



Relevance of aerobiological studies in Nigeria: a two-year aerospora record of Lagos

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Received: 14 July 2020 / Accepted: 29 April 2021
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Abstract Pollen and fungal spores (aerospora) are major atmospheric bioaerosols for pollen allergy sufferers. Aerospora types and concentration vary seasonally, depending upon the flowering period and meteorological factors which are variable in different geographical regions. The aim of this study was to analyze a two-year record of aerospora from two locations (Epe and Ojo) in Lagos (Nigeria), from May 2014 to April 2016. Aerospora were monitored with a modified Tauber sampler. The residual solution was harvested monthly throughout the duration of the study and acetolyzed, and microscopic slides were prepared. Aerospora were analyzed with light and

scanning electron microscopy (SEM). SEM studies were applied to reach a higher level of pollen identification. A plant enumeration was carried out in the surroundings of the sampling sites. The aerobiological study revealed seasonal distribution patterns of various aerospora. The highest total pollen counts for 2014–2015 and 2015–2016 were recorded in April–July for both sites while minima occurred in January–December. Pollen of Poaceae, Euphorbiaceae, Convolvulaceae, Cyperaceae was dominant. Other taxa include *Borreria* sp., *Elaeis guineensis*, *Amaranthus* sp., *Tridax procumbens*. Fungal spores showed a high recovery for the months April–August for Epe in 2014–2015 and 2015–2016. In Ojo, fungal spores were high in July–August for 2014–2015 and in April–August for 2015–2016. Common fungal spores include those of *Alternaria*, *Nigrospora*, and *Curvularia*. The relationship between the aerospora spectra and the vegetation at the study locations was qualitatively investigated. There is a need to further test the allergenicity of pollen of common plants in Nigeria to inform pollen-hypersensitive individuals.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10453-021-09710-x>.

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Keywords Aerospora · Seasonality · Allergenicity · Aeropalynology · Lagos

1 Introduction

The atmosphere is laden with organic and inorganic particles, having a great diversity in size, shape, and atmospheric concentration hailing from plants, arthropods, fungi but also combustion particles from traffic, industry, and household fuels (Essien & Agwu, 2013a, 2013b). These atmospheric particles trigger various allergic conditions, including allergic rhinitis (AR), conjunctivitis, asthma, and atopic dermatitis (International Study of Asthma and Allergies in Childhood, 1998). AR often covaries with asthma, an important global cause of morbidity, and shares a similar pathophysiology. Additionally, asthma might be triggered by AR (Khan, 2014; Ozoh et al., 2019). From 2005 until 2015, a global increase in asthma of 12% predominantly in developing countries is noted (Asher et al., 2006; Soriano et al., 2017). Allergies and asthma are increasing in African countries due to a rise in urbanization: Major factors are an increased skin reactivity due to urban diets, stronger air pollution, and atopic sensitization (Obeng et al., 2008). A recent study, investigating the prevalence of asthma and AR in Nigeria focusing on five cities, revealed that the highest prevalence for AR occurred with 25.8% in Lagos (Ozoh et al., 2019). In Nigeria, which has one of the fastest growing populations worldwide and has a great diversity in climate, vegetation, urbanization degree, and cultures, all affecting the severity and co-existence of asthma and AR (United Nations, 2017; Ozoh et al., 2019), detailed, local aeropalynological studies are a necessity. Due to Lagos being a high-risk area for asthma and AR, it seems logical that aerobiological studies are in high demand in Nigeria's largest city.

Aeropalynological investigations have revealed that pollen and fungal spores, next to dust mites and animal hair, are the most dominant, pervasive, respirable, and potent sources of allergens present in the atmosphere, which give rise to morbidity among sensitive individuals (Singh & Dahiya, 2008). This burden of allergic diseases on patients, families, health-care systems, and governments increases worldwide, affecting both developed and underdeveloped countries that are currently experiencing an epidemic in the prevalence of airborne allergies. Decreased productivity, poor concentration, and behavioral changes among adults and children have been linked with persistent symptoms of allergic

diseases (D'Amato et al., 2007). Hence, knowledge about diurnal, seasonal, and annual fluctuations of these aerospora in geographical areas of Nigeria, where both climate and vegetation are diverse, is essential for effective diagnosis and treatment of allergies (Singh & Mathur, 2012). Moreover, avoidance of the allergenic pollen and spores, based on knowledge gained from quantification of their temporal distribution, duration of their occurrence in the air, peak periods, and high-/low-risk periods throughout the year (aka a pollen calendar), is crucial in reducing epidemiological uncertainty. This also helps in developing mitigation strategies and prophylactic approaches to the problem of respiratory allergies.

Another aspect of aeropalynological studies is that aerobiology is increasingly used to gather ecological and biogeographic data, which are often essential for conservation and environmental protection programs (Benninghoff, 1991). Therefore, another goal of aerobiological studies is to investigate to which degree the natural but also the disturbed vegetation, especially in an urbanized context, is reflected in aerobiological studies. Atmospheric pollen has also been applied as models in the prediction of biological response to future climate change; this is achieved through a routine monitoring of airborne pollen distribution which is conducted on a large scale (Altıntaş et al., 2004; Beggs et al., 2017; Bielory et al., 2012; Bishan et al., 2020; Dale et al., 2002; Fernández-Rodríguez et al., 2020; Lara et al., 2019; Martínez-Bracero et al., 2018; Molina et al., 2001; Myszkowska, 2020; Newnham, 2001; Palczynski et al. 2017; Paloma et al. 2004).

1.1 Overview of climate and vegetation in Nigeria

Aerobiological studies have to be understood in the context of the natural, but also the anthropogenically disturbed vegetation (Benninghoff, 1991). Since vegetation is largely dependent on climatic parameters, a short overview of climate in Nigeria is essential. Temperature and precipitation in West Africa fluctuate along a north–south gradient (36–24 °C, and < 600–6000 mm/yr). West African climate is influenced by the Intertropical Convergence Zone (ITCZ), the West African Monsoon, and the tropical rain belt (Miller & Gosling, 2014). Nigeria lies within the tropics and is characterized by dry and rainy seasons (Eludoyin & Adedokun, 2013). The dry season is

dominated by a northern, dust-laden wind stemming from the Sahara Desert, commonly referred to as harmattan, the Tropical Continental (cT) airmass (Eludoyin & Adelakan, 2013). The rainy season is characterized by the southwest wind bringing moisture from the Atlantic Ocean; these airmasses are described as Tropical Maritime (mT) airmass (Eludoyin & Adelakan, 2013). The climate in North Central Nigeria is influenced by the higher altitude (Eludoyin et al., 2014). Mean annual temperature in Nigeria is 27.1 °C and mean relative humidity 62.8% (Eludoyin et al., 2014). Lagos, located on the southwestern coastal plain of Nigeria, has a humid tropical climate. The wet season is April–November and the dry season December–March (Adeleye et al. 2018). Annual rainfall is 1381.7–2733.4 mm, and monthly precipitation is 25 mm→400 mm (Adeleye et al. 2018; Ogundele, 2012). Temperature is 29–34 °C with sea breezes prevailing throughout the year and dominant south-westerly winds (Adeleye et al., 2018; Ogundele, 2012).

The Nigerian vegetation zones are described following Adekanmbi and Ogundipe (2009b) based on Keay (1959a, b) (Fig. 1). The following vegetation zones are recognized from North to South: a. Sahel Savanna with *Vachellia* and *Senegalia* species (acacias), *Commiphora* (Keay 1959a), b. Sudan savanna, c.

Northern Guinea savanna with *Isoberlinia doka*, *I. dalzielii* also classified as miombo woodland (Keay 1959a; Collins 1977), d. Southern Guinea savanna, a moist savanna type with trees like *Daniellia oliveri*, *Azelia africana*, *Burkea africana*, *Butyrospermum paradox*, *Uapaca togoensis* (Collins 1977), e. Lowland rain forest, high biodiversity, with numerous trees like *Celtis zenkeri*, *Picralima* sp., *Ricinodendron heudelotii*, *Buchholzia coriacea*, *Anthocleista djalonensis*, *Cola millenii*, *Ficus lutea*, *Olex subscorpioides*, *Vitex grandifolia* (Wakawa et al., 2018). Mangroves (f.) grow along the Atlantic Ocean coast with three species of *Rhizophora* (*Rhizophora harrisonii*, *R. mangle*, *R. racemosa* (Adegbihin, 1993)), *Avicennia germinans*, *Laguncularia racemosa*, and the brackish (mangrove) water fern *Acrostichum aureum* (Adekanmbi & Ogundipe, 2009b).

1.2 A review of aerobiological and epidemiological studies in Nigeria

In Nigeria, aeropalynological studies need to be expanded. Across the geopolitical zones of the country, aeropalynological studies have been carried out but were not exceeding a one-year sampling period. Only five studies (Adekanmbi et al., 2018; Adeniyi et al., 2014; Alebiosu et al., 2018; Ezike et al., 2016; Njokuocha, 2006) feature a sampling period of one year, and no published information from this region is available for two or more years of sampling.

The current study involved monitoring atmospheric pollen and fern spores for a period of two years, covering wet and dry seasons. Another aim was to compare the recovered airborne pollen spectra with identified plants in the immediate vegetation around the study locations, within Lagos, the most populous city in Sub-Saharan Africa.

In Fig. 1, aerobiological sampling sites are marked by yellow asterisks, allergenic studies (Ozoh et al., 2019) by red dots.

