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POLLEN SPECTRUM VARIATIONS IN THE ATMOSPHERE OF SANTINIKETAN, WEST BENGAL AND INFLUENCE OF METEOROLOGICAL PARAMETERS & AIR POLLUTION

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ABSTRACT

The present study deals with the survey of airborne pollen spectrum in the atmosphere of Santiniketan, West Bengal (Eastern part of India) using a Burkard personal volumetric sampler for the two-years period 2014–2015, with the aim of supplementing and extending the knowledge of the city air plankton. A total of 66 pollen taxa belonging to 37 angiosperm families and one gymnosperm have been identified, of which pollen of Grasses (Poaceae) showed a maximum frequency followed by *Cassia* sp., *Acacia* sp., Solanaceae, Asteraceae and Cyperaceae. Pollen grains of *Cycas* sp., *Lagerstroemia* sp., *Spathodea campanulata*, *Lantana camara, Eucalyptus* sp., Malvaceae, Liliaceae, *Parthenium hysterophorus*, *Carica papaya*, *Peltophorum pterocarpum*, *Areca catechu*, *Catharanthus roseus* were also predominant in the air of Santiniketan. Total pollen catch in these 2 years' survey was 1,57,400 /m^3 of air which reflects the rich pollen diversity of this famous sub-urban tourist spot of West Bengal. The place has the highest annual concentrations of pollen in April (13024/m^3in 2014 and 12160/m^3 in 2015) in both of the study years. Peak pollen season was observed twice in a year i.e. one in pre-monsoon time and other in post- moonsoon time. The studies carried out disclosed the relationship between air pollen concentration, meteorological factors an air quality data (pollutants). Yearly variations on these seasons could be related to the influence of meteorological factors such as temperature, rainfall, relative humidity and wind speed which have been proven statistically by correlation analysis. PM10 and PM 2.5 were found to be statistically significant with total pollen count, while other pollution parameters like NO_2 and SO_2 were found to be non-significant. So, we have analysed the air quality data as independent variables, with pollen counts as dependent variables for 2014 and 2015 employing a Multiple Regression Analysis (MRA) model using MiniTab 17.0 and fitted a regression equation for prediction of weekly pollen counts for future years. Employing the MRA we also have plotted Fitted line plot for two significant air pollutants PM10 and PM 2.5 separately. We also compiled a pollen calendar showing data on monthly pollen concentrations, from which a great deal of useful and important information has been obtained. Pollen calendars are useful in the prevention and diagnosis of hay fever, in that they enable the timing and severity of the pollen season to be clearly defined. This aeropalynological survey may serve as guide for allergologiests to predict and manage the source and the incidence of allergic diseases among local inhabitants.

Keywords: Pollen diversity, Santiniketan, Multiple regression analysis, Pollen calendar

In the past few years, air quality analysis in different part of country has taken on an important role in the field of environmental research and prevention. The problem of the presence of pollen grains in air that could cause allergies in immunologically predisposed persons in the air plankton of different locations of country is very important, especially when tree and/or shrub essences of a proven allergenic role are planted or wildly grows in areas dedicated to public roads, parks and gardens. The atmosphere concentration of different pollen types varies enormously from one country to another, in regions of the same country, and even among different cities, because pollen emissions depend on vegetation and environmental conditions (Banik and Chanda, 1990; Puc and Puc, 2004). Generally, meteorological factors have a direct influence on aeropalynological spectrum of a particular place (Andersen, 1974, 1980; Carin˜anos et al., 2004). Aerobiological researches are of higher significance in order to chart the behaviour of airborne allergens over the year (Boral et al., 2004; Mandal et al., 2008); the data obtained are valuable both to allergologists for planning treatments and to allergy sufferers for planning their work and recreational activities (Ballero and Maxia, 2003). Pollen calendars, defined as graphs summarising the annual dynamics of major airborne pollen types in a given location (Belmonte and Roure, 2002), are of particular interest since they provide readily accessible visual information on the various airborne pollen types occurring in the course of the year. So, one has to make pollen calendars which are useful in the prevention and diagnosis of allergic disease and to detect the timing and

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severity of the pollen season to be clearly defined (Recio et al., 1998). As India is one of the megadiverse countries with divergent geoclimatic zones showing marked fluctuation in climatic conditions, the sources and nature of pollen thus vary in different parts of the country. Due to succession of different flowering seasons throughout the year in different geographic area, it is important to document the timing, floral intensity and types of airborne pollen in different locations, especially in highly populated cities (Kasliwal et al., 1959; Chanda and Mandal, 1980; Agashe and Vinay, 1980; Tilak, 1981; Gupta et al., 1984; Gupta and Chanda, 1989; Banik and Chanda, 1990; Nayar et al., 1996; Gupta-Bhattacharya et al., 1994; Chowdhury, 1998; Boral and Bhattacharya, 1999; Chakraborty et al., 2003; Boral et al., 2004; Mandal et al., 2006; Sharma et al., 2009; Ghosal et al., 2012).

