

Pollen diversity in the atmosphere of Havana, Cuba

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Abstract With a view to obtaining fuller information on airborne pollen content in the city of Havana, pollen sampling was carried out using a volumetric capture method, for the first time in Cuba. The study was conducted during 2 years (2011 and 2015). An annual pollen integral of 3414 grains was registered during the first year of study, whereas 5120 grains were observed along the 2015. Monthly maximum concentrations were recorded during April, June and July with total values close to 800 pollen grains. Of the 45 pollen types identified, *Cecropia* (38% of the total pollen identified in both years), *Poaceae* (18%), *Urera* type (9%) and *Casuarina* (6%) were particularly abundant. Although the main pollen types differed in terms of intradiurnal distribution, the highest concentrations were in all cases recorded between 0900 and 1300 hours. Maximum temperature was the variable most influencing airborne pollen counts in the air, with the exception of *Casuarina*. This paper sought to

establish a methodological basis for the further development of aerobiological research in Cuba, thus helping to enhance the prevention and diagnosis of pollen allergies in the affected island population.

Keywords Pollen · Atmosphere · Allergy · Biodiversity · Havana · Cuba

1 Introduction

Over recent decades, aerobiological research has proved to be a valuable tool for the diagnosis and prevention of allergic diseases. Nowadays, the pollinosis symptomatology constitutes an important worldwide public health problem (Subiza 2004; Mösges and Klimek 2006; Nitiu 2009; Perdomo-Ponce 2009; Terán et al. 2009; García 2010; Rodríguez et al. 2010; Cebrino et al. 2017). Estimates suggest that between 10 and 25% of the world's population currently suffer from pollen allergies, and future projections point to an upward trend (Olabuenaga et al. 2007).

A correlation has been demonstrated between bioaerosol qualitative and quantitative characteristics and the incidence of pollen-related allergic disorders (López et al. 2003; Reha and Ebru 2007; Rodríguez et al. 2010). The incidence is greater in genetically predisposed individuals and involves more than 12

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different genes (Sattar et al. 2003). Harley et al. (2009) reported about the effect of pollen on the children allergic diseases incidence and noted that those kids born during the high season of pollen are three times more predisposed to develop wheezing, which is often an early sign of asthma.

In industrialized countries, the increased incidence of pollen allergy has been linked to high levels of environmental pollution, which prompt greater irritation of the respiratory tract as well as increased expression of pollen allergenic proteins (Ring et al. 2004).

A number of studies have explicitly demonstrated temporal associations between airborne allergenic pollen counts and the incidence of hay fever and asthma (Singh and Kumar 2002; D'Amato 2011). Some authors have suggested that the trend toward increasing airborne pollen counts aggravates and exacerbates respiratory diseases (Singh and Kumar 2002; D'Amato 2011). One factor thought to account in part for higher pollen counts is the increase in atmospheric carbon dioxide levels, which cause plants to make a greater reproductive effort: for example, *Ambrosia*, recognized worldwide as a potent allergen, produces up to 90% more pollen in the presence of high CO₂ levels (Ziska et al. 2003; Rogers et al. 2006).

Furthermore, changes in the distribution of certain plants, as consequence of global warming, exert an impact for the increase in the pollen content in the bioaerosol (Ziska et al. 2003; Gilmour et al. 2006; Bartra et al. 2007).

Aerobiological research has hitherto focused primarily on temperate areas, in which pollen allergies are most widely reported, diagnosed and described (Oliveira et al. 2009). In tropical countries, by contrast, there is a dearth of information regarding the quantitative and qualitative characteristics of bioaerosols (and particularly pollen grains); given the size of the population living in these latitudes, such information would be of considerable value (Alzate Guarín et al. 2015). The paucity of data may to some extent reflect the traditional idea that since insect-pollinated species are more abundant in tropical areas, airborne pollen levels tend to be low and have scarcely any impact on allergic respiratory diseases (Lewis 1986). However, research has shown that wind pollination is a major strategy for most plants in humid tropical forests (Sakai 2001).

In Cuba, Cadrecha (1946) conducted the first investigations focuses about pollinosis. In recent times, González et al. (2009) pointed out that pollen allergy in this island does not present a seasonal pattern. A number of authors have expressed concern regarding the problems caused by airborne biological particles, which exacerbate allergic processes such as rhinitis, conjunctivitis and bronchial asthma in the Cuban population (Carmona 2009).

Most of the research carried out to date in Cuba has addressed aspects of environmental mycology: methodological studies (Aira et al. 2002), characterization of indoor and outdoor aeromycota (Rojas and Aira 2012; Rojas et al. 2007; Almaguer et al. 2013)

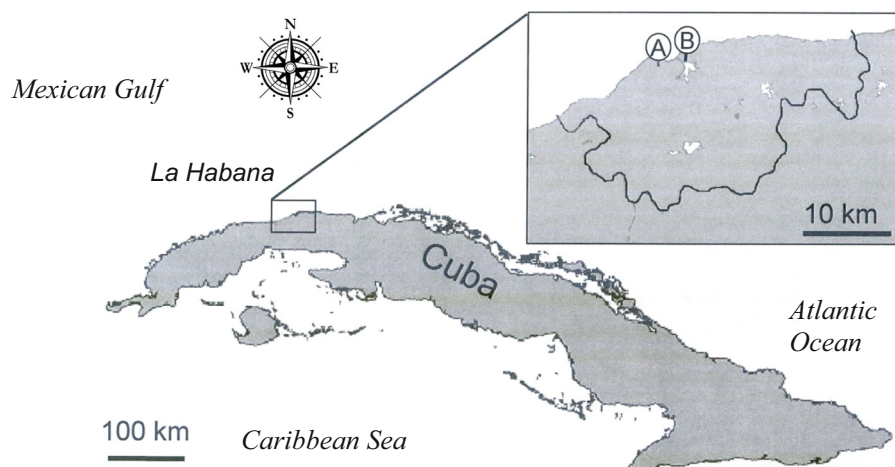


Fig. 1 Location of Havana city. A: Faculty of Biology (23°08'N and 82°23'W). B: Meteorological station of Casablanca, Cuban Institute of Meteorology, INSMET (23°08'N and 82°20'W)