South-Eastern region In Enugu, the largest city in the region, a study at the Pediatric Asthma Clinic, revealed that, although AR is lower than in Lagos (Ozoh et al., 2019), AR prevalence is alarmingly high among children (33% in Ayuk et al., 2018). The pivotal aerobiological studies of Agwu and Osibe (1992), Agwu (2001), Agwu et al. (2004) and Njokuocha and Osayi (2005) created a rich database for comparison and research in the aeropalynology of

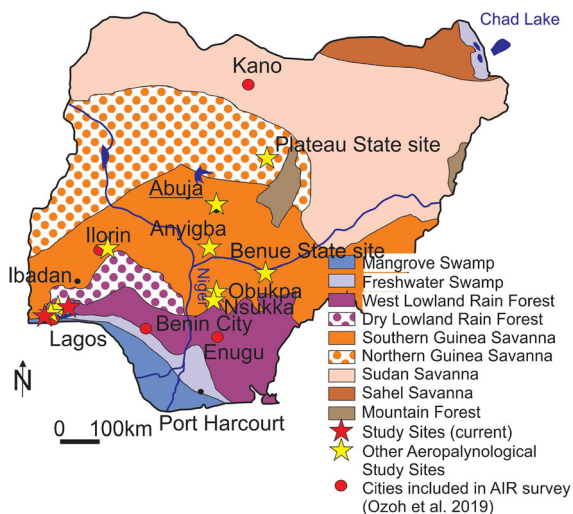


Fig. 1 Vegetation map of Nigeria (after FGN 2002 based on Keay, 1959a, Adekanmbi & Ogundipe, 2009b), red asterisk: this study, yellow asterisk: other aeropalynological studies (references in chapter 3.), red dot: cities included in AIR (Asthma Insight and Reality) survey (Ozoh et al., 2019)

South-Eastern Nigeria. They revealed the diversity of aerospora, providing basic data for the one-year aeropalynological study, carried out by Njokuocha (2006) in the Nsukka area of South-Eastern Nigeria. The aeroflora of Nsukka, Enugu State, recorded 56 pollen types, mostly reflecting natural vegetation. Poaceae, *Alchornea cordifolia*, *Elaeis guineensis*, Asteraceae, Amaranthaceae, Moraceae were the most abundant aerospora. Ikegbunam et al. (2019) carried out a three-month aeropalynological study at Obukpa town in Enugu State and recorded a total of 3,899 palynomorphs consisting of 3365 pollen grains and 38 fungal spores. Dominant pollen types in the atmosphere of the study area were Combretaceae/Melastomataceae, Poaceae, Asteraceae, Amaranthaceae, *Lannea* sp., *Pentaclethra macrophylla*, and *Alchornea cordifolia*, while the major fungal aerospora were *Glomerularia* sp., *Nigrospora* sp., *Cercospora* sp., *Asperosporium* sp., *Fusoma*, *Dreschlera*, and *Helminthosporium*.

North-Central region In the city of Ilorin in the North central region, AR and asthma prevalence is lower than in Lagos (Ozoh et al., 2019) due to lower air pollution and less traffic (lowest prevalence of AR, 7.3%, in the study covering five Nigerian cities). Alebiosu et al. (2018) conducted an aeropalynological study at two locations in North-Central Nigeria. Their findings revealed seasonal distribution patterns of various airborne pollen types in the study locations. They recorded abundant pollen types recovered from the two locations (Plateau and Benue States), including *Syzygium guineense*, *Tridax procumbens*, *Casuarina equisetifolia*, *Alchornea* sp., *Terminalia* sp., Poaceae, Cyperaceae, and Amaranthaceae, while spores of *Pteris* sp., *Nephrolepis* sp. and an unidentified trilete fern spore type were documented. In addition, the airborne pollen spectra corresponded well with identified plants in the study locations.

Ezike et al. (2016) reported the relationship between the prevalence of aerospora and meteorological parameters for one year at a sampling site in Abuja; 53 pollen types belonging to 36 families were documented. Dominant aerospora include Poaceae, *Pentaclethra macrophylla*, *Elaeis guineensis*, *Justicia* spp., *Cassia* sp., *Alchornea cordifolia*, and *Luffa* spp.

Abdulrahman et al. (2015) carried out a bimonthly aeropalynological investigation at the University of Ilorin. Dominant pollen types belonged to Apocynaceae, Poaceae and Cyperaceae.

Essien and Agwu (2013a, 2013b) reported a total of 61 pollen types belonging to 36 plant families in their study in Anyigba town, Kogi State. Dominant were pollen types of Poaceae, *Elaeis guineensis*, *Lannea acida*, *Nauclea latifolia*, *Alchornea cordifolia*, *Syzygium guineense*, *Berlinia grandifolia*, *Senna* sp., Asteraceae (Tubiflorae), and Combretaceae/Melastomaceae.

North-western region In Kano, one of the largest Nigerian cities, results of the survey regarding the prevalence of asthma and AR (Ozoh et al., 2019) point to a high prevalence of AR in children. Adekanmbi et al. (2018) carried out a survey of atmospheric pollen and spores in North-western Nigeria. Most dominant pollen types were those of *Alchornea laxiflora*, *Pinus caribaea*, *Syzygium guineense*, *Alchornea* sp., *Terminalia* sp., Sapotaceae and Poaceae. Spores of *Pteris* sp. and *Nephrolepis* sp. were also detected. Adekanmbi et al. (2018) observed that some local plants in the immediate vegetation contributed to the aeroflora of these locations.

South-western region In Lagos, prevalence for AR and asthma reaches the highest percentages among all surveyed Nigerian cities (Ozoh et al., 2019), underlining the importance of aerobiological studies in that city.

Adekanmbi et al. (2019) investigated the aeroflora and allergenic potentials of two dominant airborne pollen types at selected sites in South-western Nigeria. Crude protein contents were extracted from pollen of *Tridax procumbens* and *Alchornea cordifolia* and used in *Mus musculus* sensitization. Statistical significance was observed to correlate between the levels of certain hematological and serological parameters elicited by the test groups, differences between the levels of certain hematological and serological parameters elicited by each test group and those of the control, as well as at some sensitization periods. Hair loss (alopecia) was observed on the skin of a *M. musculus* in the *Alchornea cordifolia* test group.

Ajikhah et al. (2017) carried out an aeropalynological survey from May to July at three locations in the Lagos metropolis. They correlated the monthly total pollen counts with mean values of meteorological parameters. Their findings revealed the highest total pollen load in May, while the lowest pollen count was observed in June.

Ajikhah et al. (2015) conducted aeropalynological studies at three different locations within the

University of Lagos, Akoka campus. Spores of Polypodiaceae and Adiantaceae as well as pollen of Poaceae, Cyperaceae, Sapotaceae, Combretaceae, and Euphorbiaceae were the most abundant aerospora at their study locations.

Adeniyi et al. (2014) examined the pattern of airborne pollen distribution for a period of one year. In their study, dominant pollen types were identified, with deductions on high-risk periods, correlation with meteorological and allergy prevalence data.

Adeonipekun (2012) carried out an aeropalynological study in Ayetoro-Itele Ota, South-Western Nigeria. A total of 305 sporomorph types belonging to 17 plant families were recorded. Poaceae, Amaranthaceae, and Cyperaceae were preponderant. No pollen grains of savanna taxa were detected, unlike previous findings of the aeroflora at the same location, in which *Vitex* cf. *doniana*, *Parinari* spp., and *Isoberlinia doka* of the Guinea/Sudan Savanna were represented. Adeonipekun (2012) affirmed that the transportation of savanna tree pollen to the source of recovery was attributed to a late harmattan, characterized by haze dust.

Adekanmbi and Ogundipe (2010) sampled four selected sites within Akoka campus, University of Lagos, Nigeria. Their findings revealed a total of 393 palynomorph types, belonging to 22 families. Poaceae pollen was dominant, followed by Asteraceae, Arecaceae, and Euphorbiaceae as well as the subfamily Mimosoideae.

In a study in Ijegan in Lagos, spider webs were collected from nine localities over a 12-month period (Okwong et al., 2019). This investigation revealed that spider webs can be utilized as a natural spore trap although biases might exist. The pollen load was high in March–August and significantly lower in November–January.

2 Materials and methods

2.1 Climate and vegetation at study sites

The two study sites are located in Lagos in a distance of 120 km from each other. Ojo lies at latitude 6°27'0" N; longitude 3°13'0" E, while Epe lies at latitude 6°31'N; longitude 4°E (Fig. 2). The climate of the area is tropical, with seasonal wet and dry conditions, a mean annual rainfall of ca. 1800 mm, and mean

annual temperature of 27 °C (Soladoye & Ajibade, 2014). The region is dominated by a bimodal rainy season. The rainy season is divided into two periods; the first spans from April to July, and the second one occurs between September and November. Between these wet periods is a relatively dry phase in August and September, commonly referred to as the “August break.” The main dry season spans from December to March, usually bringing the harmattan from the North-East trade winds.

Generally, the vegetation of Lagos falls under the lowland forest zone of western Nigeria which consists of rainforest and coastal vegetation. The forested freshwater swamp dominates the lagoon fringes, and the river floodplain complexes both in the East and West of city. They consist of both forests and *Raphia* palm complexes (Ogunkunle, 2013). They are extensive around the islands of the Lekki lagoons in the East and around the Ologe lagoon toward the Badagry creek in the West. By far, most abundant is the secondary vegetation which is subclimax and regularly disturbed vegetation interspersed with cultivated lands. Cultivated land is extensive to the North of the Lagos lagoon systems and away from the main river floodplains both in the East and West. They are far more extensive in the western parts which has been characterized as part of the Dahomey Gap—a zone of the Guinea-Congolian forest zone comprising of a mosaic of savanna and the drier type of rainforest (Sowunmi, 2004). Vegetation in the region has suffered from accelerating degradation due to massive human disturbances, e.g., agricultural activities, traffic installations, habitat fragmentation, and land fillings (Adeonipekun et al., 2019a).

Most of the plant species encountered in Lagos belonged to the families Asteraceae, Cyperaceae, Poaceae, Euphorbiaceae, and Acanthaceae.

