	1	32	0	0	7	1	9	0	0	171	35
0	0	0	0	0	0	0	0	0	0	0	6	0
0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	1	2	1	0	0	2	2
0	0	0	0	0	1	0	1	0	0	0	3	0
0	0	0	8	9	0	1	0	3	0	0	8	13
0	2	0	1	0	0	0	0	0	0	0	3	0
5	5	0	2	6	11	3	3	3	3	16	71	65
6	2	317	3	7	4	0	3	1	12	0	918	343
3	0	0	0	22	0	0	0	0	0	0	4	25
10	0	2	2	0	1	0	0	0	0	0	11	12
0	7	0	14	0	9	0	0	0	0	0	52	14
0	0	0	0	0	0	4	0	0	0	0	3	21
0	0	0	0	0	13	0	2	0	0	0	15	0
0	1	2	0	0	0	0	0	0	0	0	1	2
0	0	0	0	0	0	0	0	0	0	0	2	0
2	0	0	1	0	1	7	1	2	2	0	5	20
0	6	4	0	0	0	0	0	0	0	0	9	8
0	0	0	0	1	3	1	0	0	0	0	7	3
0	0	0	0	0	0	0	0	0	0	0	6	0
0	0	0	0	0	0	1	0	0	0	0	0	2
24	98	87	78	63	52	34	44	47	56	36	1404	975
6	1	8	7	1	11	0	9	9	3	4	79	72
0	4	0	0	0	0	0	0	0	0	0	4	9
0	0	0	0	0	0	0	0	0	0	0	93	2
0	0	0	0	0	0	0	0	0	0	0	0	12
0	0	0	0	0	0	0	0	0	0	0	39	0
0	0	1	0	1	0	0	0	0	0	0	0	3
0	0	0	3	0	0	1	0	0	10	0	28	3
0	0	0	0	0	0	0	0	0	0	0	2	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	1	5	12	5	15
0	1	0	0	0	1	0	0	0	0	0	2	0
0	0	0	0	0	0	1	0	0	0	0	0	1
1	0	0	0	0	0	0	0	0	0	0	1	20
0	24	4	6	11	0	0	0	0	0	0	286	15
0	0	0	0	0	0	0	0	0	0	0	2	1
0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	0	2	0
0	61	2072	0	4	6	0	1	0	0	0	1217	2076
0	0	0	0	0	0	0	0	0	0	0	2	0

File 2

Species	Total pollen _Ist year	Total pollen_IInd year	2005-06	2006-07
Ruellia	2	0	1	0
Polyalthia	41	21	5.357552	4.392317
Amaranthus/Chenopodium	121	61	6.918863	5.930737
Alternanthera	3	0	1.584963	0
Coriandrum	4	0	2	0
Nerium	11	4	3.459432	2
Vinca	2	0	1	0
Tabernemontana	1	0	0	0
Other Apocyanaceae	12	1	3.584963	0
Ageratum	107	27	6.741467	4.754888
Annual Chrysanthemum	19	0	4.247928	0
Artemisia	13	1	3.70044	0
Eclipta	1	1	0	0
Parthenium	3	0	1.584963	0
Xanthium	2	0	1	0
Other Asteraceae	2	1	1	0
Alnus	4	11	2	3.459432
Bignonia tudiana	17	0	4.087463	0
Tecoma	3	2	1.584963	1
Bombax	15	11	3.906891	3.459432
Chorisia	106	4	6.72792	2
Heliotropium indicum	1	6	0	2.584963
Brassica	5	3	2.321928	1.584963
Iberis	0	1	0	0
Other Brassicaceae	24	1	4.584963	0
Canna	31	11	4.954196	3.459432
Cannabis	358	113	8.483816	6.820179
Capparadaceae	1	0	0	0
Stellaria	7	0	2.807355	0
Dianthus	4	0	2	0
Other Caryophyllaceae	3	3	1.584963	1.584963
Casurina	1	4	0	2
Termanalia	18	1	4.169925	0
Cucurbit type	1	2	0	1
Cyperaceae	4	4	2	2
Shorea	7	0	2.807355	0
Other Dipterocarpaceae	4	0	2	0
Ephedra	6	3	2.584963	1.584963
Acalypha	3	0	1.584963	0
Croton	9	1	3.169925	0
Emblica	24	32	4.584963	5
Jatropha	1	1	0	0
Kirganalia	3	3	1.584963	1.584963
Phyllanthus	7	0	2.807355	0
Putranjiva	17	17	4.087463	4.087463
Ricinus	2	1	1	0
Other Euphorbiaceae	5	3	2.321928	1.584963
Bahunia	4	0	2	0
Cassia	41	25	5.357552	4.643856
Cassia siamea	21	0	4.392317	0
Calliandra	11	0	3.459432	0
Pongamia type	3	2	1.584963	1
Prosopis	26	0	4.70044	0
Sesbania type	3	0	1.584963	0
Tephrosia	1	0	0	0
Other Fabaceae	234	120	7.870365	6.906891