Table 1 Annual pollen integral for each year of study

Family	Genera/species	Year 2011	Year 2015
Amaranthaceae	<i>Alternanthera</i> (2)	6	17
	<i>Amaranthus</i> type (3)	52	54
Anacardiaceae		0	2
Apiaceae		0	3
Arecaceae	<i>Cocos</i> (11)	3	53
	<i>Roystonea</i> (27)	13	64
Other Arecaceae		68	0
Asteraceae	<i>Ambrosia</i> (4)	0	9
	<i>Artemisia</i>	0	8
	<i>Helianthus</i> (5)	8	67
	<i>Parthenium</i>	0	10
Other Asteraceae		102	9
Brassicaceae		0	5
Burseraceae	<i>Bursera</i> (6)	40	108
Casuarinaceae	<i>Casuarina</i> (22)	201	310
Combretaceae	<i>Bucida</i> (7)	8	58
Caesalpiniaceae (8)		284	50
Commelinaceae (10)		4	7
Cupressaceae (12)		30	99
Cyperaceae (13)		2	32
Erythroxylaceae	<i>Erythroxylum</i> (15)	25	19
Fabaceae	<i>Acacia</i> (1)	0	5
	<i>Delonix</i> (14)	0	1
	<i>Mimosa peltata</i> (18)	9	13
	<i>Mimosa pudica</i> (17)	8	50
Other Fabaceae		8	52
Fagaceae	<i>Quercus</i> (25)	0	23
Labiatae		0	1
Moraceae	<i>Maclura</i> (20)	0	5
Other Moraceae		14	0
Meliaceae	<i>Melia</i> (16)	63	2
Myrtaceae (19)		40	41
Oleaceae (21)		0	4
Orobanchaceae	<i>Orobanche</i>	0	1
Pinaceae	<i>Pinus</i> (23)	10	26
Plantaginaceae	<i>Plantago</i>	0	8
Poaceae (24)		903	611
Polygonaceae	<i>Rumex</i>	0	3
Other Polygonaceae		1	1
Rosaceae		5	224
Rutaceae	<i>Citrus</i>	0	9
Salicaceae	<i>Salix</i>	0	2
Ulmaceae		13	6

Table 1 continued

Family	Genera/species	Year 2011	Year 2015
Urticaceae	<i>Urera</i> tipo (28)	36	762
	<i>Cecropia</i> (9)	1135	2095
Not identified		323	191
Total		3414	5120

The number in parentheses corresponds to Fig. 2 photographs

and studies in rural environments where agricultural crops predominate (Almaguer et al. 2012). By contrast, there has been little research into airborne pollen behavior; moreover, the few published studies used gravimetric methods, thereby obtaining purely qualitative data (Moncada and Machado 1989; Machado and Sotolongo 2000; González et al. 2009).

This paper reports on the results of airborne pollen sampling carried out for the first time in Cuba using a volumetric method. The study sought to characterize and quantify the major airborne pollen types in the city of Havana, analyze their seasonal and intradiurnal distribution, determine potential correlations with weather-related variables and evaluate their potential to trigger allergies.

At the same time, the study sought to establish a methodological basis for the further development of aerobiological research in Cuba, thus helping to enhance the prevention and diagnosis of pollen allergies in the affected population. The findings may also be useful when selecting forest species on the island or determining the most suitable species for urban green areas, in order to exclude those species with a proven allergic character, or at least to minimize their impact (Alzate Guarín et al. 2015; Cariñanos et al. 2017).

2 Materials and methods

2.1 Study area

The study was carried out during 2 years (2011 and 2015) in the city of Havana, located in the Northern coast of the Cuba. The island has an extension of 728 km² and more than 2 million inhabitants (Fig. 1). The Cuban climate is defined as subtropical humid, with a dry season (November to April) and a rainy

season (May to October). According to the climatic data recorded at the Meteorological Station of Casablanca, and supplied by the Institute of Meteorology (Insmet), during the year 2015 the average maximum temperature was higher than in 2011 (30.7 vs. 29.5 °C) as well as the humidity values (78.4 vs. 74.0%) and total precipitation (1127 vs. 999 mm).

2.2 Sampling methodology

Airborne pollen sampling was performed by using a Lanzoni VPPS 2000 device (Lanzoni srl, Bologna, Italy), located on the roof of the Biology Faculty (23°08'N and 82°23'W), 35 m above the ground level. Close to the sampler location area there is no dense vegetation, but the gardens abound with a wide variety of trees, shrubs and ornamental plants which forms part of the city design (Castillo and Pastrana 2015).

The identification of the pollen types has been based on the own experience (Jato et al. 2001; Aira et al. 2005) and specialized literature (Moncada and Salas 1983; Hurtado and Riegler-Goihman 1986; Moncada and Sotolongo 1994; Machado 1995a, b, 2003; Machado et al. 2002; Molina and Fernández 2002; Molina et al. 2007; Alzate Guarín et al. 2015). For the identification of the pollen grains of *Cecropia* and *Urera*, the study of Silva Corrêa et al. (2016) was preferentially followed.