2.2 Inventorying plant taxa around sampling sites

The listing of local plant taxa (Tables 1, 2) followed after a qualitative vegetation description achieved using 10 plots of 25 × 25 m for tree species, 1.0 × 1.0 m for herbs and grasses, respectively, around the pollen samplers used. Plant samples were collected randomly within each plot, owing to the larger sampling areas covered and listed as present or absent. They were identified using keys following Keay (1989), Keay et al. (1964), Hutchinson & Dalziel

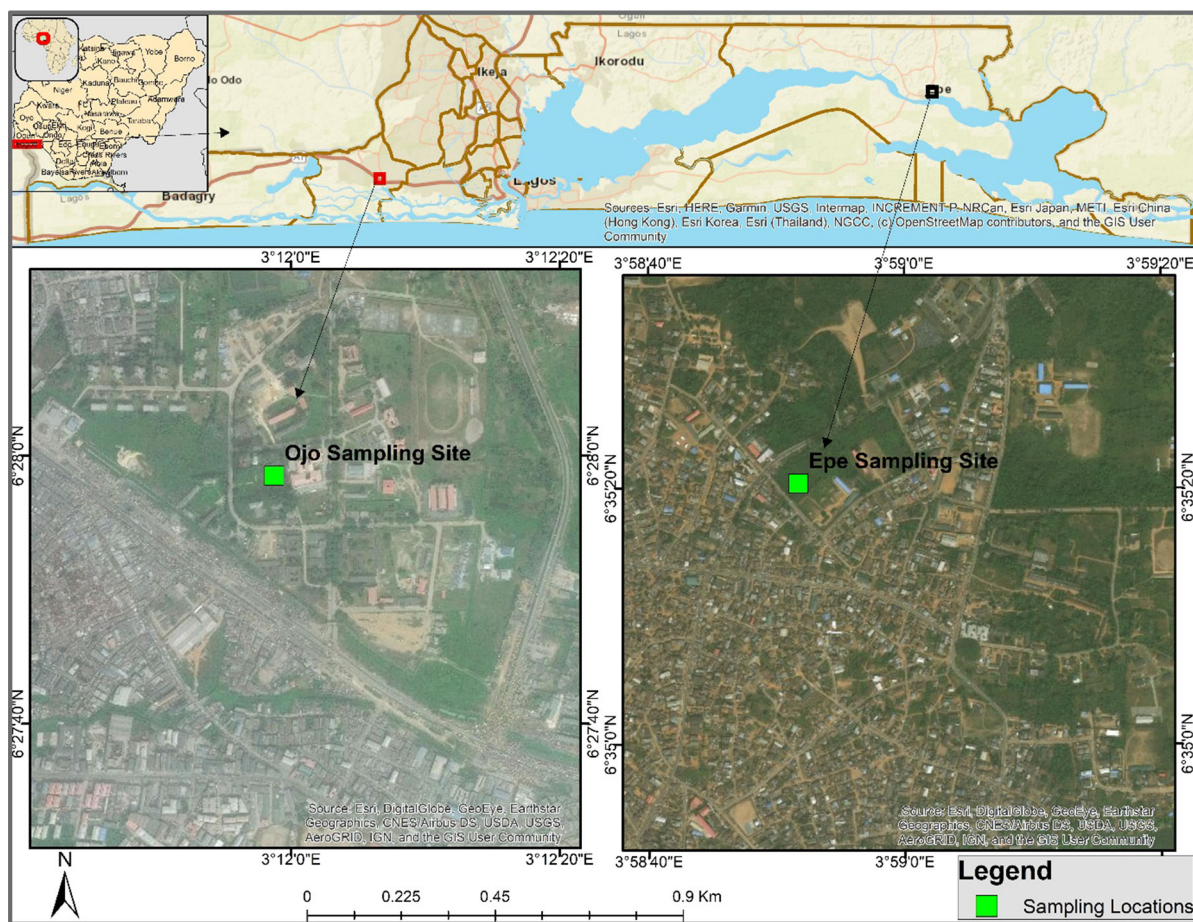


Fig. 2 Map of the study locations in Lagos, Nigeria

(1954), and Dalziel (1937). Voucher specimens of all plants were collected and deposited at the University of Lagos Herbarium.

Anthers of flowering plants were collected and further processed using acetolysis (Erdtman 1969). This procedure was to allow for precise identification of pollen types and a better understanding of pollen transport modes in the city. The pollen reference collection is located at the Laboratory of Paleobotany and Palynology, University of Lagos.

2.3 Aerobiological data

2.3.1 Sampling aerospora

A modified Tauber pollen sampler was installed at each location ca. 1.50 m above ground level, together with a 10-cm ring fixed at the top of it. Each sampler

was covered with a lid, having a small opening which served as an inlet for pollen and spores. To prevent it from being blown around by the wind, it was cemented ca. 30 cm underground to provide support. A solution containing 50 ml glycerol (to prevent drying up of organic particles), 10 ml formaldehyde (to prevent the decay of dead organisms), and 5 ml phenol (to kill insects) was prepared and poured into the Tauber samplers at the two locations, following the published procedures (Adekanmbi et al., 2018; Ajikah et al., 2017; Alebiosu et al., 2018; Ezike et al., 2016).

The content (residual solution) from the pollen traps was collected monthly for a period of two years, from May 2014 to April 2016. The traps were rinsed at the end of each monthly harvest before a fresh solution was filled into the pollen traps.

Table 1 List of encountered plant species in the vegetation study around the sampling sites and the aeropl原因nological samples of both study sites (Epe, Ojo), ferns, grasses, herbs, sedges. PD, pollen diagram, BS, botanical survey

Species	Family	Habit	Epe BS	Epe PD	Ojo BS	Ojo PD
<i>Acrostichum aureum</i>	Adiantaceae	Fern	x	x	*	x
<i>Ceratopteris cornuta</i>	Adiantaceae	Fern	*	x	x	x
<i>Cyclosorus</i> sp.	Thelypteridaceae	Fern	x	x	*	x
<i>Lygodium microphyllum</i>	Schizaeaceae	Fern	*	x	x	x
<i>Lygodium smithianum</i>	Schizaeaceae	Fern	x	x	*	x
<i>Nephrolepis</i> sp.	Nephrolepidaceae	Fern	x	*	x	*
Polypodiaceae undiff	Polypodiaceae	Fern	x	*	x	*
<i>Pteris</i> sp.	Pteridaceae	Fern	x	*	x	*
Trilete fern	diverse fern families	Fern	N/A	*	N/A	*
<i>Brachiaria deflexa</i>	Poaceae	Grass	*	x	*	x
<i>Panicum maximum</i>	Poaceae	Grass	*	x	*	x
<i>Paspalum vaginatum</i>	Poaceae	Grass	*	x	*	x
<i>Pennisetum purpureum</i>	Poaceae	Grass	*	x	*	x
Poaceae undiff	Poaceae	Grass	x	*	x	*
Poaceae cuticle	Poaceae	Grass	x	*	x	x
<i>Acalypha crenata</i>	Euphorbiaceae	Herb	*	x	x	x
Acanthaceae undiff	Acanthaceae	Herb	*	x	*	x
<i>Ageratum conyzoides</i>	Asteraceae	Herb	*	x	*	x
<i>Alternanthera sessilis</i>	Amaranthaceae	Herb	*	x	*	x
Amaranthaceae undiff	Amaranthaceae	Herb	x	*	x	*
<i>Amaranthus</i> sp.	Amaranthaceae	Herb	x	*	x	*
<i>Aspilia Africana</i>	Asteraceae	Herb	*	x	*	x
Asteraceae undiff	Asteraceae	Herb/Shrub	x	*	x	*
<i>Asystasia gangetica</i>	Acanthaceae	Herb	x	x	*	x
<i>Bidens pilosa</i>	Asteraceae	Herb	*	x	x	x
<i>Borreria scabra</i>	Rubiaceae	Herb	*	x	*	x
<i>Borreria</i> sp.	Rubiaceae	Herb	x	*	x	*
<i>Brilliantaisia</i> sp.	Acanthaceae	Herb	x	*	*	*
<i>Celosia argentea</i>	Amaranthaceae	Herb	x	x	*	x
<i>Cochorus olitorius</i>	Tiliaceae	Herb	*	x	*	x
Convolvulaceae undiff	Convolvulaceae	Herb	x	*	x	*
<i>Emilia coccinea</i>	Asteraceae	Herb	*	x	*	x
<i>Ethulia conyzoides</i>	Asteraceae	Herb	*	x	*	x
Euphorbiaceae undiff	Euphorbiaceae	Herb	x	*	x	*
<i>Euphorbia heterophylla</i>	Euphorbiaceae	Herb	*	*	*	*
<i>Gomphrena celosoides</i>	Amaranthaceae	Herb	x	*	x	*
<i>Pentodon pentandrus</i>	Rubiaceae	Herb	*	x	x	x
<i>Senna</i> sp.	Fabaceae	Herb/Shrub/Tree	x	*	x	*
<i>Sida corymbosa</i>	Malvaceae	Herb	*	x	x	x
<i>Tridax procumbens</i>	Asteraceae	Herb	x	*	x	*
<i>Triumffeta cordifolia</i>	Tiliaceae	Herb	x	x	*	x
<i>Typha latifolia</i>	Typhaceae	Herb	x	x	*	x
<i>Vernonia cinerea</i>	Asteraceae	Herb	x	x	*	x
Cyperaceae undiff	Cyperaceae	Sedge	x	*	x	*

Table 1 continued

Species	Family	Habit	Epe BS	Epe PD	Ojo BS	Ojo PD
<i>Cyperus esculentus</i>	Cyperaceae	Sedge	*	x	x	x
<i>Cyperus involucratus</i>	Cyperaceae	Sedge	*	x	*	x

*, present; x, absent

Table 2 List of encountered plant species in the vegetation study around the sampling sites and the aeroplanylogical samples of both study sites (Epe, Ojo), climbers, shrubs, trees. PD, pollen diagram, B, botanical survey