The studies carried out in Santiniketan, a semi-urban township in eastern part of India, led to a full assessment of the pollen concentrations (number of pollen grains per cubic metre of air) both from the systemic point of view and numerically, and disclosed the relationship between pollen concentrations and climatic data such as temperature, rainfall, wind, and relative humidity (Andersen, 1974 and 1980) and air quality data like NO_2, SO_2, PM2.5 and PM10 (Ghosh et al., 2010).

MATERIALS AND METHODS

Sampling site

Santiniketan is a semi-rural establishment based on Visva-Bharati, a central university established by famous poet and Nobel Laureate R.N. Tagore, on the outskirts of the Bolpur town having luxuriant vegetation. It is located at 160 km north-west of Kolkata (23.68°N 87.68°E) and has an average elevation of 56 m. As it is a lateritic zone, the summer temperature is moderately high, less humid, the maximum temperature goes up to 46^{o} C in the month of May being the hottest; monsoon season starts from June and continues up to October and the daily mean temperature during this period varies between 32-38^{o} C and the winter temperature becomes much lower.

Aerobiological Monitoring

Monitoring of airborne pollen flora was conducted with the help of “Burkard portable volumetric sampler” (suction rate = 10L/min), placed at a height of 0.5m above the ground for two consecutive years (January 2014 to December 2015) at two different places (Gurupally and Shyambati). Air sampling was done at three different time intervals: morning (09:30hr-10:30hr), afternoon (12:30hr- 13:30hr) and evening (19:30hr-20:30hr) at weekly intervals. The hourly counts were then averaged to obtain the mean concentration which in turn gave the monthly concentration. The exposed slides were mounted, scanned thoroughly, counted and converted into number of pollen per m^3 following the guidelines of The British Aerobiology Federation (1975). Possible plant sources of airborne pollen were identified by conducting monthly vegetation surveys and field collections. Both entomophilous and anemophilous plants were recorded and observed their flowering times. The identification of air borne pollen was done mainly with the help of prepared reference slides by our laboratory and also by consulting published literatures (Erdtman, 1969; Huang, 1972, Nayar, 1990, Bhattacharya et al., 2006).

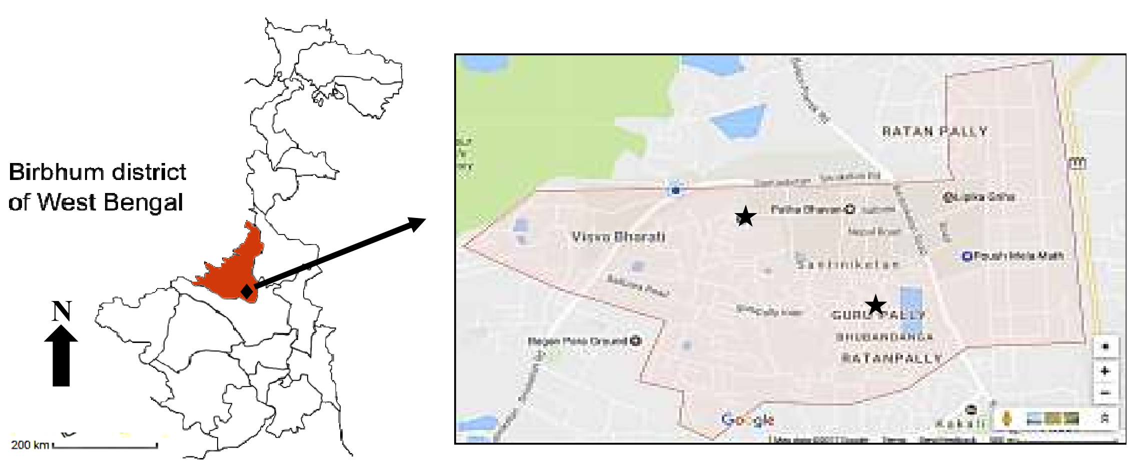

Figure 1: Experimental site: Santiniketan, Birbhum, West Bengal

Meteorological and Pollution Data

The detailed weekly meteorological data such as maximum and minimum temperature (°C), rainfall (mm), wind speed (km/h), relative humidity (%) were collected weekly for both from the Sriniketan Meteorological station, situated about 3 km away from the sampling site. The pollution data such as NO_2, SO_2, PM 2.5 and PM10 of ambient air of Santiniketan were collected from Pollution Control Board of West Bengal, Kolkata.