In addition, reference slides of the Cuban flora belonging to our research group data base have been considered. The pollen photographs, included in this study, were obtained with a Nikon camera (Coolpix MDC lens) assembled to a Nikon Eclipse Ci microscope, using a dry 60× lens.

The methodology proposed by Galán et al. (2007) was applied for the pollen counts, expressing the results as grains of pollen/m³ of air. In order to calculate the atmospheric pollen season, the Nilsson and Persson (1981) method was considered. To determine the relationship between the meteorological parameters and the airborne pollen concentration, the Spearman correlation test was applied using SPSS 18 version 18.0.0 (2009). The meteorological variables evaluated were maximum, minimum and average temperature (°C), relative humidity (%) and precipitation (mm).

Recommended terminology for aerobiological studies was used in this article (Galán et al. 2017).

Fig. 2 Main pollen types identified (1) *Acacia*, (2) *Alternanthera*, (3) *Amaranthus* type, (4, 5) *Asteraceae*, (6) *Bursera*, (7) *Bucida*, (8) *Caesalpinaceae*, (9) *Cecropia*, (10) *Commelinaceae*, (11) *Cocos*, (12) *Cupressus*, (13) *Cyperaceae*, (14) *Delonix*, (15) *Erythroxylaceae*, (16) *Meliaceae*, (17) *Mimosa pudica*, (18) *Mimosa pellita*, (19) *Myrtaceae*, (20) *Moraceae*, (21) *Oleaceae*, (22) *Casuarina*, (23) *Pinus*, (24) *Poaceae*, (25) *Quercus*, (26) *Rosaceae*, (27) *Roystonea*, (28) *Urera* type

