

Seasonal distribution of airborne pollen in Manila, Philippines, and the effect of meteorological factors to its daily concentrations

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Abstract Pollen-related allergic diseases are a growing health problem. Thus, information on prevalence of airborne pollen may serve as guide for clinicians to accurately manage allergic diseases. In this study, an aeropalynological survey was conducted from November 2013 to October 2014 in Manila, Philippines, to determine the seasonal distribution of the most prevalent airborne pollen and correlate the influence of meteorological factors on their daily concentrations. A volumetric pollen trap was placed on a rooftop, 21 m above ground level. A total of 5677 pollen grains from 18 pollen types were identified, of which Urticaceae, Cannabaceae, Poaceae and Moraceae were the most prevalent. Other pollen types observed that represented 1 % of the total pollen

concentration, in descending order, were *Terminalia catappa*, Myrtaceae, *Muntingia calabura*, Verbenaceae, Amaranthaceae, Cyperaceae, Caricaceae and *Mimosa* sp. Of the total airborne pollen, 87 % were obtained during the dry season (November–May). Pollen concentrations peaked (55 %) during the summer months (March–May), indicating a positive correlation ($p < 0.01$) between pollen concentration and temperature (maximum and mean). Alternatively, only 13 % of the pollen concentrations were obtained during the wet season (June–October). It was observed that pollen concentrations were negatively correlated ($p < 0.01$) with rainfall and humidity. As the pollen collection was done for one sampling year, only an approximation of the daily concentration of the pollen types was identified and correlated with meteorological factors. Further data collection is required to generate an accurate pollen calendar for use in allergy studies.

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1 Introduction

Pollen-related allergic diseases such as allergic rhinitis, asthma and urticaria are a growing health problem especially in urban cities and developing countries.

Previous aeropalynological studies in Manila showed that the most prevalent were Poaceae, *Mimosa*, Moraceae-Urticaceae, Myrtaceae and Cyperaceae (Payawal and Laserna 1966; Remo and Laserna 1976). Comparable results were also obtained in different capital cities of the Philippines (Bulalacao 1983, 1994; Cua-Lim et al. 1978), and pollen peaks were detected during November–January.

Local climate plays a vital role in plant phenology, especially on reproductive phenology. Moreover, meteorological parameters, i.e., temperature, precipitation, humidity and wind, affect atmospheric pollen dispersion and loads (Puc and Puc 2004). Climate change, which is synonymous to global warming, is brought about by natural causes and human action (Bartra et al. 2007). It has influenced changes in temperature trends and has affected pollination timing and severity. Some papers have evidenced an increase in the duration of the pollen season as well as pollen production leading to higher pollen concentration in the atmosphere (Ziello et al. 2012), hence an increased risk of allergic respiratory diseases (Beggs 2010; Clot et al. 2012; Holt and Thomas 2005). Several studies illustrate how pollinosis incidence in urban areas is higher than in rural areas due to unsuitable green space construction, urban heat island effect and traffic pollution (Jianan et al. 2007). In the tropics, knowledge is limited in terms of prevalence and abundance of clinically important atmospheric pollen. Thus, this paper aims to present a vegetation survey of Manila to determine possible sources of pollen, identify the different airborne pollen types and correlate pollen concentration with meteorological parameters.

2 Materials and methods

Manila is situated at 14.6°N and 121°E, consisting of 897 *barangays* (a basic government unit) in 14 highly urbanized municipalities. It has a total land area of 38.55 km² and a total population of 1.65 million (“The 2010 Census of Population and Housing” 2010). Figure 1, created using DIVA-GIS 7.5 (Hijmans et al. 2012), shows the pollen sampling site and cities around Manila. A seven-day recording volumetric Hirst-type spore trap (Hirst 1952) was positioned on the rooftop of the Thomas Aquinas Research Complex Building of the University of Santo Tomas in Manila, Philippines, approximately 21 m above

ground. Airborne pollen sampling was conducted from November 2013 to October 2014. The four-story building is located at the southern perimeter of the university, besides two main streets, P. Noval and Dapitan. These streets are busiest during early-morning and late-afternoon rush-hour traffic. The methods for sampling, pollen monitoring, slide preparation and pollen counting were based on the recommendations of the Spanish Aerobiology Network (Galan et al. 2007) and following the minimum requirements of the European Aeroallergen Network (EAN) (Galán et al. 2014). Pollen were identified using reference slides and published keys (Bulalacao 1983, 1997; Hesse et al. 2009; Punt et al. 2007). Data were expressed as daily average of pollen grain per cubic meter of air. Pollen types representing more than 1 % of the total pollen concentrations were analyzed in this study.

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 for their flowering phases. Pollen from the collected anthers were dissected and prepared according to the methods of Wodehouse (1935) and served as reference slides for the identification of collected airborne samples.