Species	Family	Habit	Epe BS	Epe PD	Ojo BS	Ojo PD
<i>Centrosema pubescens</i>	Papilionoideae	Climber	*	x	x	x
<i>Combretum sp.</i>	Combretaceae	Climber	x	x	*	x
<i>Alchornea cordifolia</i>	Euphorbiaceae	Shrub	*	x	*	x
<i>Alchornea laxifolia</i>	Euphorbiaceae	Shrub	x	*	x	*
<i>Bambusa vulgaris</i>	Poaceae	Shrub	*	x	x	x
<i>Chromolaena odorata</i>	Asteraceae	Shrub	*	x	*	x
<i>Costus afer</i>	Zingiberaceae	Shrub	x	x	*	x
<i>Drepanocarpus lunatus</i>	Papilionoideae	Shrub	*	x	x	x
Malvaceae undiff	Malvaceae	Shrub/Tree	x	*	x	*
<i>Urena lobata</i>	Malvaceae	Shrub	x	x	*	x
<i>Vitex sp.</i>	Lamiaceae	Shrub/Tree	x	*	x	*
<i>Alstonia boonei</i>	Bombacaceae	Tree	*	x	x	x
<i>Anthocleista vogeli</i>	Loganiaceae	Tree	x	x	*	x
Arecaceae undiff	Areaceae	Tree	x	*	x	*
<i>Artocarpus altilis</i>	Poaceae	Tree	x	x	*	x
<i>Bombax buonopozense</i>	Bombacaceae	Tree	x	*	x	*
<i>Bridelia micrantha</i>	Euphorbiaceae	Tree	*	x	x	x
<i>Casuarina equisetifolia</i>	Casuarinaceae	Tree	*	*	*	*
<i>Cocos nucifera</i>	Areaceae	Tree	x	x	*	x
<i>Elaeis guineensis</i>	Areaceae	Tree	*	*	*	*
<i>Ficus exasperate</i>	Moraceae	Tree	x	x	*	x
Mimosaceae	Mimosaceae	Tree	x	*	x	*
<i>Phoenix reclinata</i>	Areaceae	Tree	*	x	x	x
Sapotaceae undiff	Sapotaceae	Tree	x	*	x	*
<i>Senegalia/Vachellia</i>	Mimosaceae	Tree	x	*	x	*
<i>Syzygium guineense</i>	Myrtaceae	Tree	x	*	x	*
<i>Terminalia sp.</i>	Combretaceae	Tree	x	*	x	*

*, present; x, absent

2.3.2 Processing samples (including acetolysis and mounting)

The samples were sieved through 200-µm mesh wire gauze to filter off large organic fragments and soil particles. The liquid with suspended palynomorphs was centrifuged at 2000 revolutions per minutes (rpm)

for 5 min. The supernatants were decanted, and the residues retained. The precipitates were washed three times with distilled water and centrifuged in order to recover the polleniferous residues.

The recovered residue (precipitate) was placed in a plastic test tube, and 45% hydrofluoric acid was added to dissolve silicates. The suspension was allowed to

stand for 35 min and stirred regularly to increase the rate of dissolution of solid inorganic compounds. At the end of the period, the samples were centrifuged, and the supernatant decanted to retain the residues. The hydrofluoric acid was disposed of through a calcium carbonate receiver.

To separate residues containing pollen and spores from the supernatant fluids, the solutions were centrifuged at 2500 rpm for 5 min. The residues were recovered and subjected to acetolysis treatment, following Erdtman (1969). Acetolysis dissolves cellular content, pollen kitt, and the intine; in addition, it stains the pollen grains yellow-brownish enhancing identification (Halbritter et al., 2018). Acetolysis involves the preparation of a mixture of concentrated sulphuric acid and acetic anhydride in the volume ratio of 1:9, respectively. Each sample residue was filled with 5 ml of the acetolysis mixture; placed in test tubes; and heated in a water bath at 100 °C for 10 min. The residues were centrifuged and decanted, then rinsed with distilled water, and decanted; this process was repeated twice. The residues were stored in vials with an addition of two drops of glycerin for their preservation in the Paleobotany and Palynology Laboratory, Department of Botany, University of Lagos.

2.3.3 Palynological analysis

The prepared residue in each vial bottle was thoroughly shaken, while 2 drops (0.2 ml) of the suspension mounted on a 32 mm × 22 mm slide and covered with a 22 mm × 22 mm cover slip. Loctite was used to hold the sample firmly on the slide. *Lycopodium* spore tablets, which are often added to calculate pollen concentration (Stockmarr, 1971), were not available for this study. The residue was then used in preparing slides and analyzed quantitatively and qualitatively with a Novex light microscope at × 400 and × 1000, respectively.

Scanning electron microscopy was undertaken to improve pollen identification of certain pollen types. For this, the prepared residue was mounted onto standard 12-mm aluminum SEM stubs and sputter-coated with a thin layer of gold to enhance conductivity. This was carried out at Central Analytical Facility (CAF), Stellenbosch University, South Africa. Pollen samples were visualized with a Zeiss Merlin field emission scanning electron microscope, using

an accelerating voltage of 2–3 kV with Inlens Secondary Electron (SE) and SE2 detection. Images were captured as TIFF files, using a store resolution of 2048 × 1536 pixels. This was carried out to ensure accurate identification through studying distinct morphological characteristics such as apertures, shape, size, surface structure, and ornamentation. Plate S4:11 showed photomicrographs of some palynomorphs captured.

Pollen types were identified to familial, generic, and specific levels. Photomicrographs in publications including Sowunmi (1973, 1995), Adekanmbi (2009a, b), Gosling et al. (2013) and unpublished pollen atlases were used for the identification of palynomorphs. Other unidentified pollen was referred to as pollen indeterminate. In addition, different pollen and fern spore types were counted on the whole slide; their total counts were also generated and expressed in frequency, following the works of Njokuocha (2006), Ezike et al. (2016) and Alebiosu et al. (2018).

3 Results

3.1 Vegetation inventory

The species composition of the two study sites is presented in Tables 1, 2. Forty-six plant species belonging to twenty-two families were encountered at Epe and Ojo. Most of the plant species belonged to the family Asteraceae and include *Ageratum conyzoides*, *Aspilia africana*, *Bidens pilosa*, *Chromolaena odorata*, and *Emilia coccinea*. Poaceae was dominant; the following species were recorded: *Artocarpus altilis*, *Brachiaria deflexa*, *Bambusa vulgaris*, *Panicum maximum*, *Paspalum vaginatum* and *Pennisetum purpureum*. Common tree taxa were *Alchornea cordifolia* (Euphorbiaceae), *Anthocleista vogelli* (Loganiaceae), and *Elaeis guineense* (Arecaceae). The species distribution across the studied area could be attributed to the status of the environment considering the prevailing anthropogenic activities.

3.2 Aerobiological data

In this study, 25 pollen types representing 18 plant families were identified during the two consecutive years in the aerobiological samples (Tables 1, 2, supplement tables S1-4 May 2014 to April 2015 and

May 2015 to April 2016). Selected pollen and spores are depicted on plate **S4:1**; aerospora fluctuations for Ojo and Epe are shown in Figs. 3, 4.

Eleven, six, and eight pollen types were identified to family, genus, and species levels, respectively—partly with help of above-mentioned SEM studies—while others were designated as pollen indeterminate. At the study site in Epe, Lagos State, higher airborne pollen abundance was recorded in April, during the first (120, 14.17%) and second (132, 13.62%) years of sampling, whereas lower records were observed in December (27, 3.19%) and November (27, 2.79%), for the first and second sampling years, respectively (tables S1–S2, compare Figs. 3a, 4a). At the study site

in Ojo, Lagos State, higher airborne pollen abundance was recorded in the month of April, during the first (140, 14.72%) and second (152, 15.39%) sampling years, while lower records were observed in the months of January (28, 2.94%) and December (14, 1.42%) (tables S3–S4, compare Figs. 3b, 4b). The most dominant airborne pollen types at the study site in Epe were produced by *Elaeis guineensis* (Tree/palm, plate 1), Poaceae (Grass), Asteraceae (Herb), Convolvulaceae, and Euphorbiaceae. Airborne pollen types of *Euphorbia heterophylla* (Herb), *Borreria scabra* (Herb), Poaceae (Grass), Euphorbiaceae, and Convolvulaceae were dominant at the study site in Ojo. *Euphorbia heterophylla* is herbaceous, and its