3 Results

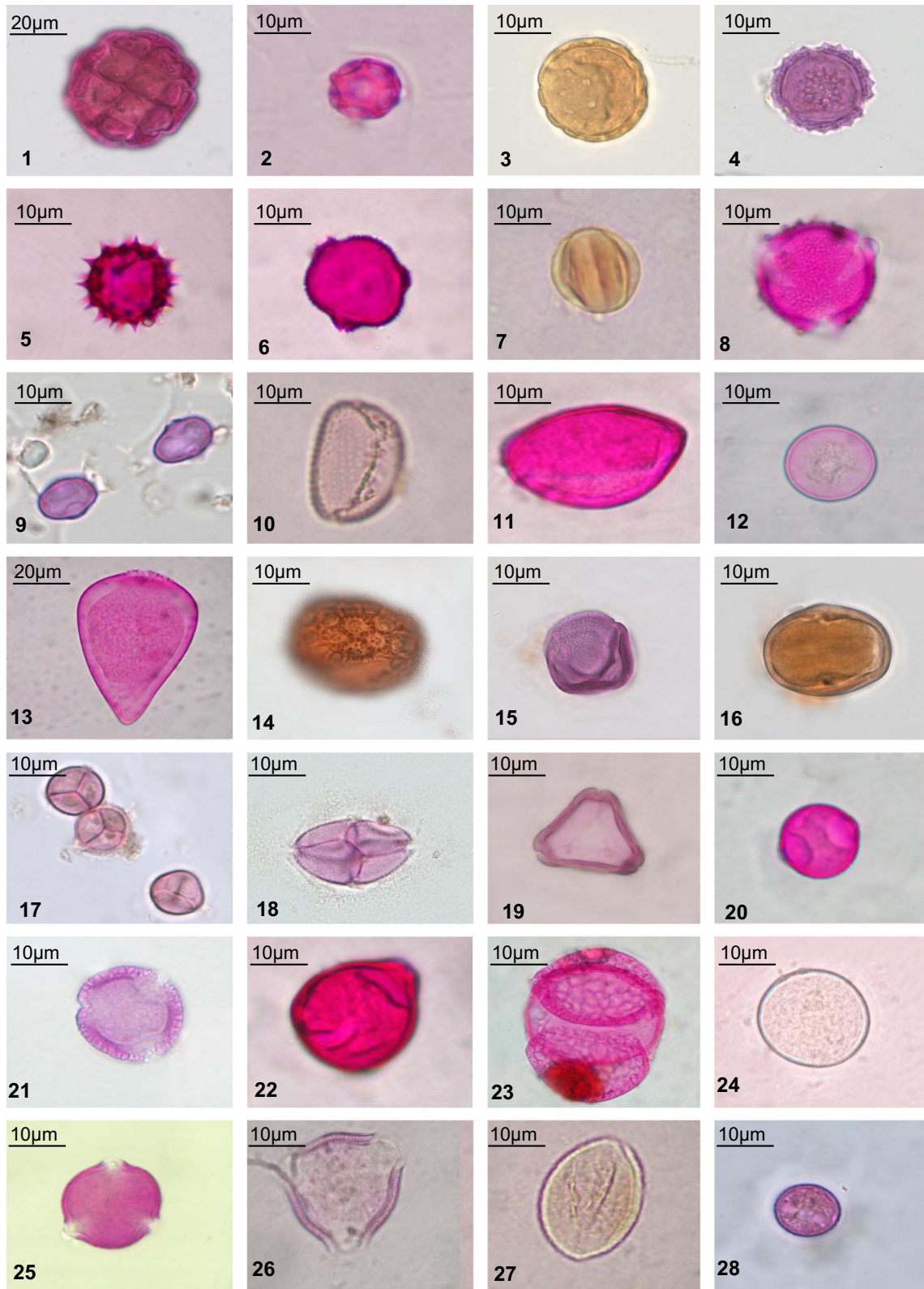
3.1 Incidence of atmospheric pollen

The total number of airborne pollen grains recorded in Havana over the two sampling years was 8534; of this total, 40% (3414 grains) were recorded in 2011 and 60% (5120 grains) in 2015 (Table 1). Biodiversity was greater in 2015 than in 2011. Although certain pollen types displayed similar values in both study years (*Amaranthus* type, *Erythroxylum*, *Mimosa pellita*, *Myrtaceae* among others), most exhibited year-on-year differences in concentrations (mainly *Bursera*, *Bucida*, *Mimosa pudica*, *Pinus*, *Rosaceae* and *Urticaceae* increased in the year 2015). Of the 45 pollen types identified in both study years, *Urticaceae* (mainly *Cecropia* and *Urera* type), *Poaceae* and *Casuarina* were particularly abundant.

The pollen types most representative of local flora, together with others commonly found in other latitudes, are shown in Fig. 2. *Cecropia* pollen is small in size (5 × 10 µm) and has 2 prominent pores. The *Urera* type pollen present a size of 13 µm is spheroidal and with 3 (4) pores. Grass pollens (monoporate) and *Casuarina* (triporate) have been more widely studied worldwide, owing to their extensive distribution.

Pollen was recorded in the air throughout the two study years. Sampling was interrupted for only four days (late July 2011), due to an electrical failure in the sampler. In 2011, total airborne pollen counts reached a maximum monthly total pollen in April (801 grains), with a secondary peak in July (463 grains). In the year 2015, the monthly maximum values were registered in June and July, with a total of 935 and 808 pollen grains, respectively (Fig. 3).

More detailed analysis of the most abundant pollen types (*Cecropia*, *Poaceae*, *Urera* and *Casuarina*) was performed in order to determine their seasonal and intradiurnal distribution as well as the influence of weather-related variables. In Table 2, the percentage



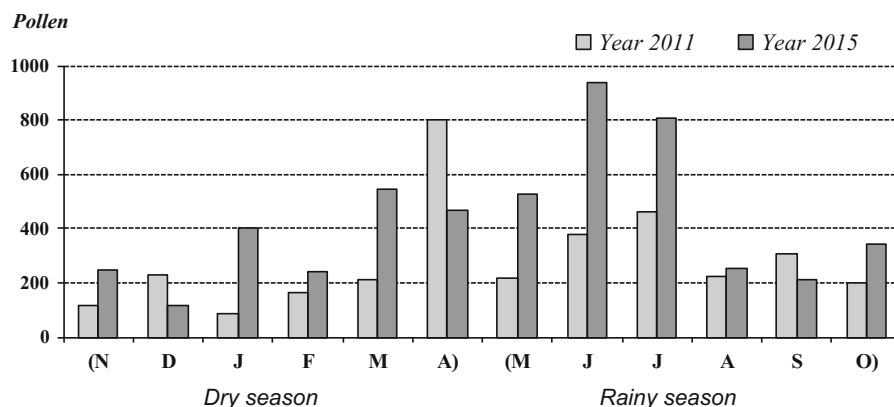


Fig. 3 Monthly total distribution of the pollen concentration in the atmosphere of Havana during 2011 and 2015

Table 2 Incidence of the four major pollen types in the atmosphere of Havana

	%	Mean	Days > average	Daily maximum	Date maximum	MPS start	MPS end
Year 2011							
<i>Cecropia</i>	33.2	4.0	85	97	4-Dec	16-Mar	5-Dec
Poaceae	26.4	2.8	92	32	12-Jul	12-Feb	1-Dec
<i>Urera</i> type	1.1	1.1	13	7	9-Jul	8-Apr	11-Jul
<i>Casuarina</i>	5.9	.6	85	43	7-Apr	4-Feb	28-Nov
Year 2015							
<i>Cecropia</i>	40.9	7.7	115	63	15-Jul	27-Feb	29-Oct
Poaceae	11.9	2.0	132	14	26-Oct	4-Feb	1-Dec
<i>Urera</i> type	14.9	14.8	64	32	15-Jun	14-Feb	19-Oct
<i>Casuarina</i>	6.1	1.0	122	45	9-Mar	15-Jan	12-Nov

% = percentage over the total annual pollen–pollen; mean = average annual daily pollen concentration (pollen/m³); days > average = number of days with concentration above the average annual daily pollen concentration; daily maximum: daily maximum pollen concentration of the year (pollen/m³); date maximum = date of the daily maximum pollen concentration of the year; MPS start: start date of the main pollen season; MPS end: end date of the main pollen season)

representation of the four main pollen types with respect to the total pollen integral identified each year of study was showed. *Cecropia* represented between 33.2 and 40.9% of the total pollen identified in both years, Poaceae between 26.4 and 11.9%, *Urera* type between 1.1 and 14.9% and *Casuarina* values close to 6% independently of the year of study.