The country’s climate is tropical and maritime with relatively high temperature (mean annual is 26.6 °C), high humidity (varying between 71 % in March and 85 % in September) and abundant rainfall (mean annual varies from 965 to 4064 mm) (climate of the Philippines, 2015). All meteorological data in this study, which include temperature (mean, minimum and maximum), relative humidity, rainfall, wind speed and direction, were taken from Manila PAGASA (Philippine Atmospheric, Geophysical and Astronomical Services Administration) Station Port Area approximately 3.25 km from the pollen collection site.

Since data on pollen types were non-normal based on the Kolmogorov–Smirnov test, the correlation between pollen concentration and meteorological data was determined by Spearman at 95 and 99 % levels. Data analysis was performed using SPSS (v.20) software.

3 Results

A total of 5677 pollen grains from 18 pollen types were identified and counted in Manila between

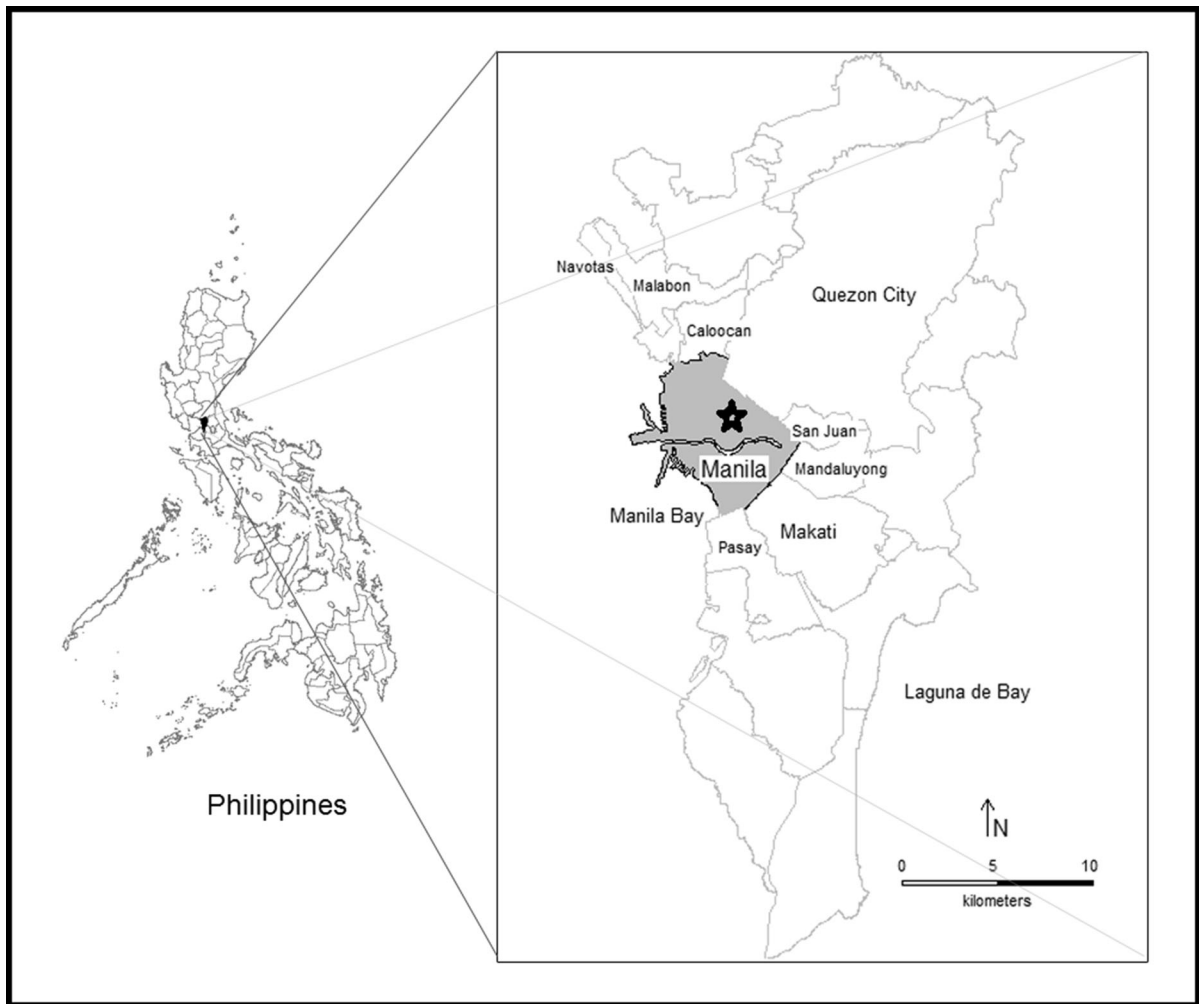


Fig. 1 The City of Manila (highlighted in gray) showing the site of the pollen trap (represented by a star) and the surrounding cities. Maps created and sampling site plotted using DIVA-GIS 7.5 (Hijmans et al. 2012)

November 2013 and October 2014 (Table 1). The three most predominant pollen types were Urticaceae, Cannabaceae and Poaceae, at 38, 16 and 10 % prevalence, respectively. All pollen types were representative of the plants found in Manila except for *Pinus* pollen probably detected by medium- or long-distance transport, 15–20 kms from Manila (Marikina and Antipolo) or 45–65 kms from Manila (Rizal and Tagaytay).