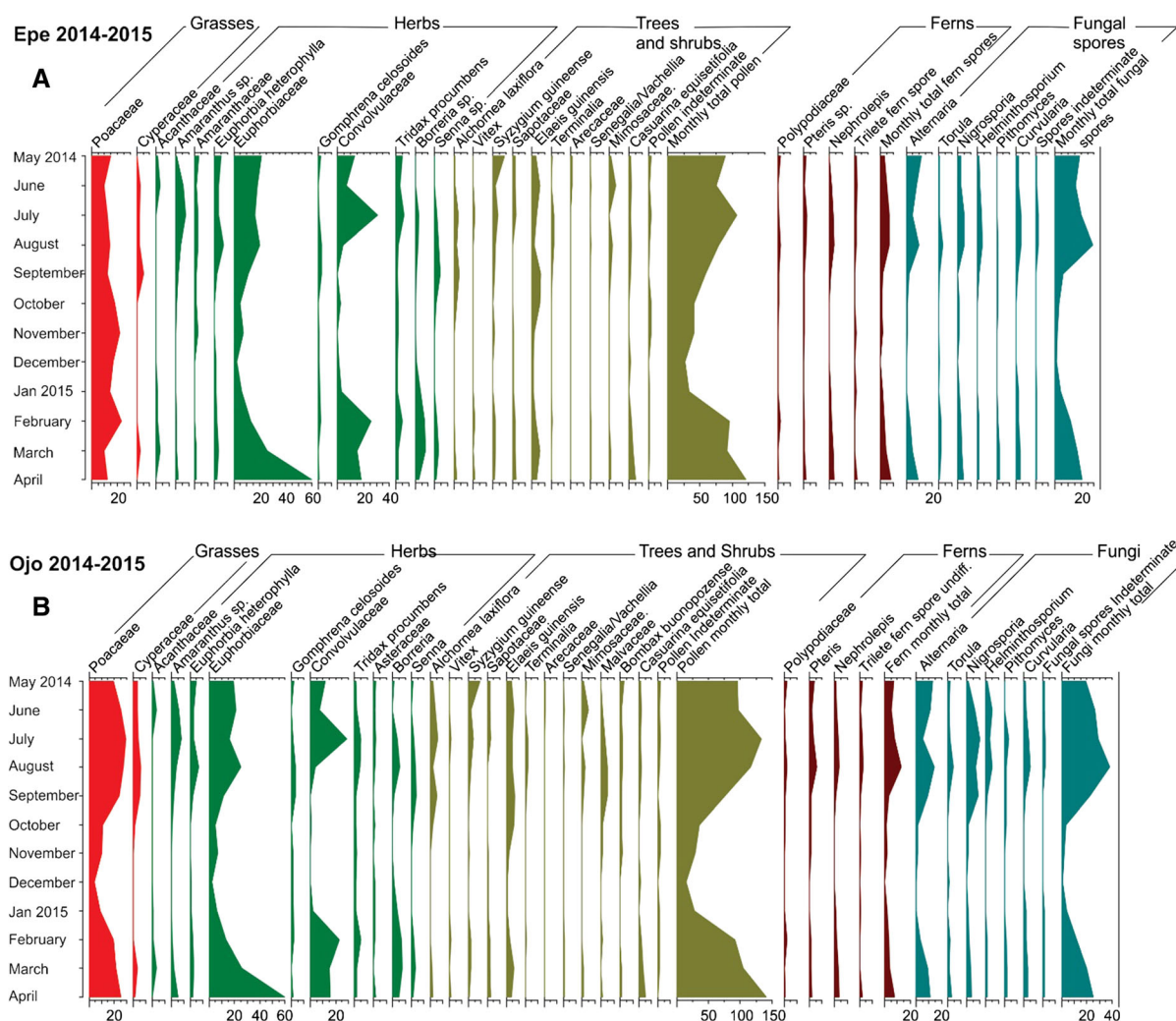


Fig. 3 **A** Absolute pollen and spore fluctuations of spore trap Epe, May 2014–April 2015, **B** absolute pollen and spore fluctuations of spore trap Ojo, May 2014–April 2015

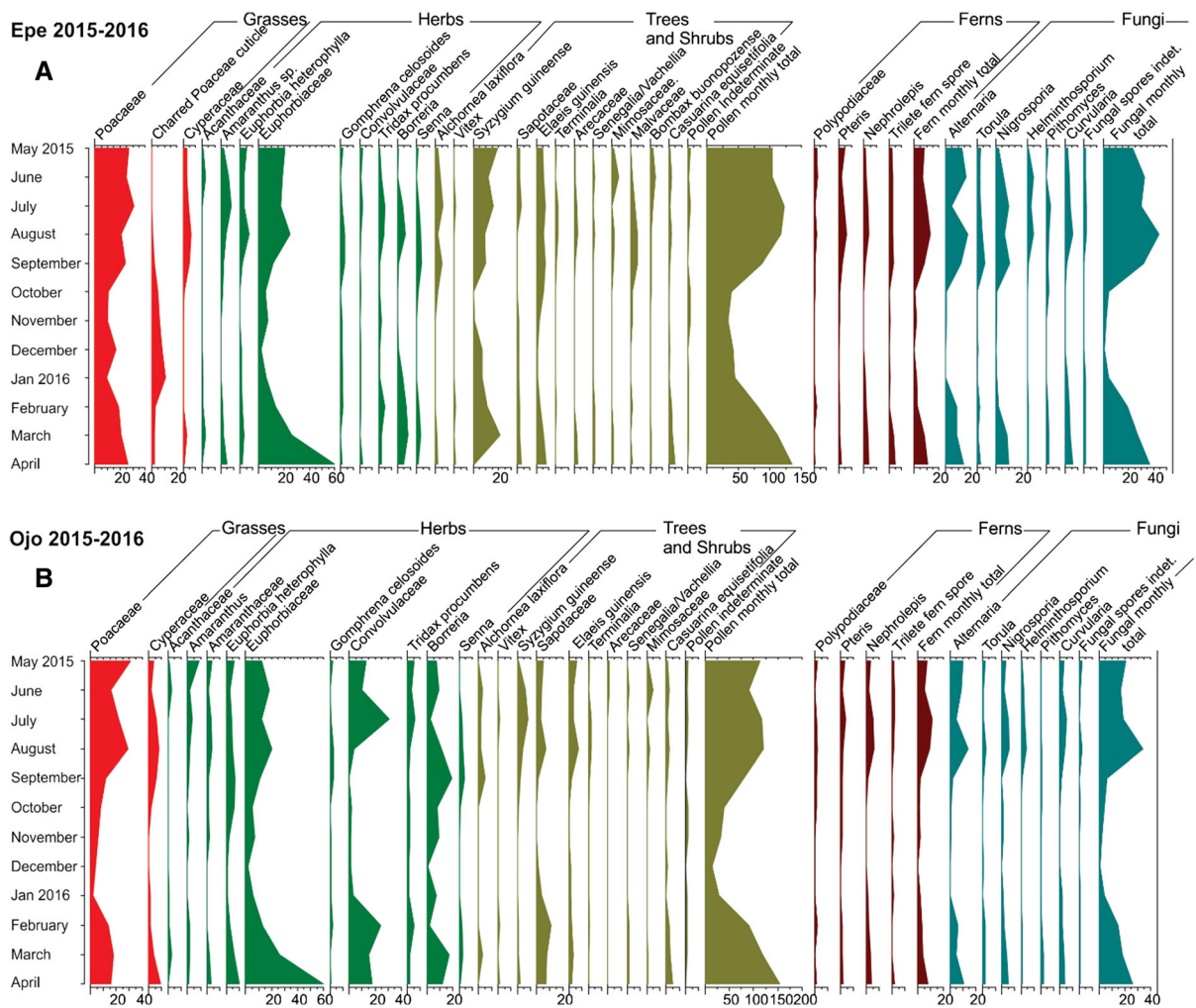


Fig. 4 **A** Absolute pollen and spore fluctuations of spore trap Epe, May 2015–April 2016, **B** absolute pollen and spore fluctuations of spore trap Ojo, May 2015–April 2016

pollen type can be morphologically differentiated from other members of the Euphorbiaceae with similar pollen morphology, representing varied growth forms (herbs, shrubs, trees, etc.). Pollen grains of *Euphorbia heterophylla* are tricolpate as seen in many species of Euphorbiaceae, but its colpi are slender, long, and ellipsoidal not clearly distinct and the exine is rather thick, and sexine pattern is gemmate, forming spines, contour fluctuating allowing the palynological differentiation from other members of Euphorbiaceae. At both study locations, spores of *Pteris* sp., *Nephrolepis* sp., and a trilete fern spore were detected.

Both locations exhibited the same airborne mycoflora, as represented by *Alternaria* sp., *Torula* sp., *Nigrospora* sp. (plate S4:1), *Helminthosporium* sp.,

Curvularia sp., *Pithomyces* sp., and other indeterminate types. Spores of *Alternaria* sp., *Nigrospora* sp., and *Curvularia* sp. were most abundant in both locations.

At both study sites in Lagos State, higher concentrations of atmospheric fungi were observed in August, during the first (13.33%) and second (17.19%) years of sampling in Epe, first (18.91%) and second (20.36%) sampling years in Ojo. Both locations also yielded lower records in December, 0.39% and 0.67% in Epe and 0.5% and 0.6% in Ojo for the first and second sampling years, respectively (tables S1–4).

4 Discussion

This study has revealed variations in the monthly depositional rate of pollen and fern spores across the study locations 2014–2015 and 2015–2016 for sum of the monthly pollen and spore occurrence carried out, which indicate significant variation in the monthly occurrence and deposition of the aeroapora across the study locations (Table 2). This is supported by Frenze (2000), who remarked that airborne pollen and spore concentration exhibits variability because pollen from nearby vegetation tends to exert a profound local influence on the recovered palynomorphs. At the two study sites, the highest atmospheric pollen level was observed in April, with the lowest records between November and December (Figs. 3,4). This is in conformity with Okwong et al. (2019) and Essien (2019), who reported the highest prevalence of airborne pollen between the months of April to July. These high recoveries of pollen are linked to increased blossoming during this period; also the frequency of pollen grains generally depends on the distribution and density of local vegetation as well as the rate of pollen production. Hence, they are more abundant in the air during their respective pollination period. This is confirmed by Malu (2014) who affirmed that most plants may not undergo anthesis in December, unlike the onset of rains when most flowering plants blossom. These records, however, contrast with the findings of Adeniyi et al. (2010) who reported an incidence of greater pollen load in the month of October and December at their study locations and attributed their high recovery to the influence of meteorological factors. During the dry season, December until March, when the harmattan is prevailing, no change in pollen composition was observed at all sites. This might be explained by the sampling sites being situated deep within the lowland rain forest zone so that the influence from the north, especially the savanna, was weak.

Pollen of some identified autochthonous plants was also represented in the atmospheric pollen spectra of the study locations (Figs. 3, 4).

At the study site in Epe, pollen types of *Alchornea cordifolia*, *Borreria scabra*, *Casuarina equisetifolia*, *Euphorbia heterophylla*, *Elaeis guineensis*, *Sida* sp., Asteraceae, Cyperaceae, Euphorbiaceae, Acanthaceae, Amaranthaceae, and Poaceae were produced by the surrounding plants. At the study site in Ojo,

plants within the immediate vegetation produced pollen types of *Alchornea cordifolia*, *Elaeis guineensis*, *Borreria scabra*, *Casuarina equisetifolia*, *Euphorbia heterophylla*, Malvaceae, Cyperaceae, Arecaceae, Acanthaceae, Amaranthaceae, Euphorbiaceae, Asteraceae, and Poaceae.