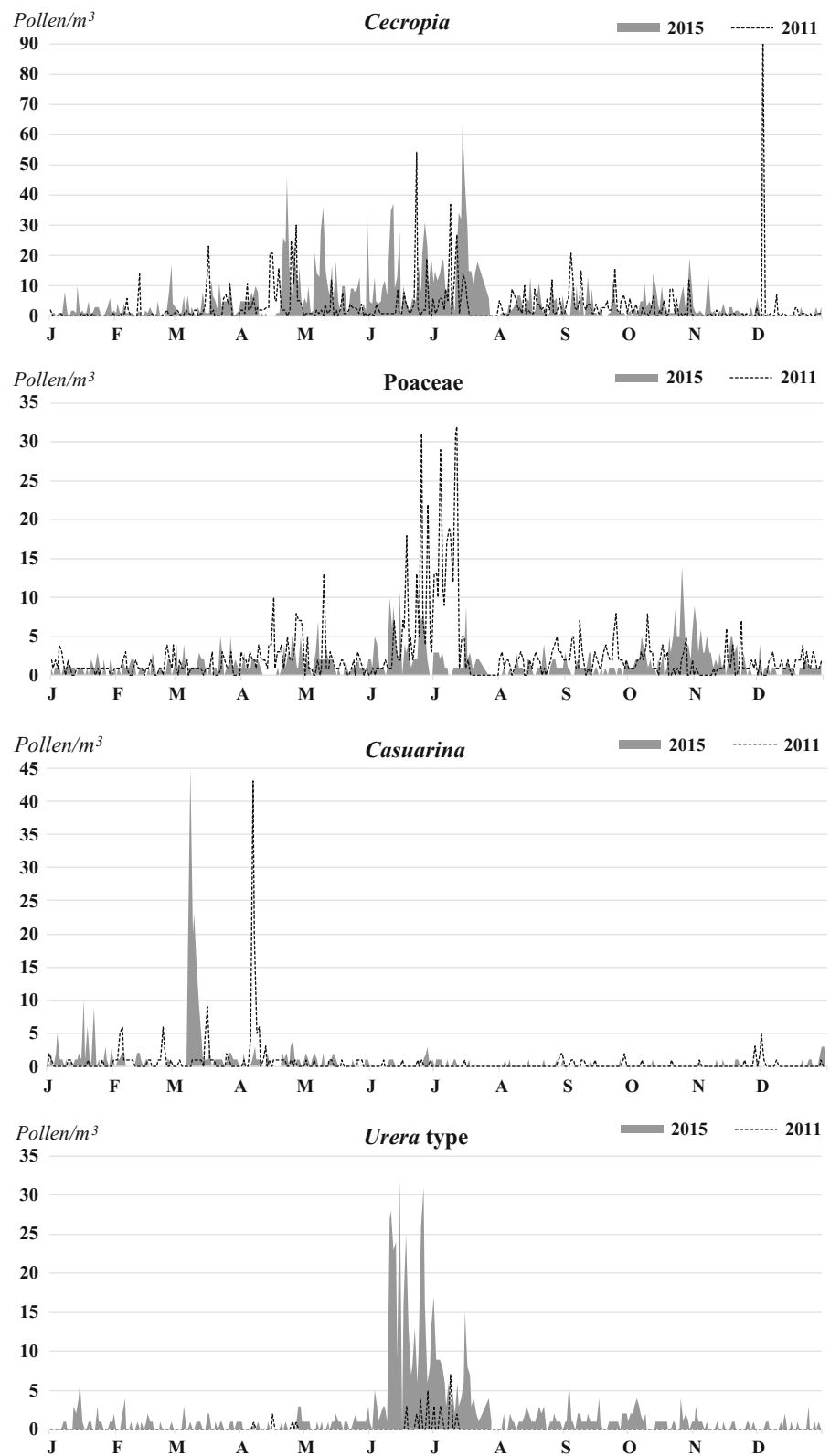
The predominance of *Cecropia*, *Casuarina* and Poaceae (Fig. 4 and Table 2), was evident in their maximum daily pollen counts (97 and 63 pollen grains/m³ for *Cecropia*, and 32 and 14 pollen grains/m³ for grasses, respectively, in each study year). The maximum daily pollen of *Urera* was registered in 2015 (32 pollen/m³). The timing of airborne *Cecropia*

and Poaceae pollens did not coincide in either year. Maximum daily values were registered in July, October or December depending on the year. Maximum daily values were recorded in March–April for *Casuarina*, and in June or July for *Urera*.

The main pollen season registered for principal pollen types was long during the studied years. The number of days ranged between 294 and 302 for *Casuarina*, 289 and 301 for Poaceae or 261 and 243 for *Cecropia* (during 2011 and 2015, respectively). For the *Urera* type lasted 247 days only during the year 2015.

Although the main pollen types differed in terms of intradiurnal distribution (Fig. 5), the highest