Pollen types that represented more than 1 % of the total pollen concentration are shown in Fig. 2. Of the total airborne pollen, 87 % were obtained during the dry season (November–May), wherein the highest peak-days were observed during summer (March–

May) obtaining 55 % of the total pollen concentrations. Alternatively, only 13 % of the pollen concentrations were obtained during the wet season (June–October). Pollen types that were observed sporadically and in less numbers or pollen with unclear features were designated as “not identified” and comprised 8 % of the total pollen concentration.

Surrounding the sampling site are arboreal plants, e.g., *Ptychosperma macarthurii*, *Cocos nucifera* and *Adonidia merrillii* (Arecaceae); *Albizia saman*, *Pterocarpus indicus* and *Tamarindus indicus* (Fabaceae); *Alstonia scholaris*, *Plumeria* sp., (Apocynaceae); and *Terminalia catappa* (Combretaceae). At the northwestern part of the sampling site is the university’s botanical

Table 1 Annual pollen index of 18 taxa in Manila (November 2013–October 2014)

Taxon	Pollen index	Peak (pollen m ⁻³)	Date of peak (d/m)
Urticaceae	2155	48	11/5
Cannabaceae	902	15	5/3
Poaceae	558	11	16/5
Moraceae	430	16	17/2; 5/3
<i>Terminalia catappa</i>	220	11	9/3
Myrtaceae	169	19	14/4
<i>Muntingia calabura</i>	123	10	8/5
Verbenaceae	108	27	15/4
Amaranthaceae	87	5	9/1; 31/1
Cyperaceae	79	8	18/3
Caricaceae	75	6	12/5
<i>Mimosa</i> sp.	72	4	20/11; 26/12
Arecaceae	64	3	31/10
Asteraceae	50	2	4/12
Lamiaceae	43	12	30/8
Sapotaceae	42	4	13/2
<i>Pinus</i> sp.	35	19	8/3
Fabaceae	16	2	6/4
Not identified	448	29	18/2
Total	5677	86	9/3

garden which houses a number of herbs, shrubs and trees of medicinal and ornamental importance. Grasses and weeds are also found all over the campus, along pathways and in the university's football field. Principal trees and shrubs found along avenues, roadsides, sidewalks, gardens and parks in Manila mainly belong to Fabaceae, Meliaceae, Casuarinaceae, Moraceae, Myrtaceae, Anacardiaceae, Lythraceae, Arecaceae, Acanthaceae, Annonaceae, Caricaceae, Combretaceae, Muntingiaceae, Asteraceae, Rubiaceae, Euphorbiaceae and Apocynaceae. Of the >300 plants surveyed and observed, about 22 % were anemophilous.

Anemophilous species flowering throughout the year were Urticaceae (e.g., *Pilea microphylla*, *Dendrocnide meyeniana*, *Pipturus arborens*), Cannabaceae (*Trema orientalis*), Poaceae (e.g., *Paspalum distichum*, *Panicum maximum*, *Chloris barbata*, *Axonopus compressus*, *Cynodon dactylon* and *Pennisetum purpureum*), Moraceae (e.g., *Artocarpus heterophyllus*, *A. integrifolia*), Arecaceae (e.g., *Cocos nucifera*, *Adonidia merrillii* and *Ptychosperma macarthurii*), Cyperaceae (e.g., *Rhynchospora colorata*, *Cyperus rotundus* and *C. iria*), Verbenaceae (e.g., *Lantana camara*), Amaranthaceae (e.g.,

Amaranthus sp.), Fabaceae (e.g., *Mimosa* sp.), Muntingiaceae (e.g., *Muntingia calabura*), Caricaceae (e.g., *Carica papaya*) and Combretaceae (e.g., *Terminalia catappa*). However, the pollen peak for these species was observed only during shorter periods of time (Fig. 2). Distribution of pollen from Myrtaceae corresponds to the flowering months (February–May) of *Eucalyptus tereticornis*, *Syzygium cumini*, *S. calubcob* and *S. samarangense*.