Statistical Analysis

The relationship between the meteorological parameters and weekly pollen concentration was calculated using the Pearson nonparametric correlation coefficient (Bricchi et al., 1992). Statistical analysis was undertaken with R studio version 3.2.2 where values of $P < 0.05$ were considered to be statistically significant.

Pearson's correlation analysis was also performed to chart the correlations between weekly pollen count with air quality data like NO_2, SO_2, PM 2.5 and PM10 separately. Besides the effects of environmental influences, the intention of our study was to verify and correlate the bio-monitoring with the air quality data. All these correlations were followed by multiple linear regression analysis for further confirmation and fit a model for predicting pollen count. This part was done using MiniTab v. 17 for Windows software package.

RESULTS AND DISCUSSION

From the aerobiological investigation, a total of 66 pollen types were identified which belonging to 37 families of angiosperms and 1 Gymnosperm from the atmosphere of Santiniketan during the entire study period though a few pollen types remained unidentified. Among them pollen grains of 33 trees, 14 herbs, 19 shrubs and one climber were recorded. For both of the year, the average pollen contribution of trees was maximum (47.72%), followed in the degree of prevalence by herbs (28.99%), shrubs (16.85%), grasses (5.83%) and climbers (<1%) (Figure 2). A comprehensive analysis of two year's data indicates that the occurrence of total pollen load may vary, but the total pollen types were the more or less same in both of the years except few of them.

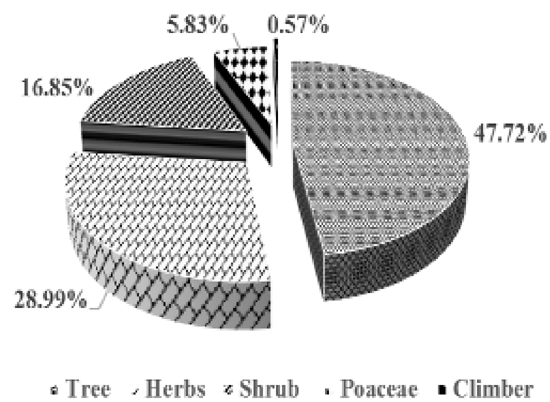

Figure 2 : Average percentage contribution of airborne pollen by five types of plants based on their habitat, in Santiniketan (2014-2015)

Altogether 1,57,400/m^3 pollen grains were trapped during the 2 years of sampling period. Of these, 1,55,608/m^3 pollen grains constituting 97.74% of the total pollen trapped were identified and assigned to 66 different pollen types. The remaining 1792/m^3 (2.26%) grains were included under unidentified category. During our observation, the maximum monthly concentration was observed in April (13024/m^3) in 2014 followed by May (10656/m^3), March (10560/m^3) and February (7840/m^3) while the highest pollen peak season was recorded in April (12160/m^3) in 2015 followed by March (11680/m^3), May (10304/m^3) and February (8416/m^3) (Figure 3). The minimum number of pollen grains were obtained during August in both the years of our study. Pollen of Poaceae were most abundant and accounted for 8.64 and 7.16 % of the total pollen load followed by *Solanum* sp. (5.41 and 5.34%) in 2014 and 2015 respectively (Table 1). The next in the order of abundance were *Cassia* sp. (4.55%), *Acacia* sp. (4.06%), Asteraceae (3.82%), the only gymnosperm *Cycas* sp. (3.05%), Cyperaceae (3.01%), *Lagerstroemia* sp. (2.64%), *Spathodea* *campanulata* (2.44%), *Eucalyptus* sp. (2.07%). The remaining types contributed less than 2.0% each (Table 1) in the 1st year of study (2014).

Table 1: Frequency (No. of pollen/m^3 of air) and percentage contribution of different pollen types observed during study period in the air of Santiniketan.

