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Aeropalynological study of two selected locations in North-Central Nigeria

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Abstract Pollen and spores have been found as major biological sources of morbidity among individuals sensitive to respiratory disorders. The aim of the present study was to analyse the deposition rate of atmospheric pollen and fern spores at selected sites in Benue and Plateau states of the North-Central Nigeria between July 2015 and June 2016. This was accomplished by: (1) determining the pollen and fern spore content of each monitoring station; (2) establishing the relationship between total pollen count and meteorological parameters; and (3) comparing the recovered airborne pollen spectra with identified plants in the surrounding vegetation types of the sampling sites. The collection of atmospheric pollen was done using a modified Tauber sampler and plants in the surrounding environment of the sampling sites were enumerated. The residual solution was collected monthly and acetolysed, after which slide preparation and microscopy of the treated residue were done. Meteorological data were obtained from the Nigerian Meteorological Agency, Lagos. The results obtained reveal seasonal distribution patterns of various airborne pollen grains in the study locations. The most abundant pollen types recovered in Plateau State were produced by *Syzygium guineense*, *Tridax procumbens*, *Alchornea* sp., *Terminalia* sp., Poaceae and Amaranthaceae. Pollen types of *Casuarina equisetifolia*, *Syzygium guineense*, *Tridax procumbens*, Poaceae and Cyperaceae were preponderant in Benue State. *Pteris* sp., *Nephrolepis* sp. and a trilete fern spore were also represented in this study. The recovered airborne pollen spectra correspond favourably with some identified plants in the study locations. There was no significant correlation between monthly total pollen count and mean monthly values of meteorological parameters in Benue State. Air temperature and wind speed correlated significantly with monthly total pollen count in Plateau State. It is suggested that the allergenic effect of these abundant pollen types on humans should be further examined.

Keywords Aeropalynological · Meteorological · Allergenic · North-Central Nigeria · Seasonality

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1 Introduction

Bio-particles including pollen grains, fungal spores, insect debris, danders, dust mites, among other airborne substances are studied under the light of aeropalynology (Singh and Kumar 2004).

These substances are found to induce respiratory disorders such as asthma, allergic rhinitis and atopic dermatitis (International Study of Asthma and Allergies in Childhood 1998). Among these substances, pollen grains and fungal spores have been identified to induce morbidity among sensitive individuals (Singh and Dahiya 2008). The relative abundance and diversity of pollen and spores have been observed to be influenced by the effects of weather parameters such as rainfall, relative humidity, temperature, wind speed and direction (Agwu and Osibe 1992; Agwu 1997). However, these climatic factors are different in various geographical regions of the world. Proper monitoring of pollen distribution is needed in order to reduce their negative impacts on human health.

Recent aeropalynological studies have been conducted in Nigeria with contributions from different parts of the country. In South-western Nigeria, previous studies include Adekanmbi and Ogundipe (2010) who sampled four selected sites within Akoka campus, University of Lagos, Nigeria. Findings from their study revealed a total of 393 palynomorphs, belonging to 22 families. Poaceae was significantly represented. Other plant families were Asteraceae, Mimosaceae, Arecaceae and Euphorbiaceae, as well as fern spores. Adeonipekun (2012) carried out an aeropalynological study of Ayetoro-Itele Ota, South-western Nigeria, in March 2011. A total of 305 sporomorphs belonging to 17 plant families were recovered. Pollens of Poaceae, Chenopodiaceae/Amaranthaceae and Cyperaceae were preponderant. He reported that no savanna pollen was recorded, unlike previous findings on aeroflora of March 2010 at the same location, in which *Vitex* cf. *doniana*, *Parinari* spp. and *Isoberlina doka* of the Guinea/Sudan savanna were represented. The transportation of savanna pollen to the source of recovery was attributed to a late harmattan characterized by haze dust and triggered by a strange event in the previous year. 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. Ajikah et al. (2015) conducted an aeropalynological sampling at three different locations within Akoka campus, University of Lagos, Nigeria. In their findings, Poaceae, Cyperaceae, Sapotaceae, Combretaceae, Polypodiaceae, Adiantaceae and Euphorbiaceae produced palynomorphs with the highest airborne concentrations in their study locations. Ajikah et al. (2017) carried out an aeropalynological survey of three locations, Apapa, Ojo and Ikeja in Lagos, Nigeria, for a period of 3 months from May to July. They correlated monthly total pollen counts with mean values of meteorological parameters, including rainfall, relative humidity, air temperature and wind speed. According to their findings, highest total pollen count was observed in the month of May, with the lowest record in the month of June. They recorded no significant correlation between pollen data and values of meteorological parameters. They stated that a combination of some other factors might have been posed a significant effect on pollen distribution.