Flowering seasons and pollen distribution are influenced by meteorological factors such as temperature, humidity, rainfall and wind. All pollen types were positively skewed and kurtotic indicating a non-normal distribution. A Spearman correlation test between pollen types and meteorological factors showed significant differences at the 95 or 99 % levels (Table 2). Daily pollen concentrations of all pollen types were negatively correlated with relative humidity and rainfall. Similarly, all pollen types except Poaceae and *Terminalia catappa* were influenced by changes in temperature, but in this case with positive or negative correlation, while Urticaceae, Cannabaceae, Poaceae, Moraceae, *T. catappa*, Amaranthaceae and Arecaceae were negatively influenced by changes in wind speed.

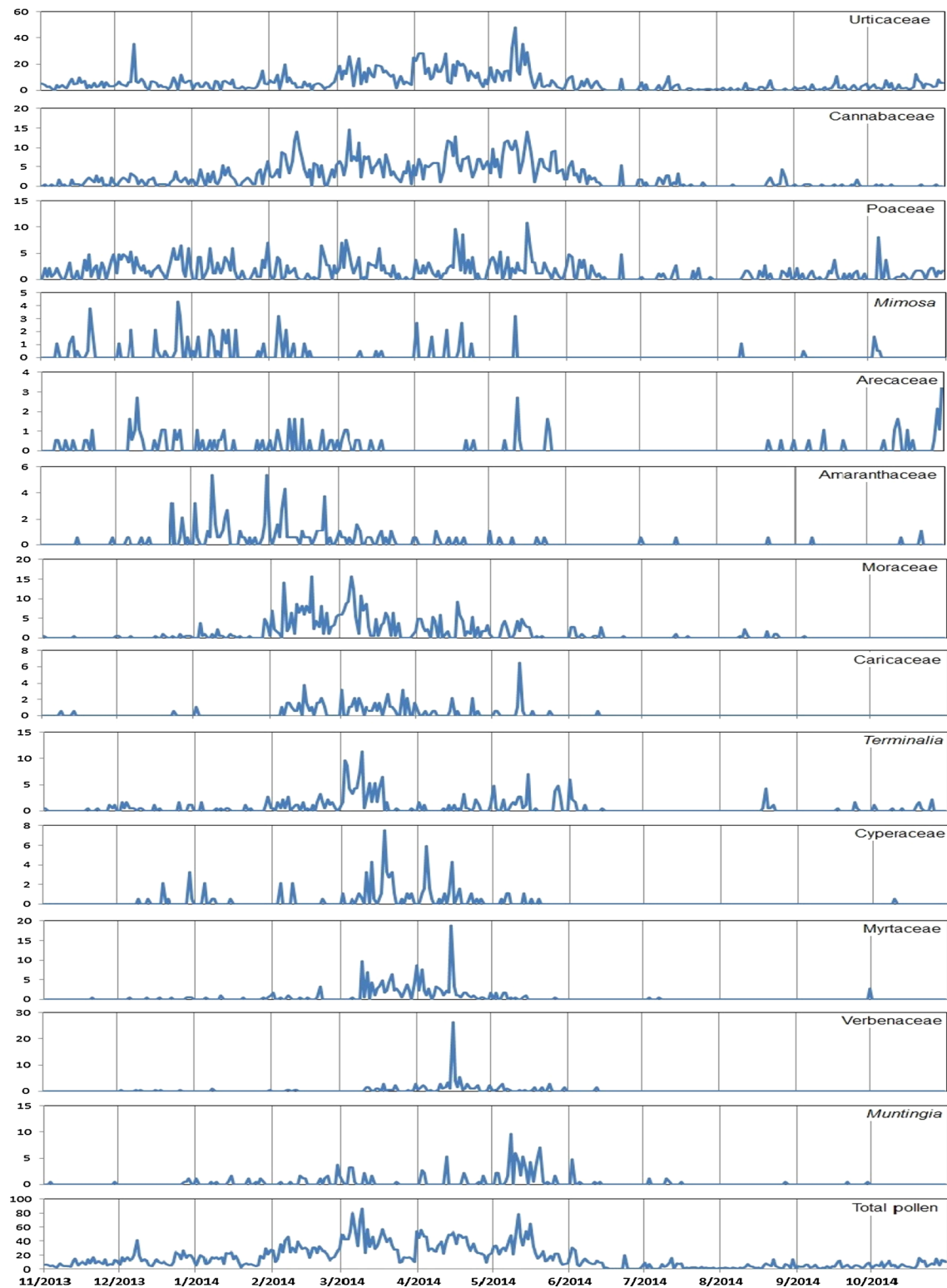


Fig. 2 Daily pollen concentration (p/m³) in Manila (November 2013–October 2014)

Table 2 Spearman's correlation between daily concentration of airborne pollen taxa in Manila and daily values of selected climatic factors