Types of pollen	Pollen loads (no./m^3) in 1st year of study (2014)	Yearly % of contribution (2014)	Pollen loads (no./m^3) in 2nd year of study (2015)	Yearly % of contribution (2015)
Acacia sp.	3200	4.06	2496	3.13
Acanthaceae	1216	1.54	1152	1.45
Ailanthus sp.	736	0.93	832	1.04
Albizia lebbeck	960	1.22	576	0.72
Alstonia scholaris	800	1.02	864	1.08
Apiaceae	1152	1.46	1152	1.45
Areca catechu	1184	1.50	896	1.12
Argemone mexicana	800	1.02	704	0.88
Asteraceae	3008	3.82	2208	2.77
Azadirachta indica	768	0.98	768	0.96
Barringtonia racemosa	608	0.77	576	0.72
Bauhinia sp.	736	0.93	800	1.00
Bombax ceiba	736	0.93	960	1.20
Borassus flabellifer	992	1.26	736	0.92
Brassica sp.	928	1.18	736	0.92
Brownea coccinea	544	0.69	672	0.84
Caesalpinia pulcherrima	1088	1.38	1088	1.37
Callistemon sp.	960	1.22	704	0.88
Carica papaya	1088	1.63	832	1.04
Cassia sp.	3584	4.55	4032	5.10
Catharanthus roseus	1152	1.46	1440	1.81
Casuarina equiseitifolia	832	1.06	896	1.12
Cheno-Amaranthaceae	1280	1.63	1344	1.69
Clerodendrum sp.	384	0.49	640	0.80
Cocos nucifera	1280	1.63	1184	1.49
Convolvulaceae	704	0.89	864	1.08
Croton bonplandianum	1312	1.32	1280	1.61
Cycas sp.	2400	3.05	2400	3.01
Cyperaceae	2368	3.01	2784	3.49
Dalbergia sisoo	704	0.89	608	0.76
Delonix regia	832	1.06	832	1.04
Eucalyptus sp.	1632	2.07	1184	1.49
Euphorbia sp.	608	0.77	576	0.72
Fabaceae	1024	1.68	1344	1.69
Gelonium multiflorum	-	-	448	0.56
Lantana camara	1664	2.11	1472	2.86
Lagerstroemia sp.	2080	2.64	2048	2.59
Lamiaceae	1184	1.50	832	1.05
Leucas sp.	416	0.53	-	-
Liliaceae	-	-	1696	2.14
Madhuca indica	832	1.06	768	0.97

Malvaceae	1472	1.87	1792	2.27
Mangifera indica	704	0.89	1088	1.38
Mimosa pudica	1056	1.34	1152	1.46
Murraya paniculata	832	1.06	1024	1.30
Nyctanthes arbor-tristis	704	0.81	640	0.81
Parthenium hysterophorus	1568	1.99	1696	2.14
Peltophorum pterocarpum	1248	1.59	1184	1.50
Phoenix sylvestris	1344	1.71	1184	1.50
Phyllanthus emblica	1056	1.34	768	0.97
Poaceae	5448	8.64	5664	7.16
Psidium guajava	1024	1.30	1152	1.46
Ricinus communis	1120	1.42	608	0.69
Shorea robusta	480	0.61	544	0.77
Solanum sp.	4256	5.41	4224	5.34
Spathodea campanulata	1920	2.44	1600	3.02
Syzygium sp.	800	1.02	608	0.77
Tabebuia sp.	256	0.33	288	0.36
Tectona grandis	512	0.65	512	0.65
Tinospora cordifolia	512	0.65	544	0.69
Trema orientalis	1056	1.34	896	1.13
Typha sp.	-	-	692	0.85
Verbenaceae	288	0.81	256	0.32
Xanthium strumarium	896	1.13	832	1.05
Zizyphus sp.	384	0.49	416	0.53
Unidentified	864	1.10	928	1.17

Unlike 1st year, in the 2nd year (2015) of study the degree of prevalence was *Cassia* sp. (5.10%), Cyperaceae (3.49%), *Acacia* (3.13%), *Cycas* sp. (3.01%), Asteracear (2.77%), *Lagerstroemia* sp. (2.59%), Malvaceae (2.27%), Liliaceae (2.14%), *Spathodea campanulata* (2.02%) and so on. A closer analysis of Table 1 shows that some of the pollen types like *Gelonium multiflorum*, Liliaceae and *Typha* sp. were found to be absent in 1st year of study (2014). Among them only Liliaceae pollen types contributed a considerable prevalence (2.14%) in 2015. For this reason, we presume that the pollen grains which found in the 2nd year could have reached the city bio atmosphere from some neighbouring places transported by the strong mistral wind. Not all the pollen grains released in the atmosphere are deposited immediately near the source of emission or in a radius of a few tens of metres from it. In fact a small percentage is transported by currents of air over very large distances (Hirst and Hurst, 1967). A further confirmation of long distance pollen diffusion is supplied by the studies by Dyakowska (1948) and Polunin (1955) who captured specific pollen grains at hundreds of kilometres from the nearest source of emission.

A comprehensive pollen calendar (considering the common pollen grains of two years) was made by compiling the two years' pollen data which showed the prevalence of different pollen grains in the atmosphere of Santiniketan (Figure 8). For Poaceae, two major seasons were obtained, first one during February – June and the second in between September – October (Fig. 8), thus coincided with the flowering period of most of the grasses which corroborate with the observation of Ghosal et al. 2015. The pollen calender describes duration and concentration of various pollen types in atmosphere. Based on the pollen calendar and aeropalynological data collected during different months of two consecutive years, two pollen seasons were recognized in Santiniketan: one from mid-February to May and other from mid-September to November (Figure 8). The first pollen season was loaded with tree and shrubs pollen, while grasses and weeds showed fairly good concentration in air in the second pollen season.