(Continued)

File 2 (*Continued*)

Species	Total pollen _Ist year	Total pollen_IInd year	2005-06	2006-07
Polyad	171	35	7.417853	5.129283
Sesamum indicum	6	0	2.584963	0
Lauraceae	1	0	0	0
Loranthaceae	1	0	0	0
Lawsonia	2	2	1	1
Hibiscus	3	0	1.584963	0
Azadirachta	8	13	3	3.70044
Other Meliaceae	3	0	1.584963	0
Monocot	71	65	6.149747	6.022368
Morus	918	343	9.84235	8.422065
Moringa	4	25	2	4.643856
Callistemon	11	12	3.459432	3.584963
Eucalyptus	52	14	5.70044	3.807355
Psidium	3	21	1.584963	4.392317
Syzygium jambosa	15	0	3.906891	0
Bougainvillea	1	2	0	1
Jasminum	2	0	1	0
Palmae	5	20	2.321928	4.321928
Pinus	9	8	3.169925	3
Argemone	7	3	2.807355	1.584963
Papaver	6	0	2.584963	0
Plumbago	0	2	0	1
Poaceae_wild	1404	975	10.45533	9.929258
Poaceae_cultivated	79	72	6.303781	6.169925
Rumex	4	9	2	3.169925
Portulaca	93	2	6.539159	1
Zizyphus	0	12	0	3.584963
Ixora	39	0	5.285402	0
Agale	0	3	0	1.584963
Citrus	28	3	4.807355	1.584963
Limonia	2	0	1	0
Other Rutaceae	0	0	0	0
Sapindaceae	0	1	0	0
Mimusops	5	15	2.321928	3.906891
Other Sapotaceae	2	0	1	0
Scoparia	0	1	0	0
Russelia	1	20	0	4.321928
Ailanthus	286	15	8.159871	3.906891
Solanaceae	2	1	1	0
Pentapetes	1	0	0	0
Umbelliferae	2	0	1	0
Holoptelea	1217	2076	10.24911	11.01959
Other Urticaceae	2	0	1	0

File 3 (Sheet 1) Principal components analysis

The PRINCOMP procedure

Observations 100

Variables 12

	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06
Simple statistics												
Mean	5.27	3.9	3.27	2.36	0.97	0.89	27.72	4.67	2.67	3.21	1.45	2.07
StD	39.8157	18.47384	16.38727	11.06228	3.379842	4.784012	147.1438	14.61772	9.922991	9.570889	5.411128	8.323333

		Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06
Correlation matrix													
Aug-05	Aug-05	1	0.8587	0.8895	0.5509	0.8224	0.9456	0.1501	0.6652	0.7889	0.6117	0.8538	0.7056
Sep-05	Sep-05	0.8587	1	0.7641	0.4876	0.7004	0.7971	0.1287	0.5676	0.6716	0.564	0.7509	0.6142
Oct-05	Oct-05	0.8895	0.7641	1	0.5425	0.8763	0.8808	0.1423	0.5776	0.8931	0.5751	0.8372	0.855
Nov-05	Nov-05	0.5509	0.4876	0.5425	1	0.7108	0.5127	0.0673	0.3541	0.4685	0.3916	0.5168	0.4349
Dec-05	Dec-05	0.8224	0.7004	0.8763	0.7108	1	0.8019	0.1664	0.5201	0.7855	0.5545	0.7939	0.7742
Jan-06	Jan-06	0.9456	0.7971	0.8808	0.5127	0.8019	1	0.1439	0.648	0.8135	0.5121	0.7788	0.7046
Feb-06	Feb-06	0.1501	0.1287	0.1423	0.0673	0.1664	0.1439	1	0.4496	0.1388	0.1426	0.1596	0.1736
Mar-06	Mar-06	0.6652	0.5676	0.5776	0.3541	0.5201	0.648	0.4496	1	0.7173	0.4838	0.5865	0.438
Apr-06	Apr-06	0.7889	0.6716	0.8931	0.4685	0.7855	0.8135	0.1388	0.7173	1	0.6001	0.7874	0.8131
May-06	May-06	0.6117	0.564	0.5751	0.3916	0.5545	0.5121	0.1426	0.4838	0.6001	1	0.8251	0.6632
Jun-06	Jun-06	0.8538	0.7509	0.8372	0.5168	0.7939	0.7788	0.1596	0.5865	0.7874	0.8251	1	0.8349
Jul-06	Jul-06	0.7056	0.6142	0.855	0.4349	0.7742	0.7046	0.1736	0.438	0.8131	0.6632	0.8349	1