In South-eastern Nigeria, Njokuocha (2006) studied the aeroflora of Nsukka, Enugu State, and an average of 56 pollen types was recorded. Poaceae, *Alchornea cordifolia, Elaeis guineensis,* Asteraceae, Amaranthaceae/Chenopodaceae, Moraceae among others were identified as the most abundantly represented.

Contributions from North-Central Nigeria include Essien and Agwu (2013) where a total of 61 pollen types belonging to 36 plant families were reported in Anyigba environment, Kogi State. The predominant pollen types were those of Poaceae, *Elaeis guineensis*, *Lannea acida*, *Nauclea latifolia*, *Alchornea cordifolia*, *Syzygium guineense, Berlinia grandifolia, Senna* sp., Asteraceae tubiflorae complex and Combretaceae/Melastomaceae. Abdulrahaman et al. (2015) carried out a bimonthly aeropalynological investigation of the University of Ilorin, Nigeria. Predominant pollen types recorded in their study were those of Apocyanaceae, Poaceae and Cyperaceae. Ezike et al. (2016) provided an insight into the relationship between the prevalence of aerospora and meteorological parameters of a study location in Garki, Abuja, for a period of 1 year. A recovery of 53 pollen types belonging to 36 families was reported. Poaceae, *Pentaclethra macrophylla*, *Elaeis guineensis*, *Justicia* spp., *Cassia* sp. *Alchornea cordifolia* and *Luffa* spp. were identified as the major airborne pollen contributors.

However, most previous aeropalynological studies in Nigeria have been carried out in the southern areas of the country, and data from the north-central areas are scarce with no contribution from other parts of the northern region. There is still a paucity of information about the seasonal distribution of atmospheric pollen grains in different parts of the country. Also, little documentation exists on available pollen records generated over a period of 1 year in the entire country. Published works of Njokuocha (2006), Adeniyi et al. (2014) and Ezike et al. (2016) spanned a period of

1 year, thereby covering the traditional wet and dry seasons of the country.

This present study involved monitoring the deposition rate of atmospheric pollen and fern spores for a period of 1 year in North-Central Nigeria, in order to determine pollen and fern spore content, establish a relationship between total pollen count and meteorological parameters and compare the recovered airborne pollen spectra with identified plants in the immediate vegetation around the study sites.

2 Materials and methods

2.1 Description of the study area

The two study areas are located in North-Central Nigeria but are quite distant apart from each other, based on their respective geographical positions. They lie between latitude 7.740754°N and 8.518217°E longitude in Government Girls College, Makurdi, Benue State, and latitude 9°56′47.52″N and longitude 8°53′31.41″E in the Federal College of Forestry, Jos, Plateau State. The urbanized cities of Jos and Makurdi are developed areas of high population in the northern region (National Population Census 2006).