Globally, Poaceae pollen is regarded as the major allergen and as one of the most important factors for AR and/or asthma (Subiza et al., 1992, Garcia-Mozo, 2017). In Africa, e.g., South Africa, grass-dominated biomes like the savanna are widespread and feature a high diversity of Poaceae species which show a considerable cross-reactivity between different grass pollens (Davies, 2014; Potter, 2010). Grass pollen is also a major cause of AR in Nigeria (Adeniyi et al., 2018). Poaceae were dominant at the study sites. Also, Euphorbiaceae, Convolvulaceae, *Tridax procumbens*, *Syzygium guineense*, and *Elaeis guineensis* were prevalent in the aerospora of both Epe and Ojo (Figs. 3,4), between 2014–2015 and 2015–2016; their dominance was due to the widespread nature of this group of plants in the surrounding environment of the study sites. *Tridax procumbens* is a common weed in the tropics and subtropics (Gosh et al., 2019), evidencing human disturbance at the study site. The oil palm, *Elaeis guineensis*, is another indicator for possible disturbance since it is an element of secondary vegetation but also a cultivar (Sowunmi, 1999). *Casuarina equisetifolia*, regularly encountered during the botanical survey but also in the aerobiological samples of both sites, is an Australian neophyte planted widely, especially at the seashore for the exploitation of its biologically active compounds (Ogunwande et al., 2011). *Alchornea laxiflora*, regularly encountered in the aerobiological samples at Ojo and Epe, is regarded as another indicator for landscape degradation in Nigeria (Sehinde et al., 2016). Some ferns, e.g., *Nephrolepis* sp., also detected among other fern spores at both Ojo and Epe, are pioneer plants occurring in disturbed areas in Nigeria (Sehinde et al., 2016).

The association between the recovered aerospora of the two locations showed similarities. Pollen grains of Convolvulaceae were also dominant, largely because of weather parameters, especially in regard to wind which support the movement of pollen in the air (Essien, 2019). This is because airborne pollen exhibits seasonal fluctuations in quantity as well as composition. Unspecified numbers and type of these

grains remain airborne after the flowering season. Also, Alebiosu et al. (2018) earlier reported that airborne pollen types of Poaceae, Cyperaceae, *Elaeis guineensis*, among others, were produced by plants of the local vegetation. In the current study, the existing pollen–vegetation relationship is consistent with Njokuocha (2006) and Adeonipekun (2012) who reported that a considerable number of atmospheric pollen types were produced by the surrounding vegetation at their study locations. They affirmed the important contribution of airborne pollen load by autochthonous plants, as a major source of aeroflora.

Some of the dominant plants in this study have been previously reported from the region, including *Elaeis guineensis* and Poaceae (Agwu & Osibe, 1992; Alebiosu et al., 2018; Ezike et al., 2016; Njokuocha, 2006); *Alchornea cordifolia* (Adekanmbi et al., 2018; Essien & Agwu, 2013a, 2013b; Njokuocha, 2006); and Cyperaceae (Adeniyi et al., 2014; Alebiosu et al., 2018). Adekanmbi et al. (2018) reported that pollen of *Alchornea cordifolia* and *Tridax procumbens* is potential allergens, in which they observed alopecia in *Mus musculus* subcutaneously sensitized with pollen of *Alchornea cordifolia*. It is noteworthy that a considerable similarity was observed in the atmospheric pollen spectra of both study sites, with a total number of 12 of the same pollen types recorded (Figs. 3, 4). This incidence might have resulted from a similar subvegetation type found in the immediate localities of the study sites (Alebiosu et al., 2018).

The high recovery of fern and fungal spores in both locations peaking in August/September and March/April in both years was recorded during the early and late rainy season and declined in the drier months (October–December). According to Friday & Chukwunonyelum (2017) and Hutchinson and Dalziel (1954), this can be interpreted as a result of some ferns sporulating due to unfavorable/dry conditions. Ferns in Lagos State mainly sporulate between April and July (Adeonipekun et al., 2019b), which is in good agreement with our aerobiological results. The dominance of *Pteris* sp. and *Nephrolepis* sp. at the study sites confirms earlier findings of Njokuocha (2006), Adeonipekun et al. (2016), and Alebiosu et al. (2018). A greater representation of *Pteris dentata*, *Pteris* sp., and another type of trilete spore was previously reported by Essien et al. (2014). The recovery of these fern spore types in this study portends the establishment of a surrounding freshwater swamp forest,

consisting of their source fern plants. In addition, sporulation of dominant fungi, including *Curvularia* sp., *Nigrospora* sp., and *Helminthosporium* sp., has been previously related to possible allergic reactions (Ezikanyi et al., 2017). Spores of *Curvularia* and *Nigrospora* species have been linked to considerable dermal sensitization among Type 1 allergic patients in Corpus Christi, Texas, USA (Taketomi et al., 2006). Twaroch et al. (2015) observed that *Curvularia* induces allergic sinusitis and bronchopulmonary disorders, while Zainab and Ahmed (2013) noted that *Nigrospora* species caused allergic dermatitis among patients with respiratory allergic conditions.

5 Conclusions

This study covers a two-year period showing annual fluctuations of aerospora from a region where only few one-year studies exist next to studies only covering a few months. Therefore, the current study is significant both in terms of ecological interpretations and for a better understanding of exposure of allergy sufferers to allergenic aerospora.

A significant relationship exists between identified pollen spectra and autochthonous plants at the study locations; especially, the impact of degraded vegetation and cultivated plants is signaled due to the occurrence of neophytes like *Casuarina equisetifolia* and the oil palm (*Elaeis guineensis*) which is an indigenous component of the secondary forest but is also widely planted for its oil-rich seeds in West Africa. Typical weeds at both study sites include *Tridax procumbens*.

This study has provided basic information about candidate allergens in the atmosphere of the study sites; hence, there is the need to further investigate their allergenic potentials. The considerable similarity in the airborne pollen spectra of both sites is indicative of the same pollen exposure to hypersensitive individuals within the two areas, thereby posing similar pollinosis risks such as AR, allergic dermatitis, and asthma exacerbation.

It is recommended that a wider scaled aerobiological sampling targeting most industrialized and densely populated cities and towns should be conducted for longer periods of between 3 and 10 years in Nigeria, in order to acquire and capture a more robust and extensive understanding of the seasonality and

distribution of aerospora. Here, spore traps can be located in cities, ideally where survey results in regard to asthma and AR are available (Ozoh et al., 2019). Annual pollen monitoring should be also undertaken in regions where little information is available about the possible reflection of the surrounding vegetation in spore traps, e.g., in the Chad basin. We suggest a collaboration in terms of knowledge transfer and additional funding options with other African countries, e.g., South Africa, where the South African Pollen Monitoring Network (SAPNET) so far covers seven major cities since August 2019 (Ajikah et al., 2020). The Tauber spore trap, although much less cost-intensive than other systems and sufficient for overview and preliminary studies, has serious shortcomings with respect to a more precise calculation of pollen calendars and a better understanding of shifts in phenology. We therefore suggest the introduction of 7-day volumetric spore traps like the Burkard spore trap which, other than the Tauber trap, gives accurate daily fluctuations of aerospora. This would allow for a precise determination of flowering seasons and would not only enhance the benefit for pollen allergy sufferers but also give insights into phenology that will be useful for ecologists.

Acknowledgements We are grateful to the Wits School of Governance, sponsors of the Life in the City project, for providing funds for the lead author's research. We thank the University of Witwatersrand for offering the lead author a post-doctoral opportunity and the Evolutionary Studies Institute for providing a platform for this work to be carried out. We would also like to acknowledge the financial support of the Durand Foundation and the University of Lagos Central Research Committee (CRC). We are grateful to the editor and three anonymous reviewers who helped to improve this manuscript.

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3. Supplements

Table S3:1 Atmospheric Pollen and Spore counts at the study location in Epe, Lagos, Nigeria (2014/2015)

S/N	POLLEN TAXA	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	TOTAL
1.	<i>Alchornea cordifolia</i>	1	1	3	2	4	2	0	0	0	0	1	2	16
2.	<i>Syzygium guineense</i>	9	2	4	2	1	0	1	0	0	2	2	1	24
3.	Acanthaceae	1	3	0	0	0	0	0	0	1	1	3	0	9
4.	Amaranthaceae	3	1	2	2	1	1	2	0	0	0	1	1	14
5.	Poaceae	15	10	12	14	12	18	22	17	14	23	10	12	179
6.	Euphorbiaceae	21	18	16	20	11	5	7	2	6	13	26	60	205
7.	Sapotaceae	2	2	3	0	0	0	1	1	1	2	2	3	17
8.	<i>Elaeis guineensis</i>	3	6	4	2	7	6	2	1	1	3	6	4	45
9.	Convolvulaceae	1	0	2	0	0	1	0	1	1	1	0	2	9
10.	Cyperaceae	0	3	2	2	5	0	0	0	0	0	3	0	15
11.	<i>Vitex</i> sp.	0	0	1	0	0	0	0	0	0	1	0	1	3
12.	<i>Terminalia</i> sp.	1	0	2	2	1	0	0	0	0	1	0	0	7
13.	Arecaceae	1	1	0	0	0	0	0	0	0	0	0	0	2
14.	<i>Gomphrena celosioides</i>	2	0	1	3	3	0	1	1	0	2	0	1	14
15.	<i>Acacia</i> sp.	0	1	0	1	0	0	0	0	0	1	1	1	5
16.	Mimosaceae	1	5	0	2	1	0	0	0	0	0	1	1	11
17.	Convolvulaceae	12	7	29	4	0	1	0	0	2	23	15	16	109
18.	<i>Amaranthus</i> sp.	1	6	8	4	2	1	0	0	0	1	1	2	26
19.	Asteraceae	5	3	6	2	1	2	2	1	1	5	2	2	32
20.	<i>Borreria scabra</i>	0	0	3	2	1	0	0	1	4	7	8	3	29
21.	<i>Euphorbia heterophylla</i>	5	3	3	7	2	0	0	1	1	2	3	2	29
22.	<i>Senna</i> sp.	0	0	2	3	4	1	0	0	0	2	3	1	16
23.	<i>Casuarina equisetifolia</i>	1	2	1	2	1	0	0	1	0	2	3	5	18
24.	Pollen Indeterminate	2	1	2	1	0	2	2	0	1	1	1	0	13
	Monthly Total Pollen count	87	75	106	77	57	40	40	27	33	93	92	120	847