	Minimum temperature	Maximum temperature	Mean temperature	Relative humidity	Amount of rainfall	Wind speed	Wind direction
Urticaceae	0.109*	0.213**	0.233**	-0.581**	-0.379**	-0.241**	0.027
Cannabaceae	0.080	0.194**	0.216**	-0.625**	-0.401**	-0.209**	0.061
Poaceae	0.018	0.007	0.063	-0.361**	-0.346**	-0.256**	-0.003
Moraceae	-0.139**	0.003	-0.031	-0.476**	-0.376**	-0.151**	0.054
<i>Terminalia catappa</i>	-0.056	0.035	0.043	-0.356**	0.292**	-0.246**	0.084
Myrtaceae	0.091	0.223**	0.163**	-0.475**	-0.290**	-0.015	-0.066
<i>Muntingia calabura</i>	0.043	0.101	0.131*	-0.299**	-0.188**	-0.099	0.146**
Verbenaceae	0.254**	0.292**	0.337**	-0.419**	-0.213**	0.004	-0.011
Amaranthaceae	-0.362**	-0.198**	-0.238**	-0.378**	-0.269**	-0.252**	0.071
Cyperaceae	0.080	0.125*	0.146**	-0.356**	-0.259**	-0.051	0.033
Caricaceae	-0.076	0.064	0.021	-0.415**	-0.249**	-0.068	-0.022
<i>Mimosa</i> sp.	-0.131*	0.098	-0.083	-0.169**	-0.179**	-0.049	-0.032
Arecaceae	-0.138**	0.114*	-0.146**	-0.119*	-0.104	-0.243**	-0.009
Total pollen	0.005	0.155**	0.159**	-0.717**	-0.494**	-0.313**	0.050

Significant values in bold

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

4 Discussion

Previous aerobiological studies in Manila and other major cities, using a Durham sampler, showed high pollen distribution between November and January, with Poaceae pollen, as the most prevalent (Bulalacao 1983; Cua-Lim et al. 1978; Payawal and Laserna 1966; Remo and Laserna 1976). In contrast, for this study, a volumetric sampler was used and high pollen distribution was observed from February to May wherein Poaceae ranked only third to Urticaceae and Cannabaceae. Similarly, aerobiological studies made by Payawal (2004) in Los Baños, Laguna, showed high pollen distribution on the first half of the year and a decline in the number of airborne grass pollen in the latter years of sampling (1999–2001).

Metro Manila had become a highly urbanized metropolis compared to previous years and resulted to a deficiency in the green space cover (Hara et al. 2007) which at present is mostly found in parks and gardens and less in high-density residential, business and commercial land type and industrial land type (Moriwake 2000). Vacant lots and wastelands filled with wild grasses and other herbaceous weeds (e.g., *Amaranthus* and *Mimosa*) have now been replaced

by buildings and other infrastructures. In addition, human interventions such as clearing, weeding and mowing activities disrupt or shorten the reproductive phase of plants (Kasprzyk and Walanus 2010; Ong et al. 2011) which probably caused a decrease in airborne pollen concentrations.

The high incidence of airborne pollen coming from trees may be partially attributed to the active tree planting by Metro Manila residents contributing 80 % of the increase in the tree cover ratio from 10.9 % (1997) to 12.4 % (2004) (Murakami and Palijon 2009). Anemophilous arboreal and non-arboreal plants in Manila also described in other aerobiological studies that are allergenic include *Trema orientalis*, *Eucalyptus tereticornis*, *Cocos nucifera*, *Mimosa* sp., *Amaranthus* sp., *Cyperus* sp., *Cynodon dactylon*, *Saccharum spontaneum*, *Chloris barbata* and *Imperata cylindrica* (Ahlawat et al. 2013; Boral et al. 2004; Cabautan and Ramos 2012; Chakraborty et al. 1998, 2001, 2004; Cua-Lim et al. 1978; Fereidouni et al. 2009; Ghosh et al. 2012; Mandal et al. 2008). Likewise, pollen from entomophilous plants (*Mangifera indica*, *Lantana camara*, *Carica papaya*, *Peltophorum pterocarpum* and *Delonix regia*) which were also reported to be allergenic (Chakraborty et al.

1998; Ghosh et al. 2012; Mandal et al. 2008, 2009; Pumhirun et al. 1997) was observed periodically.