Jos, Plateau State, has a surface area of about 9400 km^2 and at an altitude of 1250 m above sea level (Olowolafe et al. 2004). The temperature is characterized by a warm weather condition during the rainy season (April to October), November to March as dry season and get extremely cold during the harmattan period (December to February). It has a mean annual rainfall of 1317.5 mm in the northern part, extending to 1460.0 mm in the southern part. The average annual temperature fluctuates between 20 and 25 °C (Ohemu et al. 2014). The soil types are alluvial, clayey loam, silt and loamy soils. (Danlami and Onimisi 2016). The remnant vegetation of the area is predominantly southern Guinea savanna with patches of gallery forests, rocky outcrop and savanna scrub (forming thickets), and bounded by short grasslands, with the grasses not exceeding 50 cm in height.

Makurdi, Benue State, has an altitude of 97 m above sea level (Ani et al. 2017). The climatic condition of this area is influenced by both wet and dry seasons. The rainy season normally spans from April to October and controlled by the moist south-westerly air mass, while the dry season prevails through the dry north-easterly air mass (Ologunorisa and Tersoo 2006). It has a mean annual rainfall of 1250 mm in the northern part, extending to 1750 mm in the southern part (Ama et al. 2015). It is also characterized by constantly high temperatures, averaging between 28 and 32 °C with an occasional rise to 37 °C, especially in Makurdi. The vegetation of this area consists of relics of the southern Guinea savanna with coarse grasses and numerous species of scattered trees. The soil type is a coarsely textured loamy soil.

2.2 Vegetation sampling

For the enumeration of local plants, a qualitative vegetation description was 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. They were identified using keys following the works of Keay (1989), Keay et al. (1964), Hutchinson and Dalziel (1954) and Dalziel (1937). Voucher specimens of all plants were collected and deposited at the University of Lagos Herbarium.

2.3 Setting up of pollen sampler

Sampling points were selected based on the safety of samplers employed and openness of the environment for free dispersal of airborne palynomorphs. An improvised pollen sampler (modified after Tauber 1974) consisting of an iron sampling stand and pollen trap (bucket) was constructed to collect airborne palynomorphs at each location (Adekanmbi and Ogundipe 2010; Ajikah et al. 2015; Ezike et al. 2016). The sampling stand was made up of a properly cemented iron rod, fixed with an iron ring at its topmost part and mounted at 5 ft. height above the ground level (head level). It was buried with one foot underground to aid its support and prevent it from being blown away by the wind. A solution of 50 ml glycerol (to prevent drying up of the biological particles), 5 ml phenol (to kill pollen-foraging insects) and 10 ml formaldehyde (to prevent the decay of dead organisms) was transferred into the pollen trap with a 17-cm-height and 23-cm aperture lid. This trap was covered with a mesh placed on the sampling stand (Fig. 1).

Fig. 1 A modified Tauber sampler mounted at one of the two study locations

2.4 Sample collection

Monthly collection of residual solution was done from July 2015 to June 2016, covering both rainy and dry seasons. After each collection, the trap was washed thoroughly with distilled water for subsequent monthly sampling in the study locations.

2.5 Sample treatment and microscopic observation

The solutions were centrifuged at 2500 r.p.m for 5 min. in order to separate the residues containing palynomorphs from the supernatant fluids. The recovered residues were then acetolysed following Erdtman (1969); preparation of acetolysis mixture consists of concentrated sulphuric acid and acetic anhydride in the volume ratio of 1:9, respectively, and 5 ml of the prepared mixture was transferred into each sample residue and heated in a water bath at 100 °C for 10 min. The residues were centrifuged and decanted. They were rinsed with distilled water and decanted; this process was repeated twice. The residues were stored in vials with the addition of two drops of glycerine for their preservation. Slide preparation involved the mounting of 0.5 ml of residues on glass slides for microscopy. 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) and Ezike et al. (2016). Photomicrographs in reference journals including Sowunmi (1973, 1995), Adekanmbi (2009a, b), Gosling et al. (2013) and unpublished albums were used for the identification of palynomorphs. Photomicrographs of some palynomorphs were captured digitally using a Motic 2300 digital camera (Fig. 2).