	% Monthly Occurrence	10.3	8.86	12.5	9.1	6.73	4.7	4.72	3.19	3.9	11	10.86	14.17	
	Fern spores													
1.	<i>Pteris</i> sp.	2	1	3	2	1	1	1	0	0	1	1	2	15
2.	<i>Nephrolepis</i> sp.	0	2	3	4	1	0	0	0	1	2	3	4	20
3.	Trilete fern spore	3	2	2	3	1	1	1	0	1	2	0	3	19
	Monthly Total Fern spore count	5	5	8	9	3	2	2	0	2	5	4	9	54
	% Monthly Occurrence	9.26	9.26	14.8	17	5.56	3.7	3.7	0	3.7	9.26	7.41	17	
	Fungal spores													
1.	<i>Alternaria</i> sp.	12	8	5	10	2	1	1	0	0	3	5	9	56
2.	<i>Torula</i> sp.	1	1	1	3	1	0	0	1	0	2	2	1	13
3.	<i>Nigrospora</i> sp.	2	2	5	5	0	1	1	0	1	2	3	4	26
4.	<i>Helminthosporium</i> sp.	1	2	3	4	1	0	0	0	0	1	1	1	14
5.	<i>Pithomyces</i> sp.	0	0	0	1	1	1	0	0	0	1	2	2	8
6.	<i>Curvularia</i> sp.	2	2	4	4	1	0	0	0	2	2	3	3	23
7.	Spores Indeterminate	1	1	2	2	0	0	0	0	1	1	1	1	10
	Monthly Total Fungal spore count	19	16	20	29	6	3	2	1	4	12	17	21	150
	% Monthly Occurrence	12.7	10.7	13.3	19	4	2	1.33	0.67	2.67	8	11.33	14	

Table S3:2 Atmospheric Pollen and Spore counts at the study location in Epe, Lagos, Nigeria (2015/2016)

S/N	POLLEN TAXA	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	TOTAL
1.	Poaceae	27	25	31	21	24	11	10	17	9	19	21	26	241
2.	Asteraceae	1	2	5	4	1	1	2	1	1	5	2	2	27

3.	<i>Bombax buonopozense</i>	2	4	2	1	1	1	0	0	0	0	1	1	13
4.	<i>Casuarina equisetifolia</i>	1	2	1	2	1	0	0	1	0	2	3	5	18
5.	<i>Amaranthus</i> sp.	2	6	8	4	2	1	0	0	0	1	2	5	31
6.	<i>Alchornea cordifolia</i>	2	4	6	2	5	2	0	0	0	0	1	2	24
7.	Euphorbiaceae	21	19	17	25	11	5	7	2	6	13	26	60	212
8.	Arecaceae	1	1	2	3	1	0	0	0	0	0	2	3	13
9.	Cyperaceae	3	3	4	6	5	1	0	0	0	0	3	1	26
10.	<i>Borreria</i> sp.	1	0	4	6	1	0	0	1	4	7	8	5	37
11.	<i>Elaeis guineensis</i>	5	6	7	6	7	6	2	1	1	3	6	8	58
12.	Convolvulaceae	2	1	2	1	0	1	0	1	1	1	0	2	12
13.	<i>Syzygium guineense</i>	19	12	16	9	10	0	1	7	7	11	21	1	114
14.	Acanthaceae	1	3	0	0	0	0	0	0	1	1	3	0	9
15.	<i>Sida</i> sp.	0	1	3	5	5	1	1	0	0	1	0	1	18
16.	Sapotaceae	2	2	3	0	0	0	1	1	1	2	2	3	17
17.	<i>Vitex</i> sp.	0	0	1	0	0	0	0	0	0	1	0	1	3
18.	<i>Terminalia</i> sp.	1	0	2	2	1	0	0	0	0	1	0	0	7
19.	<i>Euphorbia heterophylla</i>	5	3	3	7	2	0	0	1	1	2	3	2	29
20.	<i>Senna</i> sp.	1	0	2	3	4	1	0	0	0	2	3	1	17
21.	<i>Gomphrena celosioides</i>	2	0	1	3	3	0	1	1		2	0	1	14
22.	<i>Acacia</i> sp.	0	1	0	1	0	0	0	0	0	1	1	1	5
23.	Mimosaceae	1	5	0	2	1	0	0	0	0	0	1	1	11
24.	Pollen Indeterminate	2	1	2	1	0	2	2	0	1	1	1	0	13
	Monthly Total Pollen count	102	101	122	114	85	33	27	34	33	76	110	132	969
	% Monthly Occurrence	10.5	10.42	12.6	11.77	8.77	3.41	2.79	3.51	3.41	7.8	11.35	13.62	
	Fern spores													
1.	<i>Pteris</i> sp.	5	2	4	6	3	1	1	0	0	1	1	2	26

2.	<i>Nephrolepis</i> sp.	1	2	3	4	1	0	0	0	1	2	3	4	39
3.	Trilete fern spore	4	6	4	5	5	1	1	0	1	2	4	6	21
	Monthly Total Fern Spore count	10	10	11	15	9	2	2	0	2	5	8	12	86
	% Monthly Occurrence	11.6	11.63	12.8	17.44	10.5	2.33	2.33	0	2.33	5.8	9.3	13.95	
	Fungal spores													
1.	<i>Alternaria</i> sp.	13	16	5	18	12	1	1	0	0	9	9	14	98
2.	<i>Torula</i> sp.	3	2	3	4	6	0	0	1	0	2	1	3	25
3.	<i>Nigrospora</i> sp.	2	6	10	7	11	1	1	0	1	2	9	10	60
4.	<i>Helminthosporium</i> sp.	1	5	3	5	1	0	0	0	0	1	1	1	18
5.	<i>Pithomyces</i> sp.	1	0	3	2	1	2	0	0	0	1	2	2	14
6.	<i>Curvularia</i> sp.	2	3	4	6	1	0	0	0	2	3	4	6	31
7.	Spores Indeterminate	1	1	2	2	0	0	0	0	1	1	1	1	10
	Monthly Total Fungal spore count	23	33	30	44	32	4	2	1	4	19	27	37	256
	% Monthly Occurrence	8.98	12.89	11.7	17.19	12.5	1.56	0.78	0.39	1.56	7.4	10.55	14.45	

Table S3:3 Atmospheric Pollen and Spore counts at the study location in Ojo, Lagos, Nigeria (2014/2015)

S/N	POLLEN TAXA	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL	TOTAL
1.	<i>Elaeis guineensis</i>	4	6	5	5	7	6	2	1	1	3	6	4	50
2.	Asteraceae	2	1	2	1	0	1	0	1	1	1	0	2	12
3.	Cyperaceae	3	3	4	6	5	1	0	0	0	0	3	1	26
4.	<i>Borreria scabra</i>	1	0	4	6	1	0	0	1	4	7	8	5	37
5.	<i>Euphorbia heterophylla</i>	5	3	3	7	2	0	0	1	1	2	3	2	29
6.	<i>Senna</i> sp.	1	0	2	3	4	1	0	0	0	2	3	1	17
7.	<i>Amaranthus</i> sp.	2	6	8	4	2	1	0	0	0	1	2	5	31
8.	<i>Alchornea cordifolia</i>	2	4	6	2	5	2	0	0	0	0	1	2	24

9.	Euphorbiaceae	19	21	16	25	11	5	7	2	6	13	26	60	211
10.	Sapotaceae	2	2	3	0	0	0	1	1	1	2	2	3	17
11.	<i>Vitex</i> sp.	0	0	1	0	0	0	0	0	0	1	0	1	3
12.	<i>Terminalia</i> sp.	1	0	2	2	1	0	0	0	0	1	0	0	7
13.	Arecaceae	1	1	0	0	0	0	0	0	0	0	0	0	2
14.	<i>Gomphrena celosioides</i>	2	0	1	3	3	0	1	1	0	2	0	1	14
15.	<i>Acacia</i> sp.	0	1	0	1	0	0	0	0	0	1	1	1	5
16.	Mimosaceae	1	5	0	2	1	0	0	0	0	0	1	1	11
17.	Convolvulaceae	12	7	29	4	0	1	0	0	2	23	15	16	109
18.	Poaceae	19	25	29	27	24	11	10	4	9	19	21	25	223
19.	Asteraceae	1	2	5	4	1	1	2	1	1	5	2	2	27
20.	<i>Syzygium guineense</i>	9	2	4	2	1	0	1	0	0	2	2	1	24
21.	Acanthaceae	1	3	0	0	0	0	0	0	1	1	3	0	9
22.	Malvaceae	0	1	3	5	5	1	1	0	0	1	0	1	18
23.	<i>Bombax buonopozense</i>	3	1	2	2	1	1	2	0	0	0	1	1	14
24.	<i>Casuarina equisetifolia</i>	1	2	1	2	1	0	0	1	0	2	3	5	18
25.	Pollen Indeterminate	2	1	2	1	0	2	2	0	1	1	1	0	13
	Monthly Total Pollen count	94	97	132	114	75	34	29	14	28	90	104	140	951
	% Monthly Occurrence	9.88	10.2	13.9	12	7.89	3.58	3.05	1.47	2.9	9.5	10.94	14.72	
	Fern spores													
	<i>Pteris</i> sp.	4	2	4	6	1	1	1	0	0	1	1	2	23
	<i>Nephrolepis</i> sp.	4	1	2	3	2	2	1	0	1	2	0	3	21
	Trilete fern spore	1	2	3	4	1	0	0	0	1	2	3	4	21
	Monthly Total Fern Spore count	9	5	9	13	4	3	2	0	2	5	4	9	65