The Philippines has four climate types of which Manila is categorized as Type I. The dry season is experienced from November to April, while the wet season is experienced for the rest of the year. The Koppen–Geiger classification scheme categorizes the Philippines as equatorial monsoonal or “Am” (Hess and Tasa 2011). An average of 20 tropical cyclones, which form from the northwest Pacific Ocean, would visit the Philippines each year. Two prominent wind patterns regularly occur in the country: the northeast monsoon (*Amihan*), prevailed by trade winds and bringing in cool winds during the dry season, and the southwest monsoon (*Habagat*), which carries warm moist air and brings heavy rains to the western side of the country during the wet season. During the entire sampling period, it rained a total of 150 days, 66 % of which fell from June to October, and with 28 days of light and heavy rains in July. The average amount of rainfall was 165 mm, with the highest at 469 mm in September 2014, which was brought about by two typhoons and numerous monsoon rains. High relative humidity and rainfall indicated negative significant values for pollen concentration as also described in previous studies (Garcia-Mozo et al. 2007; Ho et al. 1995; Njokuocha 2006; Ong et al. 2011; Puc 2011). Wind direction was predominantly on the southwesterly side where majority of parks and gardens are located. Most of the pollen types had nonsignificant values for wind direction except for *Muntingia calabura*. In spite of its local distribution, high pollen concentrations of *M. calabura* were observed when prevailing winds are of western origin, probably due to medium- or long-range transport. As to wind speed, the average was 3 mps except during typhoons that reached an average maximum wind speed of 10 mps. The highest recorded was at 30 mps during a super typhoon, where a number of trees were uprooted and low pollen concentrations observed for several weeks thereafter.

Despite the widespread distribution of Fabaceae arboreal plants around Manila, as well as their year-round flowering season and proximity to the pollen sampler, low pollen concentrations were observed. This is probably due to more active competing pollinators (e.g., bees, butterflies and birds). In contrast, other studies showed high pollen concentrations for *Peltophorum pterocarpum* and *Delonix regia* (Banik and Chanda 1992; Mandal et al. 2008, 2009; Prakashkumar et al. 1998). Based on pollen loads and

its distinct pollen morphological characteristics, *Mimosa* sp. was not included under Fabaceae. Its pollen peak corresponded to conditions where minimum temperatures were optimal for its growth. Amaranthaceae thrive well in warm environments and produce and release less pollen due to their xerophytic nature (Cariñanos et al. 2014). Thus, low pollen concentrations may be attributed to reduced pollen production aside from periodic weeding. As this study was only made for a year, further data collection is required to draw a more accurate conclusion since flowering seasons are influenced by meteorological conditions which vary from year to year.

5 Conclusions

Aeropalynological and vegetation surveys conducted from November 2013 to October 2014 in Manila, Philippines, have determined the seasonal distribution of 18 pollen types. High pollen concentrations and peak periods were observed during the dry season, especially on the summer months between March and May, under conditions of high temperatures, low relative humidity, low amounts of rainfall and average wind speed (3 mps). Low pollen concentrations were observed during the wet season between June and October under conditions of high relative humidity and abundant rainfall.

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References

- Ahlawat, M., Dahiya, P., & Chaudhary, D. (2013). Allergenic pollen in the atmosphere of Rohtak city, Haryana (India): A pioneer study. *Aerobiologia*, 30(3), 229–238.
- Banik, S., & Chanda, S. (1992). Airborne pollen survey of Central Calcutta, India, in relation to allergy. *Grana*, 31,