The predominant pollen types in the first season belongs to *Solanum* sp., *Acacia* sp., *Cassia* sp., Asteraceae, *Areca catechu, Spathodea campanulata,* Apiaceae, *Parthenium hysterophorus,* Fabaceae, *Borassus flabellifer, Carica papaya, Casuarina equiseitifolia, Cocos nucifera, Catharanthus roseus*, etc. The second season was loaded with pollen of Cheno-Amaranthaceae, Cyperaceae and grasses (Poaceae) [Figure 3 and 8].

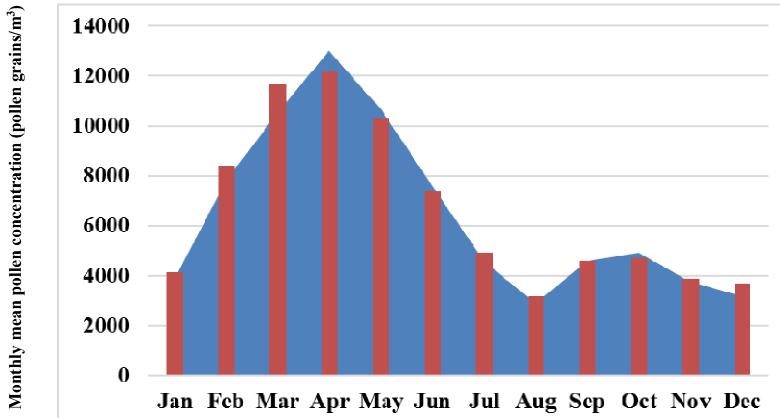

Figure 3: Seasonal variation of the monthly mean pollen concentration (pollen grains/m^3) recorded in the air of Santiniketan (2014-2015): the 1st study year (2014) are showing in bar diagram and in the 2nd study year (2015), it is showing in stacked area diagram

Statistical analysis

Meteorological factors like temperature, rainfall, relative humidity and wind speed are responsible for fluctuations in pollen concentration (Galan et al., 2000). The effects of four such most influencing meteorological factors on prevalance of pollen counts in the air of Santiniketan has been taken into account to analysis their influence on pollen dispersal. To get the correlation between total weekly pollen count and the meteorological parameters, Pearson product-moment correlation was computed and p-values were considered to judge their significance. The synchronism registered in the variations of weekly pollen concentration with maximum temperature, minimum temperature, wind and rainfall is found to be important.

Table 2: Results of correlation of meteorological factors as independent variables, with pollen counts as dependent variables for 2014 and 2015 using Pearson nonparametric correlation coefficient.

Meteorological factors	Correlation Coefficients	p value
Maximum temperature	**0.21****	**<0.001**
Minimum temperature	0.06	0.69
Relative Humidity	**-0.58****	**<0.001**
Rain fall	**-0.37***	**<0.001**
Wind speed	**0.24***	**<0.001**

Significant values in bold; Level of significance *0.05, **0.01

In the present study, flowering seasons and pollen distribution are influenced by meteorological factors where weekly total pollen count was positively skewed and kurtotic indicating a non-normal distribution. The feasibility of using weekly pollen count (PC) and weekly meteorological data from 2014-2015 as dependent and predictive variables was tested by Pearson multivariate nonparametric correlation analysis. The weekly total pollen count was correlated

Positively and significantly with maximum temperature and wind speed and negatively correlated with relative humidity and rainfall (Table 2 and Figure 4).

The statistically significant r values, for PC and maximum temperature was 0.21 and PC and wind speed was 0.24 with the given probability values p <0.001 for all the mentioned variables (Table 2) while r value for PC and minimum temperature was 0.06, which was not found to be statistically significant. However, our results showed that relative humidity (RH) and rainfall is negatively correlated with the pollen count (r value= -0.37 and -0.58 respectively) with the p value <0.001; thus less pollen grains were trapped during heavy rainfall. Thus pollen catch was low to due to wash out of pollen grains from atmosphere by rainy shower. It is evidenced that temperature is the factor that exerts the greatest influence on the release of pollen grains in the atmosphere (Vega-Maray et al., 2003). The pollen grains were found to be correlated positively with temperature, thus our finding supports the view that moderately high temperature with low relative humidity accelerates the pollen dispersal (Ghosal et al., 2015). High temperature promotes an increase in pollen concentration, while a rise in relative air humidity and rainfall cause a decrease in pollen concentration. Their effects on pollen suspension in air are shown in Figure 4. A larger data set combined with a parallel phenological study provides more insight into the effect of meteorological parameters on anthesis and the daily and seasonal pollen prevalence.