2.6 Meteorological data collection

Values of weather parameters including air temperature, wind speed, relative humidity and rainfall of the study locations within the sampling period were obtained from the Nigerian Meteorological Agency, Oshodi, Lagos.

2.7 Correlation between monthly total pollen counts and meteorological parameters

The relationship between monthly total pollen counts and mean monthly values of meteorological parameters in the study locations was examined using Pearson correlation test of SPSS statistics version 19.0. Correlation coefficients were obtained through a multivariate regression analysis carried out at 95% confidence interval.

3 Results

3.1 Palynological studies

In this study, 31 pollen types representing 20 plant families were identified. Eleven, ten and ten pollen types were identified to familial, generic and specific levels, respectively. Other unidentifiable pollen types were either morphologically described or designated as pollen indeterminate. At the study site in Plateau

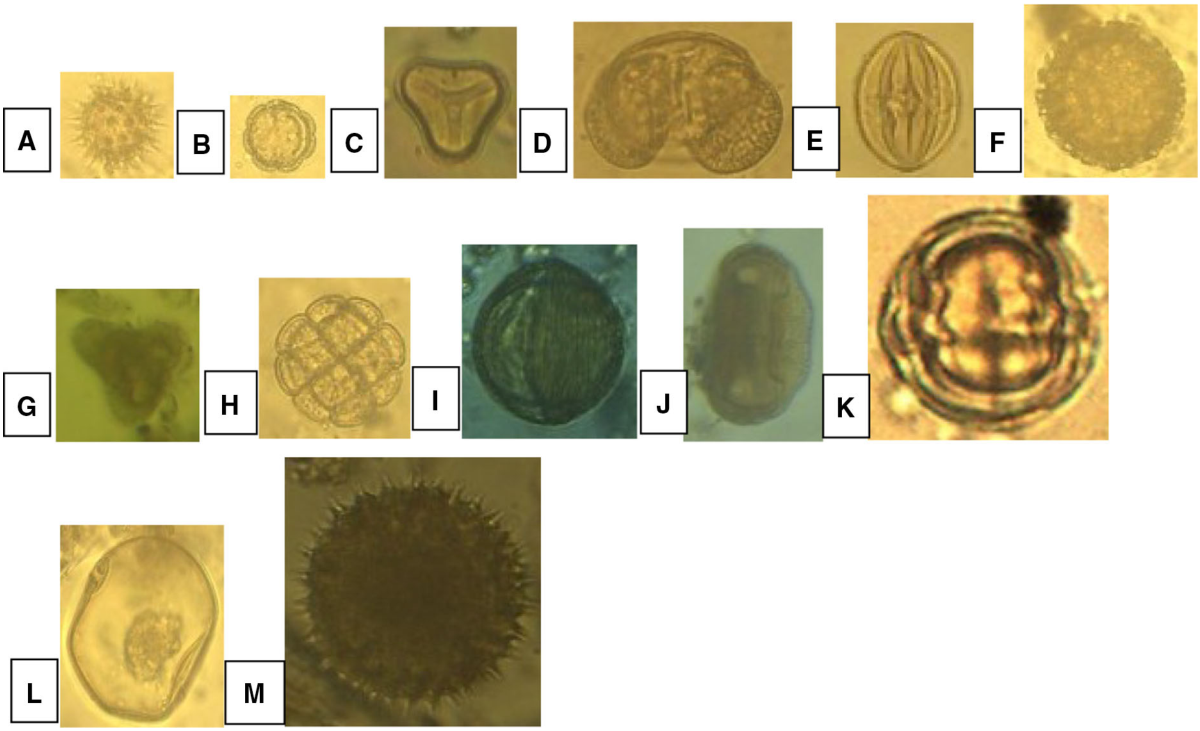

Fig. 2 Photomicrographs of some recovered pollen grains in this study. **a** *Tridax procumbens*, **b** *Borreria* sp., **c** *Elaeis guineensis*, **d** *Pinus caribaea*, **e** Sapotaceae **f** *Gomphrena celosoides*, **g** and **j**. *Asystasia gagentica* **h**. *Acacia* sp., **i**. *Isoberlinia doka*, **k**. *Terminalia* sp., **l** Poaceae and **m** *Sida acuta* (all magnification ×40 objective)