- 72–75. <http://www.tandfonline.com/doi/full/10.1080/00173139209427829>. Accessed 17 May 2013
- Bartra, J., Mullol, J., del Cuvillo, A., Dávila, I., Ferrer, M., Jáuregui, I., et al. (2007). Air pollution and allergens. *Journal of Investigational Allergology and Clinical Immunology*, 17(Suppl 2), 3–8.
- Beggs, P. J. (2010). Adaptation to impacts of climate change on aeroallergens and allergic respiratory diseases. *International Journal of Environmental Research and Public Health*, 7(8), 3006–3021. doi:[10.3390/ijerph7083006](https://doi.org/10.3390/ijerph7083006).
- Boral, D., Chatterjee, S., & Bhattacharya, K. (2004). The occurrence and allergising potential of airborne pollen in West Bengal, India. *Annals of Agriculture and Environmental Medicine*, 11(1), 45–52.
- Bulalacao, L. (1983). The seasonal variation of the modern pollen rain of Metro Manila and its relationship to allergy. *Saligang Saliksik*, 12, 135–230.
- Bulalacao, L. (1994). Recognizing allergy-provoking plants in Las Pinas. *National Museum Papers*, 4(2), 78–83.
- Bulalacao, L. (1997). *Pollen flora of the Philippines*. Taguig, Metro Manila: DOST-TAPI-SPU.
- Cabauatan, C., & Ramos, J. (2012). Immunoglobulin E-binding reactivities of natural pollen grain extracts from selected grass species in the Philippines. *Asia Pacific Allergy*, 2, 136–143.
- Cariñanos, P., Alcázar, P., Galán, C., & Domínguez, E. (2014). Environmental behaviour of airborne Amaranthaceae pollen in the southern part of the Iberian Peninsula, and its role in future climate scenarios. *Science of the Total Environment*, 470–471, 480–487.
- Chakraborty, P., Gupta-Bhattacharya, S., Chakraborty, C., Lacey, J., & Chanda, S. (1998). Airborne allergenic pollen grains on a farm in West Bengal, India. *Grana*, 37, 53–57.
- Chakraborty, P., Gupta-Bhattacharya, S., Chowdhury, I., Majumdar, M. R., & Chanda, S. (2001). Differences in concentrations of allergenic pollens and spores at different heights on an agricultural farm in West Bengal, India. *Annals of Agriculture and Environmental Medicine*, 8, 123–130.
- Chakraborty, P., Gupta-Bhattacharya, S., Roy, I., & Chanda, S. (2004). Identification of shared allergenic components from four common and dominant pollen taxa of Arecaceae. *Current Science*, 86(11), 1539–1543.
- Climate of the Philippines. (2015). <http://www.pagasa.dost.gov.ph/index.php/climate-of-the-philippines>. Accessed 9 November 2013
- Clot, B., Gehrig, R., Pauling, A., & Pietragalla, B. (2012). The wind of change: Effects of climate change on airborne pollen concentrations. *Alergologia Immunologia*, 9(2–3), 139–140.
- Cua-Lim, F., Payawal, P., & Laserna, G. (1978). Studies on atmospheric pollens in the Philippines. *Annals of Allergy*, 40(2), 117–123.
- Fereidouni, M., Farid Hossini, R., Jabbari Azad, F., Ali Assarezagdegan, M., & Varasteh, A. (2009). Skin prick test reactivity to common aeroallergens among allergic rhinitis patients in Iran. *Allergologia et Immunopathologia*, 37(2), 73–79. doi:[10.1016/S0301-0546\(09\)71108-5](https://doi.org/10.1016/S0301-0546(09)71108-5).
- Galan, C., González, P. C., Teno, P. A., & Vilches, E. D. (2007). *Spanish aerobiology network (REA): Management and quality manual*. Cordoba, Spain: Servicio De Publicaciones De La Universidad De Córdoba.
- Galán, C., Smith, M., Thibaudon, M., Frenguelli, G., Oteros, J., Gehrig, R., et al. (2014). Pollen monitoring: Minimum requirements and reproducibility of analysis. *Aerobiologia*. doi:[10.1007/s10453-014-9335-5](https://doi.org/10.1007/s10453-014-9335-5).
- García-Mozo, H., Domínguez-Vilches, E., & Galan, C. (2007). Airborne allergenic pollen in natural areas: Hornachuelos Natural Park, Cordoba, southern Spain. *Annals of Agricultural and Environmental Medicine*, 14, 63–69.
- Ghosh, D., Chakraborty, P., Gupta, J., Biswas, A., Roy, I., Das, S., & Gupta-Bhattacharya, S. (2012). Associations between pollen counts, pollutants, and asthma-related hospital admissions in a high-density Indian metropolis. *The Journal of Asthma: Official Journal of the Association for the Care of Asthma*, 49(8), 792–799. doi:[10.3109/02770903.2012.716473](https://doi.org/10.3109/02770903.2012.716473).
- Hara, Y., Ogasawara, T., Palijon, A., & Takeuchi, K. (2007). Quantitative and qualitative characteristics of greenery in suburban residential districts of Metro Manila. In *Proceedings of International Symposium on City Planning*, pp. 418–427.
- Hess, D., & Tasa, D. (2011). *McKnight's physical geography: A landscape appreciation (10th edn)*. Physical geography: A landscape appreciation. Upper Saddle River, New Jersey: Pearson Education Inc.
- Hesse, M., Halbritter, H., Buchner, R., Weber, M., & Zetter, R. (2009). Pollen terminology: An illustrated handbook. Vienna: Springer-Verlag.
- Hijmans, R., Guarino, L., & Mathur, P. (2012). DIVA-GIS Version 7.5 Manual. <http://www.diva-gis.org>
- Hirst, J. (1952). An automatic volumetric spore trap. *Annals of Applied Biology*, 39(2), 257–265.
- Ho, T. M., Tan, B. H., Ismail, S., & Bujang, M. K. (1995). Seasonal prevalence of air-borne pollen and spores in Kuala Lumpur, Malaysia. *Asian Pacific journal of allergy and Immunology/Launched by the Allergy and Immunology Society of Thailand*, 13(1), 17–22.
- Holt, P. G., & Thomas, W. R. (2005). Sensitization to airborne environmental allergens: Unresolved issues. *Nature Immunology*, 6(10), 957–960. doi:[10.1038/ni1005-957](https://doi.org/10.1038/ni1005-957).
- Jianan, X., Zhiyun, O., Hua, Z., Xiaoke, W., & Hong, M. (2007). Allergenic pollen plants and their influential factors in urban areas. *Acta Ecologica Sinica*, 27(9), 3820–3827.
- Kasprzyk, I., & Walanus, A. (2010). Description of the main Poaceae pollen season using bi-Gaussian curves, and forecasting methods for the start and peak dates for this type of season in Rzeszów and Ostrowiec Sw. (SE Poland). *Journal of Environmental Monitoring*, 12(4), 906–916. doi:[10.1039/b912256g](https://doi.org/10.1039/b912256g).
- Mandal, J., Manna, P., Chakraborty, P., Roy, I., & Gupta-Bhattacharya, S. (2009). Clinical and immunobiochemical characterization of airborne Delonix regia (Gulmohar tree) pollen and cross-reactivity studies with Peltophorum pterocarpum pollen: 2 dominant avenue trees from eastern India. *Annals of Allergy Asthma Immunology*, 103, 515–524. doi:[10.1016/S1081-1206\(10\)60269-4](https://doi.org/10.1016/S1081-1206(10)60269-4).
- Mandal, J., Roy, I., Chatterjee, S., & Gupta-Bhattacharya, S. (2008). Aerobiological investigation and in vitro studies of pollen grains from 2 dominant avenue trees in Kolkata, India. *Journal of Investigational Allergology and Clinical Immunology*, 18(1), 22–30.