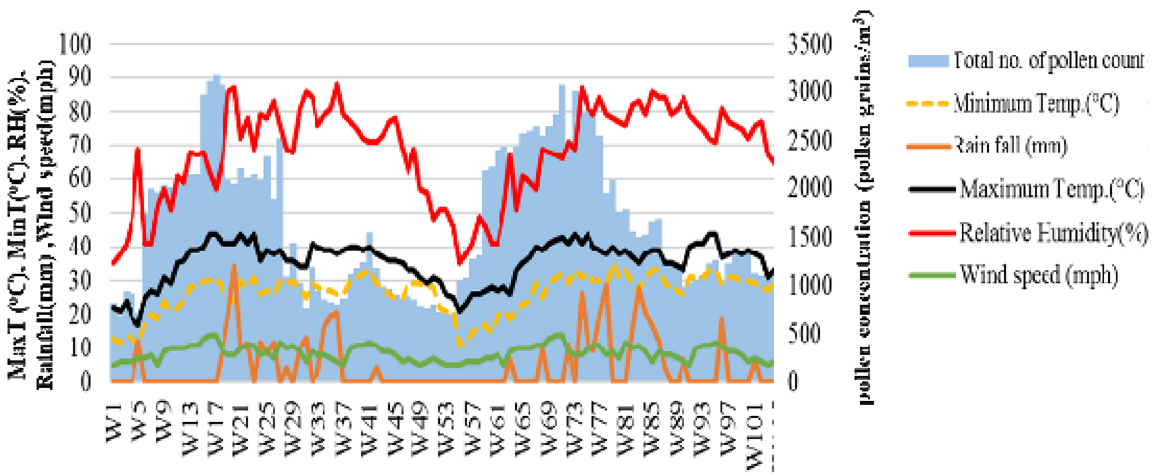

Figure 4: Average weekly (January'14 to December'15) distribution of total pollen load in the air of Santiniketan during two years, plotted with weekly maximum and minimum temperature (◦C), wind speed(m/hr), relative humidity (%) and rainfall (mm)

Pollen of anemophilous plant species outnumbered and dominated over the entomophilous type. This could be attributed to the wind currents which are the carrier of pollen from one plant to another thus wind speed was found to be significantly and positively correlated with total pollen load in atmosphere.

We have tried to interpret the correlation between the weekly total pollen count against the three major air pollutant like NO_2, SO_2, PM2.5 and PM10 (Figure 5). Both NO_2 (p-value=0.01) and SO_2 (p-value=0.09) were found to be insignificant, thereby were not correlated with total pollen count, while PM10 and PM2.5 was found to be significant and positively correlated with total pollen count having r value 0.426 and r value 0.887 with adjusted p-value<0.001(Table 3). This may be attributed to the reason that particulate matters like PM10 and PM 2.5 may adhere to the sticky surface of pollen easily, thus they are directly related with each other.

As we found that PM10 and PM 2.5 are found to be highly significant with PC in Pearson correlation coefficient, we have analysed the air quality data as independent variables, with pollen counts as dependent variables for 2014 and 2015 employing a Multiple Regression Analysis (MRA) model using MiniTab 17.0 and fitted a regression equation for prediction of weekly pollen count. Employing the MRA we also have plotted Fitted line plot for two significant air pollutants PM10 and PM 2.5 (Figure 6 and 7).

Table 3: Study on the correlation between total pollen count and three major pollutants by Pearson nonparametric correlation coefficient

	Pollen count	PM10(µg/m^3)	PM2.5(µg/m^3)	NO_2(µg/m^3)
PM10(µg/m^3)	**0.426**** **(<0.001)**			
PM2.5(µg/m^3)	**0.887**** **(<0.001)**	0.490** **(<0.001)**		
NO2(µg/m^3)	0.160 0.104	0.249 0.010	0.052 0.598	
SO2 (µg/m^3)	0.051 0.602	0.336** **(<0.001)**	0.024 0.811	0.525** **(<0.001)**

Significant values in bold; Level of significance *0.05, **0.01

Regression coefficients represent the mean change in the response variable like PM10 or PM2.5 for one unit of change in the predictor variable while holding other predictors in the model constant. This statistical control that regression provides is important because it isolates the role of one variable from all of the others in the model.