Fig. 4 Seasonal distribution of the mean daily pollen concentration of the main



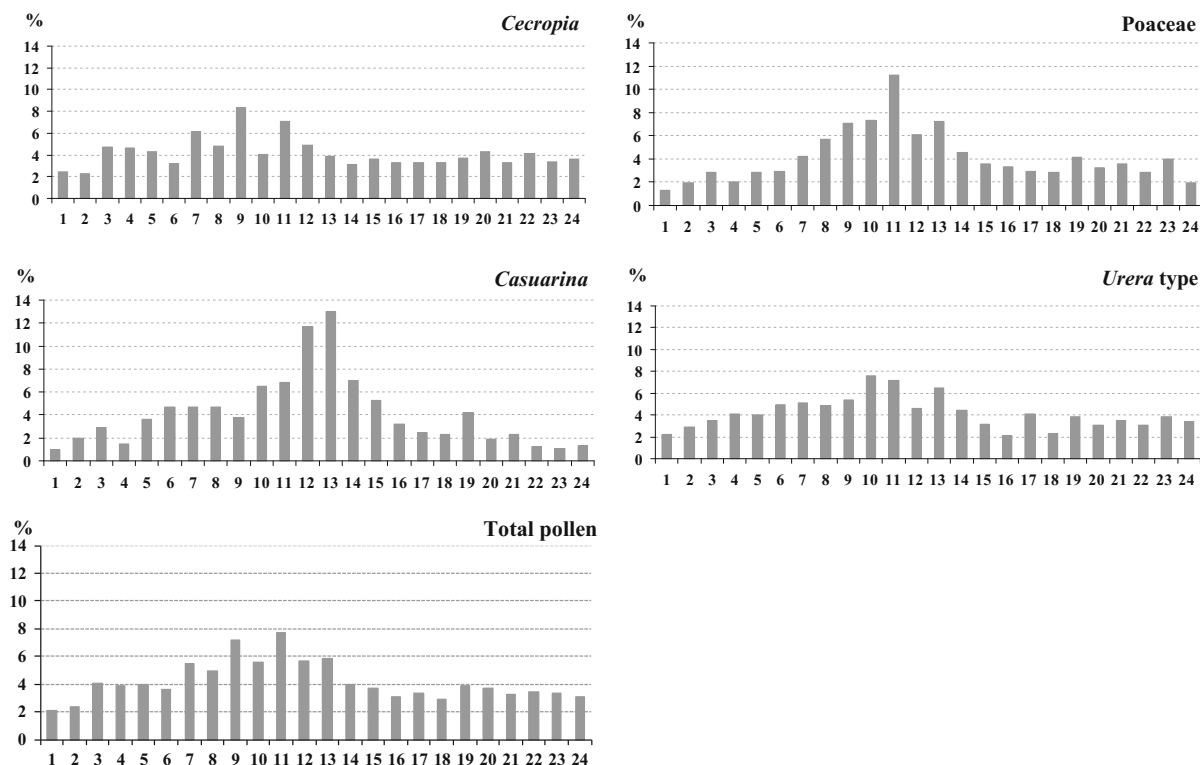


Fig. 5 Intradiurnal distribution of the total and the main pollen types identified in Havana

concentrations were in all cases recorded between 9.00 and 13.00 (32% of the total pollen). *Cecropia* and *Urera* showed no marked intradiurnal peak, whereas *Poaceae* and *Casuarina*—like total pollen—displayed a much more marked hourly interval, with higher values closer to noon.

3.2 Relation between pollen and meteorology

Daily pollen counts were slightly higher during the dry season than during the rainy season (56 vs. 42% in both study years). In periods with no rainfall, average daily counts ranged from 10 to 17 pollen grains/m³, compared with 9–11 grains/m³, respectively, on rainy days in both years.

Analysis of potential correlations between daily airborne pollen counts and weather-related variables identified maximum temperature as the most significant variable (Table 3), displaying a positive correlation with *Cecropia*, *Poaceae* and total pollen counts. All weather variables correlated negatively with airborne *Casuarina* pollen counts, with the exception of wind speed in 2011. Rainfall and relative humidity

showed no clear correlation, either positive or negative, with counts for any pollen type, while wind speed negatively affected airborne pollen counts in general.

4 Discussion

4.1 Quantitative analysis

This study marks the first contribution to the measurement of airborne pollen in Cuba using volumetric methods. Hitherto, these methods had only been used to determine the fungal content of Cuba's bioaerosol (Almaguer et al. 2013, 2014, 2015). The results showed that airborne pollen counts in Havana (8534 grains in 2 years) were lower than fungal spore concentrations. The data provided by Almaguer et al. (2013) for this city indicate values of 148,717 spores of *Cladosporium cladosporioides* (from November 2010 to October 2011) and more than 28,000 spores of *Coprinus* from November 2010 to October 2012 (Almaguer et al. 2014). The atmospheric predominance of fungal spores against pollen grains coincides

Table 3 Spearman correlation coefficient between daily values of the atmospheric pollen concentration (pollen/m³) and the meteorological variables during the main pollen season (MPS) and with the full year

	Rainfall	<i>T</i> max	<i>T</i> min	<i>T</i> mean	Hr	Wind speed	<i>N</i>
Main Pollen Season 2011							
<i>Cecropia</i>	.070	.311**	.123*	.179**	.081	– .137*	261
Poaceae	.116*	.366**	.165**	.211**	.274**	– .187**	289
<i>Urera</i> type	.274**	.171	.112	.133	.316**	– .084	95
<i>Casuarina</i>	– .146*	– .098	– .294**	– .247**	– .157**	.181**	294
Total pollen	.086	.274**	.051	.113	.073	– .117*	293
Main Pollen Season 2015							
<i>Cecropia</i>	.071	.092	– .225**	– .061	.097	– .254**	243
Poaceae	– .028	.063	.089	.079	.093	.092	301
<i>Urera</i> type	.035	.261**	.217**	.288**	.141*	– .042	247
<i>Casuarina</i>	– .039	– .156**	– .355**	– .307**	– .104	– .262**	302
Total pollen	– .005	.113	– .139*	– .029	.025	– .224**	288
Year 2011							
<i>Cecropia</i>	.106*	.434**	.366**	.401**	.057	– .274**	361
Poaceae	.087	.388**	.218**	.262**	.209**	– .229**	361
<i>Urera</i> type	.083	.149**	.121*	.137**	.096	– .036	361
<i>Casuarina</i>	– .134*	– .071	– .222**	– .177**	– .136**	.097	361
Total pollen	.066	.355**	.196**	.249**	.029	– .219**	361
Year 2015							
<i>Cecropia</i>	.069	.327**	– .034	.206**	– .065	– .266**	362
Poaceae	– .023	.167**	.137**	.177**	.036	.079	363
<i>Urera</i> type	.060	.327**	.177**	.325**	– .003	– .127*	362
<i>Casuarina</i>	– .090	– .125*	– .340**	– .269**	– .093	– .268**	363
Total pollen	– .051	.224**	– .146**	.081	– .119*	– .315**	363

N = number of data used in the correlation,

**p* level ≥ .05;

***p* level ≥ .01

with the results of other researchers in both, tropical and temperate zones (Myszkowska et al. 2002; Quintero et al. 2010).