	Eigenvalue	Difference	Proportion	Cumulative
Eigenvalues of the correlation matrix				
1	7.968688	6.81833	0.6641	0.6641
2	1.150358	0.395317	0.0959	0.7599
3	0.755041	0.086357	0.0629	0.8228
4	0.668684	0.147492	0.0557	0.8786
5	0.521192	0.111223	0.0434	0.922
6	0.409969	0.230955	0.0342	0.9562
7	0.179014	0.064667	0.0149	0.9711
8	0.114347	0.023295	0.0095	0.9806
9	0.091052	0.022929	0.0076	0.9882
10	0.068122	0.018523	0.0057	0.9939
11	0.049599	0.025664	0.0041	0.998
12	0.023935	0.025664	0.002	1

Eigenvectors	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12
Aug-05	0.333012	−0.03834	0.084749	−0.23034	0.150695	0.219222	−0.36698	0.077672	−0.06648	−0.11934	−0.2572	−0.72877
Sep-05	0.297279	−0.04818	0.067402	−0.23683	0.332816	0.530279	0.657927	−0.08437	0.031594	0.070078	0.079905	0.066552
Oct-05	0.333926	−0.09139	0.016864	−0.12503	−0.30877	0.011873	0.015212	−0.01253	0.186554	−0.5537	−0.52529	0.388644
Nov-05	0.221786	−0.18238	0.655899	0.54619	0.191648	−0.16917	0.103808	0.327924	0.004149	−0.07144	0.013694	−0.00751
Dec-05	0.31862	−0.11164	0.24793	0.16525	−0.24271	0.01304	−0.14318	−0.78798	−0.01764	0.309315	0.024861	0.012102
Jan-06	0.322457	−0.03487	0.135812	−0.34136	−0.02005	0.119474	−0.45013	0.348966	0.24333	0.364915	0.278758	0.388183
Feb-06	0.078672	0.846185	0.111008	0.258559	−0.23577	0.315327	−0.02505	0.044663	0.13495	−0.09772	0.104767	−0.04719
Mar-06	0.25091	0.464731	0.064673	−0.25949	0.358562	−0.53605	0.07822	−0.06285	−0.31826	0.173976	−0.26817	0.141736
Apr-06	0.319194	0.006412	−0.09704	−0.17708	−0.2098	−0.48052	0.270964	−0.01201	0.366775	−0.20984	0.486331	−0.30618
May-06	0.256289	0.001049	−0.53935	0.453672	0.429369	−0.02863	−0.11699	−0.05169	0.445368	0.11469	−0.15184	0.038695
Jun-06	0.32717	−0.0516	−0.27222	0.169756	0.098709	0.095073	−0.19275	−0.02695	−0.60113	−0.38851	0.433049	0.175729
Jul-06	0.301299	−0.07878	−0.29487	0.181318	−0.50287	−0.00154	0.259487	0.356344	−0.29412	0.438614	−0.20742	−0.1187

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File 3 (Sheet 2)

The PRINCOMP procedure

Observations	Apr-00	
Variables	Jan-00	

	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07
Simple statistics												
Mean	Jan-00	1.83	2.09	1.71	0.92	0.65	0.76	25.25	1.93	1.3	1.21	1.04
StD	Feb-00	9.388425	9.872004	14.1116	4.121096	2.240017	2.909823	209.3247	7.62274	5.236816	5.278688	4.462911

		Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07
Correlation matrix													
Aug-06	Aug-06	1	0.941	0.7949	0.9949	0.8839	0.4253	0.8115	0.0271	0.8036	0.673	0.9009	0.8187
Sep-06	Sep-06	0.941	1	0.8118	0.9506	0.8406	0.428	0.8445	0.0189	0.7623	0.6379	0.8961	0.8519
Oct-06	Oct-06	0.7949	0.8118	1	0.8067	0.8898	0.3614	0.7058	0.0249	0.6248	0.5202	0.8655	0.7489
Nov-06	Nov-06	0.9949	0.9506	0.8067	1	0.8752	0.415	0.8182	0.0285	0.8096	0.6339	0.8915	0.8132
Dec-06	Dec-06	0.8839	0.8406	0.8898	0.8752	1	0.4007	0.738	0.0102	0.7091	0.7252	0.9313	0.8218
Jan-07	Jan-07	0.4253	0.428	0.3614	0.415	0.4007	1	0.4441	−0.0124	0.315	0.3595	0.4291	0.3601
Feb-07	Feb-07	0.8115	0.8445	0.7058	0.8182	0.738	0.4441	1	0.0369	0.6919	0.6345	0.8326	0.7412
Mar-07	Mar-07	0.0271	0.0189	0.0249	0.0285	0.0102	−0.0124	0.0369	1	0.0711	−0.0024	0.0138	0.006
Apr-07	Apr-07	0.8036	0.7623	0.6248	0.8096	0.7091	0.315	0.6919	0.0711	1	0.5182	0.7035	0.6459
May-07	May-07	0.673	0.6379	0.5202	0.6339	0.7252	0.3595	0.6345	−0.0024	0.5182	1	0.7855	0.7454
Jun-07	Jun-07	0.9009	0.8961	0.8655	0.8915	0.9313	0.4291	0.8326	0.0138	0.7035	0.7855	1	0.8859
Jul-07	Jul-07	0.8187	0.8519	0.7489	0.8132	0.8218	0.3601	0.7412	0.006	0.6459	0.7454	0.8859	1

	Eigenvalue	Difference	Proportion	Cumulative
Eigenvalues of the correlation matrix				
1	8.325067	7.314289	0.6938	0.6938
2	1.010778	0.211047	0.0842	0.778
3	0.799731	0.205615	0.0666	0.8446
4	0.594116	0.154582	0.0495	0.8941
5	0.439534	0.149007	0.0366	0.9308
6	0.290527	0.075862	0.0242	0.955
7	0.214665	0.039384	0.0179	0.9729
8	0.175281	0.107442	0.0146	0.9875
9	0.067839	0.027561	0.0057	0.9931
10	0.040277	0.000977	0.0034	0.9965
11	0.0393	0.036414	0.0033	0.9998
12	0.002886	0.036414	0.0002	1

Eigenvectors	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12
Aug-06	0.333029	0.017245	−0.06069	−0.16021	0.098025	0.041381	−0.26971	−0.41752	−0.14756	0.255513	−0.21642	−0.68349
Sep-06	0.329952	0.005939	−0.04794	−0.16249	0.017728	−0.24128	−0.32387	−0.07287	0.53928	−0.42526	0.467348	−0.05987
Oct-06	0.299843	0.009006	−0.10564	−0.1374	−0.64957	0.115351	0.305384	0.150731	0.416535	0.383127	−0.08696	−0.03001
Nov-06	0.331906	0.023937	−0.07553	−0.22538	0.072335	−0.00556	−0.27238	−0.36903	−0.09513	0.253053	−0.13985	0.724215
Dec-06	0.324205	−0.01813	−0.08285	0.090752	−0.28486	0.342285	0.191527	−0.14343	−0.54577	−0.21162	0.530295	0.006304
Jan-07	0.168038	−0.12539	0.959068	−0.10532	−0.04711	0.123104	−0.05766	0.065283	−0.0048	0.005376	−0.00832	0.007498
Feb-07	0.302367	0.016154	0.071157	−0.07168	0.18946	−0.73709	0.499886	0.047647	−0.20733	0.126161	0.08617	−0.02096
Mar-07	0.009587	0.982615	0.136134	0.108435	−0.05318	−0.00638	−0.03011	−0.01438	−0.00387	−0.00709	0.006152	0.000844
Apr-07	0.278544	0.105051	−0.12048	−0.40285	0.554376	0.451289	0.255553	0.385756	0.07925	−0.04416	−0.034	−0.00902
May-07	0.263087	−0.06875	0.045558	0.755741	0.329337	0.176209	0.168614	−0.19387	0.316773	0.201149	0.070251	0.039621
Jun-07	0.335072	−0.02276	−0.04229	0.175051	−0.15087	−0.02646	0.103743	−0.00707	−0.04149	−0.6359	−0.64249	0.040219
Jul-07	0.310191	−0.02983	−0.09221	0.279214	−0.04756	−0.1252	−0.50952	0.669119	−0.23583	0.18838	−3.1E-05	−0.0076

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