State, the atmospheric pollen abundance was highest in the month of August 2164 (29.94%) with the lowest record in June 18 (0.25%). At the study site in Benue State, pollen abundance reached its peak in July 336 (46.41%) with the lowest record in May 23 (1.03%). Monthly atmospheric pollen counts of the study locations during the sampling period are presented in Tables 1 and 2. The most abundant pollen types recovered in Plateau State were produced by *Syzygium guineense* (shrub), *Alchornea* sp. (shrub), *Terminalia* sp. (tree), Amaranthaceae (herb), *Tridax procumbens* (herb) and Poaceae (grass). Pollen types of *Casuarina equisetifolia* (tree), *Syzygium guineense* (shrub), *Tridax procumbens* (herb), Poaceae (grass) and Cyperaceae (sedge) were the most preponderant in Benue State.

4 Discussion

Findings from the first aeropalynological survey of both Plateau and Benue states, North-Central Nigeria, have been revealed. The present work provides a basis to compare the distribution of pollen types in these two different states far apart (Fig. 3), compared to previous studies conducted in Nigeria that were limited to only a particular locality, respectively.

Annual total pollen count was higher in Plateau State (7229) than in Benue State (2235). This might have resulted from differences in factors such as the density and pollen production rate of parent plants, as well as meteorological parameters at the respective locations (Singh and Mathur 2012; Ajikah et al. 2017). The total number of pollen types recovered from Benue (28) and Plateau (30) states, respectively, for a one-year sampling period is relatively lower than annual pollen records previously reported in other parts of the country. Compared to this present study, Njokuocha (2006) reported a total number of 40 pollen types belonging to 26 plant families in Nsukka, South-eastern Nigeria. Findings from Adeniyi et al. (2014) revealed a total number of 37 pollen types belonging to 30 plant families in Lagos, South-western Nigeria. Ezike et al. (2016) also reported a total number of 53

Table 1 Frequency of atmospheric pollen and fern spores in the Federal College of Forestry, Jos, Plateau State, Nigeria (July 2015 to June 2016)