The annual pollen integral for both study years in Havana was lower than those reported in similar latitudes elsewhere (Alzate Guarín et al. 2015), and considerably lower than those recorded in many temperate areas (Galán et al. 2016). The location of the aerobiological sampler, very close to Havana Bay, could account for the scarce contribution of pollen from surrounding vegetation. There is no dense vegetation around the sampler, despite the presence of numerous gardens containing a variety of trees, shrubs and ornamental plants (Castillo and Pastrana 2015). Wind direction also negatively affected airborne pollen counts, since winds are predominantly north–easterly, i.e., from the sea inland, during much of the year.

No marked differences in the seasonal distribution of pollen counts were recorded in either study year.

The same results were reported for the nearby area of San Juan in Puerto Rico (Quintero et al. 2010). Despite this homogeneity, high concentrations during the months of April, June and July were observed in Havana. A previous work conducted in Boyeros (Cuba) by means other sampling methodology, noted the highest pollen incidence during the months of February and March (González et al. 2009). Studies conducted in Caracas, Venezuela, indicate two periods of the year in which pollen concentrations increased (Hurtado and Riegler-Goihman 1986; Hurtado and Alson 1990, 1995). The first one during April–May as consequence of the pollen of autochthonous species (such as *Cecropia*) and the second in November–December related to the pollination of introduced species (like *Cupressus*).

Our study showed slightly higher concentrations during the dry season (from May to October) than the registered in the rainy season (November–April). In the Caribbean island of Trinidad, by contrast, pollen

concentrations are reported to be generally higher during the rainy season (Gowrie 2016). In Barbados, monthly pollen peaks are also recorded during the wettest season, from September to October (Blades et al. 2005). However, a number of studies have shown that rainfall causes atmospheric washout, and may affect flower fall as well as giving rise to the precipitation of airborne pollen (Pérez et al. 2009). In Medellín (Colombia), Alzate Guarín et al. (2015) also observed an inversely proportional relationship between the quantity and diversity of pollen grains in air and the precipitation. The aforementioned monthly differences in the timing of pollen counts may be linked to local flora and to the specific weather patterns of each country.

Although none of the weather-related variables studied correlated strongly with daily airborne pollen counts during the main pollen season, higher counts were recorded in 2015 than in 2011, possibly because 2015 was a warmer year. The average daily maximum temperatures reached 30.7 °C compared to 29.5 °C in 2011.

There are not many studies in the tropical area analyzing the effects of meteorological factors on the airborne pollen concentrations. In San Juan (Puerto Rico), no significant correlation is reported between pollen counts and meteorological factors, perhaps because plants in the tropics tend to flourish throughout the year, and no single season is particularly associated with high pollen counts (Quintero et al. 2010). In the light of these findings, the influence of major weather-related variables was analyzed during the main pollen season (MPS) as well as over the whole year, with a view to detecting potential secondary flowerings occurring outside the MPS (Borchert et al. 2004).

Rainfall and relative humidity positively influenced counts for certain pollen types during the drier year (*Cecropia* year 2011, Poaceae and *Urera* type MPS 2011), but a negative correlation was recorded in both years for *Casuarina* pollen. Similar results were found for relative humidity, although values were lower because Havana is a coastal city, with high relative humidity throughout the year.

Wind in all cases exerted a negative influence. Increased wind speed might be expected to facilitate the dispersal of airborne pollen, although in Havana the highest speeds were recorded for winds blowing

inland from the sea, whose bioaerosol could not contain pollen from nearby sources.

Finally, temperature was the variable most influencing airborne pollen counts; positive correlations were recorded between maximum temperature and both *Cecropia* and total pollen counts. Further research is required to determine whether these correlations are constant, or whether the results for the two study years were anomalous.

Few published studies have addressed intradiurnal airborne pollen distribution in Latin America. The data obtained in this work showed a higher pollen incidence near midday, according to the results obtained in Hawaii (Tam and Muilenberg 2011) or the south of Spain (García et al. 1997) where the 56–44% of the pollen was recovered in the same hourly interval.

4.2 Qualitative analysis

Many of the 45 pollen types identified in this study corresponded to vegetation growing in green areas close to the sampler (*Bursera*, *Casuarina*, *Cecropia*, *Cocos*, *Delonix*, *Mimosa peltata* and *Mimosa pudica*, *Roystonea*, etc.), while others correspond to cosmopolitan plants (Poaceae, Asteraceae, Urticaceae, Amaranthaceae, etc.). Previous research in Cuba has already highlighted the predominance of airborne Casuarinaceae, Oleaceae, Poaceae and Asteraceae pollen (González et al. 2009).

Cecropia, the most abundant pollen in Havana's atmosphere, is a neotropical genus growing from Mexico to South America, including the West Indies (Judd et al. 2009). The genus includes arboreal and dioecious species with small flowers arranged in ants. Its main pollination system involves wind processes, although insects can also contribute the transport of their pollen (Lok et al. 2010). *Cecropia* includes 61 known species (Berg and Rosselli 2005) and is currently taxonomically located within the Urticaceae family (Wu et al. 2013; Treiber et al. 2016), even though it recently has changed its taxonomic position.