- Moriwake, N. (2000). Distribution and structure of urban green spaces in Metro Manila. In *Proceedings of International Symposium on City Planning*, pp. 214–223.
- Murakami, A., & Palijon, A. M. (2009). Study on the urbanization and the change of green space covered by trees in the urban fringe area of Metro Manila, the Philippines. *Landscape Research Japan*, 72(5), 693–696.
- Njokuocha, R. C. (2006). Airborne pollen grains in Nsukka, Nigeria. *Grana*, 45, 73–80. doi:[10.1080/00173130600555797](https://doi.org/10.1080/00173130600555797).
- Ong, T. C., Lim, S. H., Chen, X., Mohd Dali, S. D., Tan, H. T. W., Lee, B. W., et al. (2011). Fern spore and pollen airspora profile of Singapore. *Aerobiologia*, 28(2), 135–151. doi:[10.1007/s10453-011-9217-z](https://doi.org/10.1007/s10453-011-9217-z).
- Payawal, P. (2004). Atmospheric pollen pollution in the Philippines and its implication on the incidence of inhalant allergy. In 7. *Asian Apicultural Association Conference and 10. BEENET Symposium and Technofora* (pp. 43–48). UPLB College, Laguna (Philippines).
- Payawal, P., & Laserna, G. (1966). Aeropalynological studies in Manila, 1963. *The Philippine Journal of Science* 1, 95, 171–187.
- Prakashkumar, R., Mathew, P., & Ravindran, P. (1998). Studies on the allergenicity of nine tropical pollen allergens. *Grana*, 37(1998), 185–188.
- Puc, M. (2011). Threat of allergenic airborne grass pollen in Szczecin, NW Poland: The dynamics of pollen seasons, effect of meteorological variables and air pollution. *Aerobiologia*, 27(3), 191–202. doi:[10.1007/s10453-010-9188-5](https://doi.org/10.1007/s10453-010-9188-5).
- Puc, M., & Puc, M. (2004). Allergenic airborne grass pollen in Szczecin, Poland. *Annals of Agricultural and Environmental Medicine*, 11, 237–244.
- Pumhirun, P., Towiwat, P., & Mahakit, P. (1997). Aeroallergen sensitivity of Thai patients with allergic rhinitis. *Asian Pacific Journal of Allergy and Immunology/Launched by the Allergy and Immunology Society of Thailand*, 15(4), 183–185.
- Punt, W., Hoen, P. P., Blackmore, S., Nilsson, S., & Le Thomas, A. (2007). Glossary of pollen and spore terminology. *Review of Palaeobotany and Palynology*, 143(1–2), 1–81. doi:[10.1016/j.revpalbo.2006.06.008](https://doi.org/10.1016/j.revpalbo.2006.06.008).
- Remo, I., & Laserna, G. (1976). Aeropalynological studies in the Manila area, 1970. *The Philippine Journal of Science*, 101, 106–114.
- The 2010 Census of Population and Housing Reveals the Philippine Population at 92.34 Million. (2012). National Statistics Office (NSO). <http://web0.psa.gov.ph/content/2010-census-population-and-housing-reveals-philippine-population-9234-million>. Accessed 3 February 2015
- Wodehouse, R. (1935). Pollen grains. Their structure, identification and significance in science and medicine. New York and London: McGraw-Hill Companies, Inc.
- Ziello, C., Sparks, T. H., Estrella, N., Belmonte, J., Bergmann, K. C., Bucher, E., et al. (2012). Changes to airborne pollen counts across europe. *PLoS One*, 7(4), e34076. doi:[10.1371/journal.pone.0034076](https://doi.org/10.1371/journal.pone.0034076).