S. no	Pollen types	July 2015	August 2015	September 2015	October 2015	November 2015	December 2015	January 2016	February 2016	March 2016	April 2016	May 2016	June 2016	Total	%
1.	*Syzygium guineense*	118	1624	424	229	596	72	52	0	13	7	8	0	3143	43.48
2.	*Elaeis guineensis*	1	11	27	5	2	2	1	6	1	2	9	0	67	0.93
3.	*Pinus caribaea*	0	0	0	0	0	0	0	1	0	0	0	0	1	0.01
4.	*Casuarina equisetifolia*	0	0	2	0	1	0	0	0	0	0	0	0	3	0.04
5.	*Terminalia* sp.	20	79	4	5	3	0	3	0	6	5	22	0	147	2.03
6.	*Podocarpus* sp.	0	1	1	1	1	0	1	0	0	0	0	0	5	0.07
7.	*Senna* sp.	0	0	0	0	0	0	0	3	0	0	0	0	3	0.04
8.	*Citrus* sp.	0	0	0	0	0	0	0	0	0	30	17	0	47	0.65
9.	*Acacia* sp.	0	0	3	19	14	0	0	0	0	0	0	0	36	0.50
10.	*Albizia* sp.	0	0	0	0	0	1	1	0	0	0	0	0	2	0.03
11.	Arecaceae	0	0	0	1	2	0	0	1	1	2	3	0	10	0.14
12.	Sapotaceae	0	0	0	0	3	6	0	0	13	8	1	0	31	0.43
13.	Fabaceae	0	0	0	0	0	10	0	3	0	2	1	0	16	0.22
14.	Euphorbiaceae	0	7	0	0	0	0	2	4	0	0	0	0	13	0.18
15.	*Vitex* sp. type	43	48	17	3	1	0	0	0	0	0	0	0	112	1.55
16.	*Alchornea* sp.	0	0	40	26	20	2	9	4	5	48	60	0	214	2.96
17.	*Gomphrena celosioides*	0	0	0	0	0	0	0	0	0	0	1	0	1	0.01
18.	*Sida acuta*	0	0	1	6	1	0	0	0	0	0	0	0	8	0.11
19.	*Tridax procumbens*	5	3	148	105	84	1	15	1	1	6	5	0	374	5.17
20.	*Euphorbia heterophylla*	0	0	0	0	0	0	0	0	0	5	4	0	9	0.13
21.	*Borreria* sp.	0	2	1	12	8	4	3	2	0	0	0	0	32	0.44
22.	*Amaranthus* sp.	61	35	39	20	34	6	10	1	1	11	15	5	238	3.29
23.	*Sida* sp.	0	0	0	0	0	0	0	2	0	0	0	0	2	0.03
24.	*Mimosa* sp.	0	0	0	0	0	0	0	0	0	1	1	0	2	0.03
25.	Asteraceae	0	0	0	0	20	2	2	0	1	4	0	0	29	0.40
26.	*Ipomoea* sp.	0	0	1	0	1	0	0	0	0	0	0	0	2	0.03
27.	Cyperaceae	6	17	0	11	3	0	0	0	0	4	12	0	53	0.73

Table 1 continued

S. no	Pollen types	July 2015	August 2015	September 2015	October 2015	November 2015	December 2015	January 2016	February 2016	March 2016	April 2016	May 2016	June 2016	Total	%
28.	Poaceae	281	337	411	695	522	38	105	20	10	81	110	13	2623	36.28
29.	A triad	0	0	0	0	0	0	0	1	0	0	0	0	1	0.01
30.	Pollen Indeterminate	0	0	0	0	0	0	0	4	1	0	0	0	5	0.07
Total pollen count		535	2164	1119	1138	1316	144	204	53	53	216	269	18	7229	
%		7.40	29.94	15.48	15.74	18.21	1.99	2.82	0.73	0.73	2.99	3.72	0.25		
Fern spores														Total	%
30.	*Nephrolepis* sp.	0	3	2	4	0	1	2	1	0	3	4	0	20	66.67
31.	*Pteris* sp.	0	0	0	0	0	0	0	2	0	0	0	0	2	6.67
32.	Trilete fern spore	0	2	0	0	0	0	0	1	0	4	1	0	8	26.67
Total fern spore count		0	5	2	4	0	1	2	4	0	7	5	0	30	
%		0	16.67	6.67	13.33	0.00	3.33	6.67	13.33	0	23.33	16.67	0		

pollen types belonging to 36 plant families in Garki, Abuja, North-Central Nigeria. The relatively lower diversity of pollen types recorded in this study may be attributed to an inferred sparse array of parent plants in the immediate vegetation of these locations.

From the meteorological data, dry season consisted of months with lower rainfall values (October to March) and rainy season consisted of months with higher rainfall values (April to September) in the study locations (Table 3). A higher total pollen count was observed in the rainy season (Plateau, 4321; Benue, 1176) than in the dry season (Plateau, 2908; Benue, 1059) in the respective locations (Tables 1, 2). This is in agreement with Essien and Aina (2014) who reported total pollen count to be more abundant in the month of May, followed by June in Anyigba, North-Central Nigeria. Malu (2014) observed that the prevalence of allergic conjunctivitis among outpatients in Jos, Plateau State, was highest in July, followed by a subsequent decline and at minima in December. He attributed this incidence to an increase in airborne pollen load after the onset of rainy season, with a peak around July to August and a decline in December during which most parent plants may not flower.