	% Monthly Occurrence	13.9	7.69	13.9	20	6.15	4.62	3.08	0	3.1	7.7	6.15	13.85	
	Fungal spores													
	<i>Alternaria</i> sp.	13	11	5	14	9	1	1	0	0	3	9	11	77
	<i>Torula</i> sp.	2	1	2	4	1	0	0	1	0	2	1	3	17
	<i>Nigrospora</i> sp.	1	6	10	7	9	1	1	0	1	2	3	4	45
	<i>Helminthosporium</i> sp.	1	5	3	5	1	0	0	0	0	1	1	1	18
	<i>Pithomyces</i> sp.	0	0	3	1	1	1	0	0	0	1	2	2	11
	<i>Curvularia</i> sp.	1	2	4	5	1	0	0	0	2	2	3	3	23
	Spores Indeterminate	1	1	2	2	0	0	0	0	1	1	1	1	10
	Monthly Total Fungal spore count	19	26	29	38	22	3	2	1	4	12	20	25	201
	% Monthly Occurrence	9.45	12.9	14.4	18.9	11	1.49	0.99	0.5	2	6	9.95	12.44	

Table S3:4 Atmospheric Pollen and Spore counts at the study location in Ojo, Lagos, Nigeria (2015/2016)

S/N	POLLEN TAXA	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL	TOTAL
1.	Cyperaceae	4	2	6	8	6	2	0	0	1	1	4	9	43
2.	<i>Amaranthus</i> sp.	9	2	4	2	1	0	1	0	0	2	2	1	24
3.	Acanthaceae	1	3	0	0	0	0	0	0	1	1	3	0	9
4.	Amaranthaceae	4	1	3	4	1	1	2	0	0	0	2	3	21
5.	Poaceae	31	16	22	29	12	8	6	4	2	14	18	16	178
6.	Euphorbiaceae	12	18	12	20	11	5	7	2	6	13	26	60	192
7.	<i>Borreria scabra</i>	7	9	3	11	19	8	9	1	7	2	17	12	105
8.	<i>Euphorbia heterophylla</i>	6	3	4	5	7	6	2	1	1	3	6	10	54
9.	Convolvulaceae	1	0	2	0	0	1	0	1	1	1	0	2	9
10.	<i>Alchornea cordifolia</i>	0	3	2	2	5	0	0	0	0	0	3	0	15
11.	<i>Vitex</i> sp.	0	0	1	0	0	0	0	0	0	1	0	1	3

12.	<i>Terminalia</i> sp.	1	0	2	2	1	0	0	0	0	1	0	0	7
13.	Arecaceae	1	1	0	0	0	0	0	0	0	0	0	0	2
14.	<i>Gomphrena celosioides</i>	2	0	1	3	3	0	1	1	1	2	0	1	15
15.	<i>Acacia</i> sp.	0	1	0	1	0	0	0	0	0	1	1	1	5
16.	Mimosaceae	1	5	0	2	1	0	0	0	0	0	1	1	11
17.	Convolvulaceae	12	7	29	4	0	1	0	0	2	23	15	16	109
18.	<i>Syzygium guineense</i>	1	6	8	4	2	1	0	0	0	1	1	2	26
19.	Asteraceae	5	3	6	2	1	2	2	1	1	5	2	2	32
20.	Sapotaceae	5	4	3	7	1	0	0	1	4	11	8	7	51
21.	<i>Elaeis guineensis</i>	6	3	3	7	2	0	0	1	1	2	3	2	30
22.	<i>Senna</i> sp.	0	0	2	3	4	1	0	0	0	2	3	1	16
23.	<i>Casuarina equisetifolia</i>	1	2	1	2	1	0	0	1	0	2	3	5	18
24.	Pollen Indeterminate	2	1	2	1	0	2	2	0	1	1	1	0	13
	Monthly Total	112	90	116	119	78	38	32	14	29	89	119	152	988
	% Monthly Occurrence	11.3	9.11	11.7	12.05	7.9	3.85	3.24	1.42	2.94	9.01	12.05	15.39	
	Fern spores													
1.	<i>Pteris</i> sp.	3	1	4	2	1	1	1	0	0	1	1	2	17
2.	<i>Nephrolepis</i> sp.	3	2	5	6	1	0	0	0	1	2	3	4	27
3.	Trilete fern spore	3	2	3	3	2	1	1	0	1	2	0	3	21
	Monthly Total	9	5	12	11	4	2	2	0	2	5	4	9	65
	% Monthly Occurrence	13.9	7.69	18.5	16.92	6.15	3.08	3.08	0	3.08	7.69	6.15	13.9	
	Fungal spores													
1.	<i>Alternaria</i> sp.	10	9	5	14	2	1	1	0	0	6	5	11	64
2.	<i>Torula</i> sp.	2	1	1	3	1	0	0	1	0	2	2	2	15
3.	<i>Nigrospora</i> sp.	3	2	5	6	0	1	1	0	1	2	4	5	30

4.	<i>Heminthosporium</i> sp.	1	2	3	4	1	0	0	0	0	1	1	1	14
5.	<i>Pithomyces</i> sp.	0	0	0	1	1	1	0	0	0	1	2	2	8
6.	<i>Curvularia</i> sp.	3	2	5	4	1	0	0	0	2	2	3	4	26
7.	Spores Indeterminate	2	1	0	2	0	1	0	0	1	1	1	1	10
	Monthly Total	21	17	19	34	6	4	2	1	4	15	18	26	167
	% Monthly Occurrence	12.6	10.18	11.4	20.36	3.59	2.4	1.2	0.6	2.4	8.98	10.78	15.57	

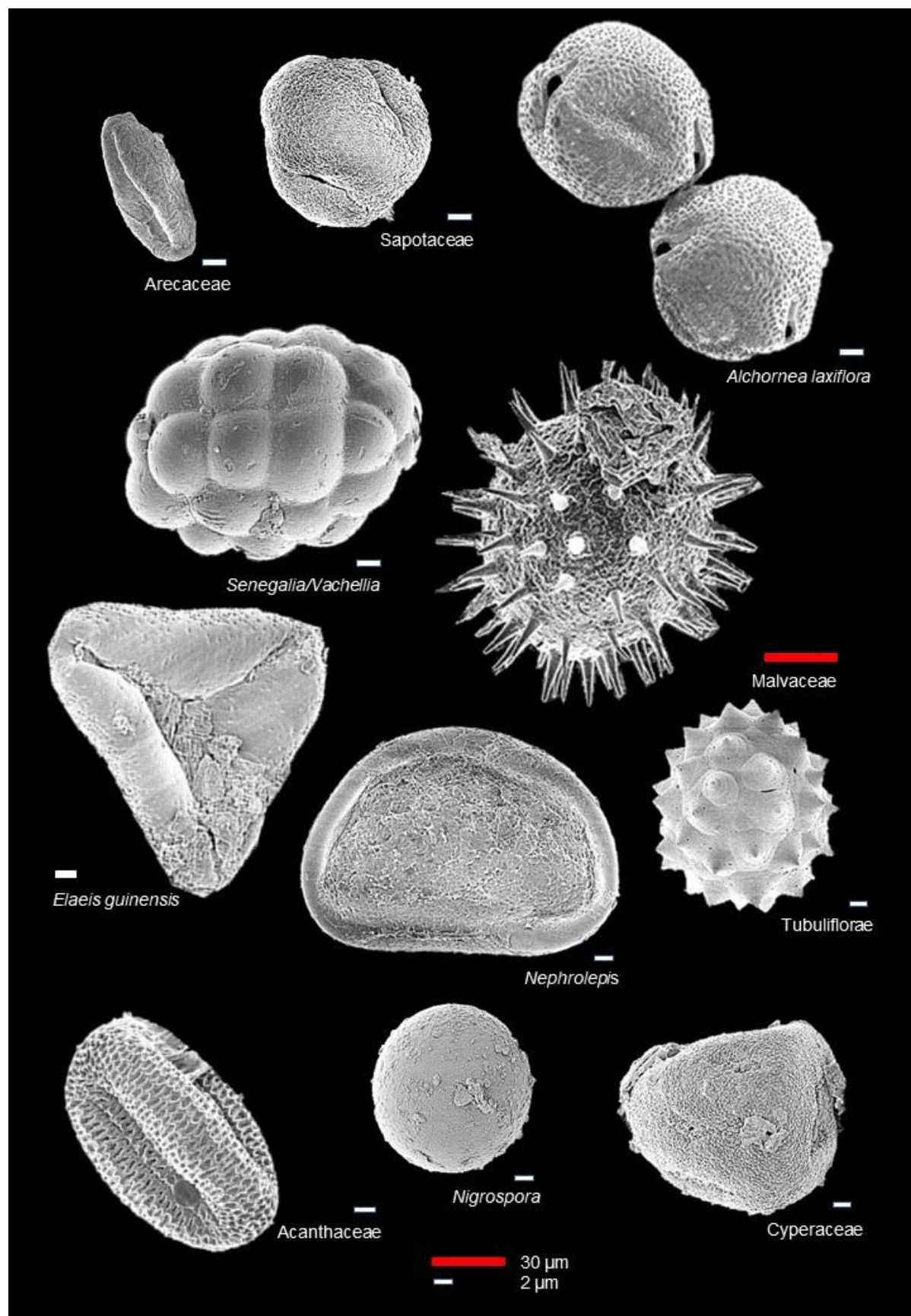


Plate S4:1 Scanning Electron Microscope (SEM) microphotos of several important aerospora of sites Epe and Ojo