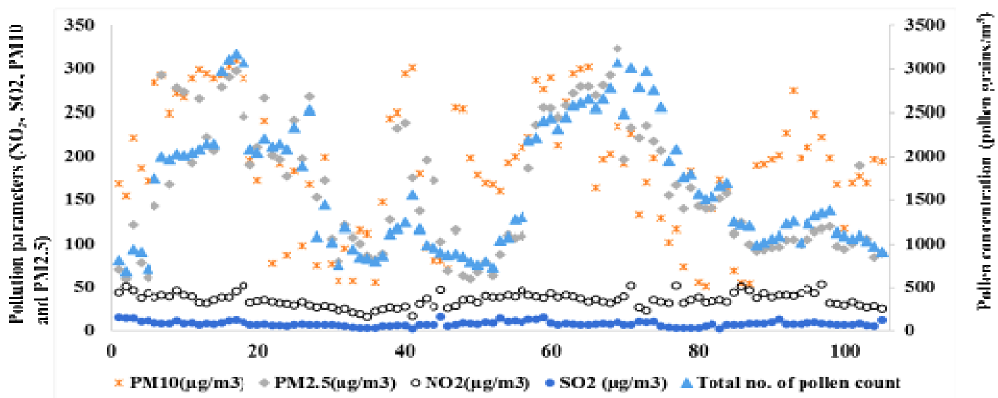

Figure 5: Scattered plot showing the correlation between total weekly pollen count with air quality data (NO_2, SO_2, $PM_{2.5}$ and PM_{10})

The attainability of using weekly PC and weekly air quality data (PM 10 and PM 2.5) from the Pollution control board from 2014–2015 as predictive and dependent was tested by multiple regression analysis. The results for the PC versus PM10 and PM2.5 were statistically significant with an adjusted R2 value of 0.750 with a given probability value p<0.00 (Table). Moreover, the t value calculated for each variable indicated that all the associated coefficients were significant in each analysis.

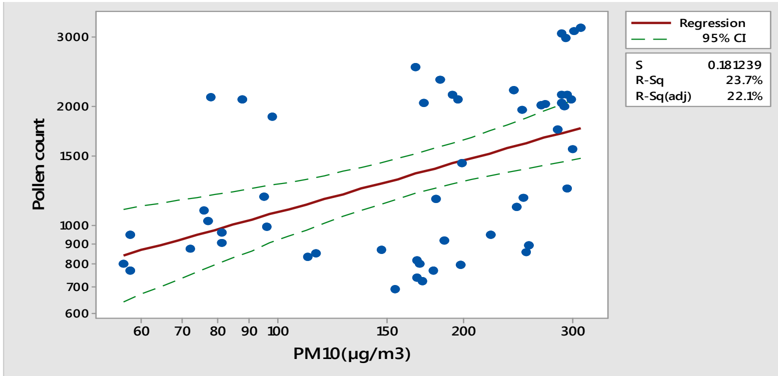

Figure 6: Fitted line plots (straight line) displaying the results from simple regression regression along with the observed values (dots), which is one predictor variable (PM^{10}) and the response (Pollen count)

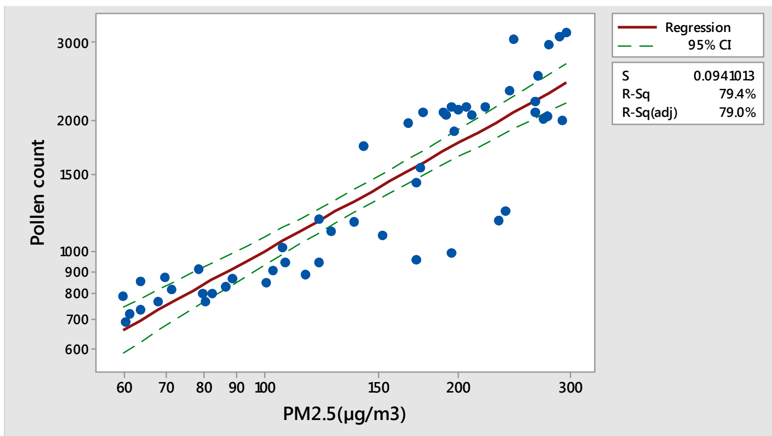

Figure 7: Fitted line plots (straight line) displaying the results from simple regression along with the observed values (dots), which is one predictor variable (PM2.5) and the response (Pollen count)

Table 5: Multiple Regression analysis with Pollen count vs PM10 and PM 2.5

Model Summary

PM10 and PM 2.5	S	R^2	R^2(adj)
2014-2015	0.91×10^{-5}	76.02%	75.05%

Coefficients

Term	Coef SE	Coef	T-Value	P-Value
Constant	92	137	0.67	0.507
PM10(µg/m^3)	0.805	0.735	1.09	0.279
PM2.5(µg/m^3)	7.758	0.796	9.75	**0.000**

We fit a regression equation using MRA for predicting the pollen count in air in the following years using PM10 and PM2.5 as predictive and dependent variable.