In Cuba and other countries with a humid tropical climate, pollen grains are not generally regarded as a cause of allergy, presumably due to the relative scarcity of wind-pollinated plants. The pollen of entomophilous plants is usually heavy, large and with sticky surfaces, attributes which difficult its aerodynamic character (Busse et al. 2000). In Cuba, however,

there has been no systematic research on this issue, hindering the establishment of any link between pollen counts and the incidence of allergies. It is widely accepted today that an increasing number of people are affected by pollen allergies. In Medellín, Colombia, some Type II respiratory pathologies showed a prevalence of 31.1% (Dennis et al. 2004), even higher than the global average (Olabuena et al. 2007).

Little data are available on the relative abundance of the identified pollen types in Latin America and the Caribbean, or on pollen dispersal by the species concerned as a function of local flowering patterns. The studies analyzing the atmospheric pollen concentration in the same latitudes reported the Poaceae, Urticaceae and Cupressaceae common presence (Hurtado et al. 1989; Orozco Suarez and Samacona 1991; Perdomo-Ponce et al. 1991; Hurtado and Alson 1995; Latorre 1999; Crisci and Arduoso 2000; Rojas and Roure 2001; Murray et al. 2002; Cabrales et al. 2003; Nitiu et al. 2003; Tejera and Beri 2005; Nitiu 2006; González-González et al. 2009; Quintero et al. 2010). The pollen of *Amaranthaceae/Chenopodiaceae*, *Ambrosia*, *Casuarina*, *Cyperaceae*, *Moraceae*, *Myrtaceae*, *Cecropia*, *Oleaceae*, *Leguminosae* and *Mimosa* is also cited in many of these countries. The presence of *Casuarina* pollen in the atmosphere was described in Florida (Bucholtz et al. 1991) and Buenos Aires (Majas and Romero, 1992) from mid winter to spring. Its presence in the air has also been documented in the city of Mexico (Ríos et al. 2016).

High airborne *Cecropia* pollen levels have been reported for Caracas (Venezuela) where this pollen type accounts for 29% of total airborne pollen (Hurtado and Alson 1990). The same authors attribute this high pollen levels to *Cecropia peltata* because it is the most abundant species in the metropolitan area. Poaceae also reach high levels (47%), as well as *Alternanthera* sp. (3.2%), *Arecaceae* (7.3%) and *Rumex* sp. (3.2%). Due to their abundance and small size, *Cecropia* pollen grains are regarded as a major source of inhalant allergens, and pollen counts are well above those deemed necessary for human sensitization (Hurtado and Alson 1995). In other islands such as Hawaii, Trinidad and Puerto Rico, *Cecropia* pollen was also found in abundance (Quintero et al. 2010; Tam and Muilenberg 2011; Gowrie 2016). Some studies conducted in San Juan (Puerto Rico) indicate the small pollen size of this tree and its anemophilous pollination character as the main causes of its

abundance in the atmosphere (Joglar 2008; Quintero et al. 2010).

A number of authors indicate a correlation between pollen counts in various parts of Colombia and the magnitude of their impact on health. Dennis et al. (2004) noted that the high prevalence of allergenic pathologies reported in the city of Medellín was due to the particular local atmospheric pollen and spore content. In Bogotá, pioneering studies by Sánchez-Medina and Fernández (1961) concluded that the most frequent allergenic pollens associated with asthma and rhinitis are Poaceae, *Chenopodiaceae/Amaranthaceae* and a group of trees such as acacia, poplar and cedar. Alzate Guarín et al. (2015) identified 30 pollen types in the same city, among them *Oleaceae*, Poaceae, *Cecropia*, *Cyperaceae* and *Chenopodiaceae* with a marked allergological character. Skin reactivity in the Colombian capital was analyzed (Rodríguez and Leal 2000) resulting in 2.9% of sensitization rate for *Cecropia* pollen, 8.21% for *Salix*, 12% for *Artemisia*, 12% for *Chenopodium*, 14.5% for *Plantago* and 15.9% for *Amaranthus*.

In Cuba, only the pollen of certain *Asteraceae* (*Parthenium hysterophorus*, *Bidens pilosa*) has been identified as a locally important source of allergens (Rodríguez and Rodríguez 2001; Álvarez et al. 2004; Rodríguez Pérez et al. 2009; Rodríguez et al. 2013). Pollen from *Pinus*, *Eucalyptus*, Poaceae and some leguminous plants with allergen potential has also been reported. Many of these plants are part of the forest or are grown as ornamentals in urban areas (Rosete Blandariz et al. 2011).

However, as the present study shows, airborne pollen in Havana is highly diverse, and many of the pollen types identified have a marked allergenic character (Rodríguez and Leal 2000; Mösges and Klimek 2006; Trigo et al. 2008; González et al. 2009).

This paper marks a first step toward determining airborne pollen content in Cuba using volumetric methods. Further research is required both into airborne pollen content and into the incidence of clinical allergies, in order to measure the real respiratory Type II allergenic risk for the Cuban population.

5 Conclusions

A total of 45 airborne pollen types were characterized in Havana (Cuba). The pollen biodiversity in the

atmosphere is high, and the most abundant types were *Cecropia*, Poaceae, *Urera* type and *Casuarina*. Airborne pollen was recorded throughout most of the year, and daily counts were highest around noon. Maximum temperature was the meteorological variable displaying the strongest positive correlation with airborne pollen counts, except in the case of *Casuarina*. Insufficient attention has been paid in Cuba to the association between the presence of airborne pollen and the incidence of allergic respiratory diseases, and this study provides useful information for a more effective assessment of hay fever risk periods in Cuba.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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