Regression Equation

Pollen count = 92 + 0.805 PM10(µg/m^3) + 7.758 PM2.5(µg/m^3)

Analysis of Pearson's correlation and multiple regressions showed that there was a high correlation between the PM10 and PM2.5 with pollen counts in the air which corroborate the finding of Basak et al. (2015).

Forecasting atmospheric pollen load in the future years is a topic of major importance in aerobiology. For simple forecasting models based on the weekly pollen count, and influenced pollution parameters, we developed a model employing the multivariate regression analysis to formulate a prediction equation which will forecast the pollen season and pollen count in future years. The above regression model is characterized by a corrected coefficient of determination R^2 (adjusted) of 0.750 which tells us good fit of the model (Table 4). The diffusion of pollen data and pollen forecasts should improve the prevention of allergic episodes (Chakraborty et al., 2014).

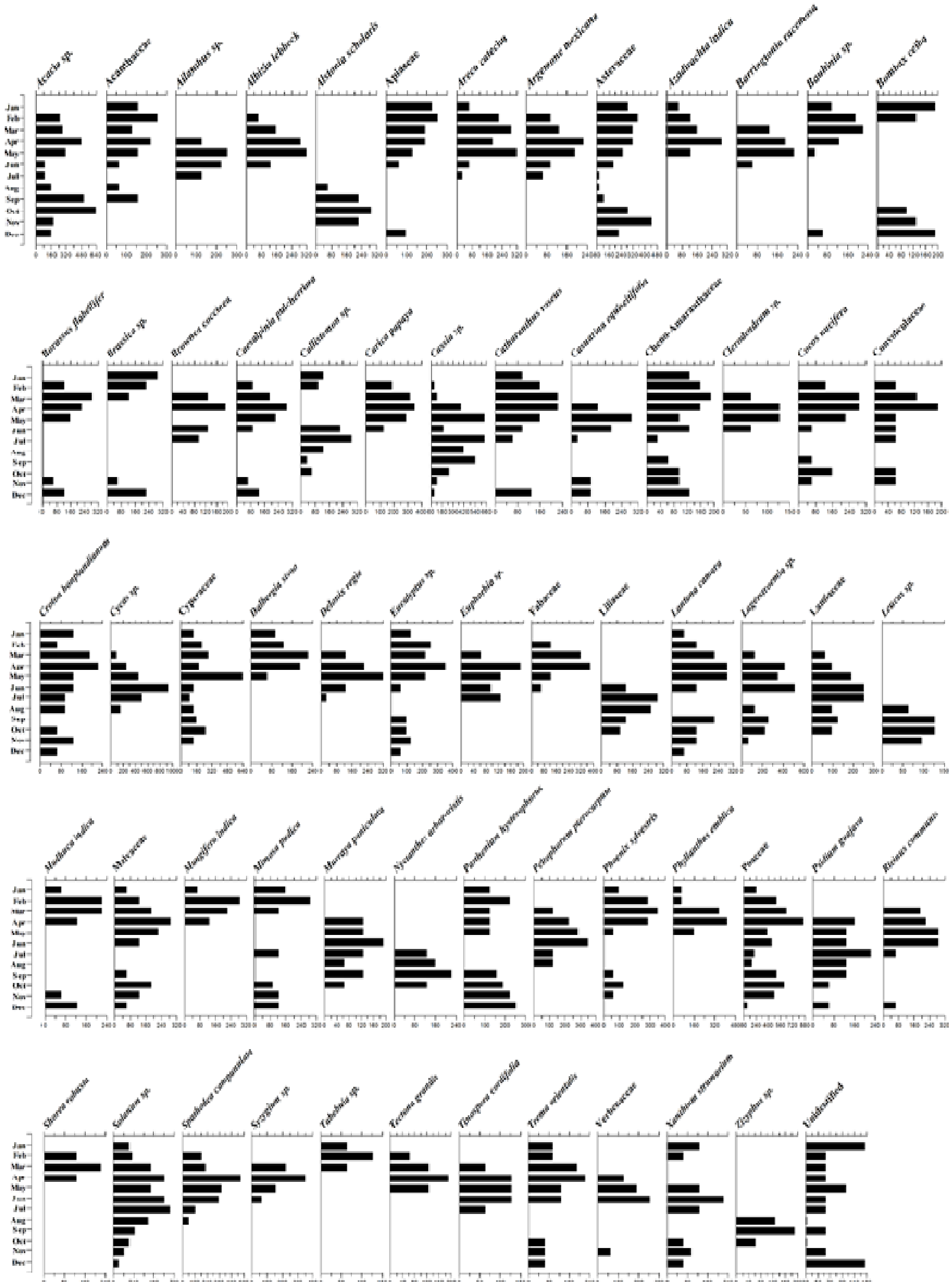

Fig 8: A comprehensive pollen calendar of Santiniketan, West Bengal 2014-2015

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