This is in contrast to previous findings reported by some workers, including Njokuocha (2006) and Ezike et al. (2016). Njokuocha (2006) recorded highest incidence of pollen during the late rainy season to early dry season, September to January in Nsukka, South-eastern Nigeria. Ezike et al. (2016) reported October, November and December, as months with the highest pollen abundance in Garki, Abuja, North-Central Nigeria. In their study, they stated that harmattan period October to January is to be designated as a higher-risk period for hypersensitive individuals due to their greater airborne pollen load.

In Plateau State, the most abundantly represented plants during rainy season were *Syzygium guineense*, *Tridax procumbens*, *Terminalia* sp., *Alchornea* sp., *Amaranthus* sp. and Poaceae. *Syzygium guineense*, *Tridax procumbens*, *Amaranthus* sp. and Poaceae produced the most preponderant pollen types during dry season in Plateau State. The most preponderant pollen types during rainy season in Benue State were produced by Poaceae, *Casuarina equisetifolia* and Cyperaceae. *Syzygium guineense*, *Tridax procumbens* and Poaceae produced the most abundant pollen types in Benue State during dry season. The recovery of

Table 2 Frequency of atmospheric pollen and fern spores in Government Girls College, Makurdi, Benue State, Nigeria (July 2015 to June 2016)

S. no	Pollen types	July 2015	August 2015	September 2015	October 2015	November 2015	December 2015	January 2016	February 2016	March 2016	April 2016	May 2016	June 2016	Total	%
1.	*Syzygium guineense*	0	9	12	6	14	1	5	149	0	1	0	0	197	8.81
2.	*Elaeis guineensis*	9	0	0	4	6	4	11	1	32	4	0	3	74	3.31
3.	*Casuarina equisetifolia*	23	1	0	0	0	0	0	0	1	2	0	69	96	4.30
4.	*Isoberlinia doka*	0	0	1	0	0	0	0	0	0	0	0	0	1	0.05
5.	*Bombax buonopozense*	0	0	0	0	1	0	0	0	0	0	0	0	1	0.05
6.	*Terminalia* sp.	5	1	0	6	18	6	10	4	3	0	0	2	55	2.46
7.	*Podocarpus* sp.	0	0	0	0	0	0	0	0	1	0	0	0	1	0.05
8.	*Senna* sp.	0	0	0	0	0	0	0	0	0	1	0	0	1	0.05
9.	*Acacia* sp.	0	2	1	3	0	0	0	0	0	2	0	0	8	0.36
10.	Arecaceae	0	0	0	0	0	0	0	0	4	0	0	2	6	0.27
11.	Sapotaceae	8	0	1	2	0	1	4	3	0	0	0	2	21	0.94
12.	Fabaceae	8	0	0	0	0	0	0	7	0	40	1	0	56	2.51
13.	Euphorbiaceae	7	2	0	0	2	0	0	0	4	1	0	0	16	0.72
14.	*Vitex* sp. type	2	4	3	0	8	4	0	5	0	0	0	0	26	1.20
15.	Malvaceae	0	0	0	0	0	0	0	1	0	0	0	0	1	0.05
16.	*Lannea* sp./ *Sclerocarya* sp.	0	0	0	0	0	0	0	0	0	1	0	2	3	0.13
17.	*Alchornea* sp.	0	0	4	1	5	0	4	0	0	0	5	6	25	1.12
18.	*Gomphrena celosioides*	0	0	0	2	2	1	0	0	6	1	0	2	14	0.63
19.	*Tridax procumbens*	0	0	0	16	27	14	10	1	12	3	0	5	88	3.94
20.	*Euphorbia heterophylla*	0	0	0	0	0	0	0	0	1	0	1	0	2	0.09
21.	*Borreria* sp.	34	1	0	0	1	2	2	3	0	0	0	0	43	1.92
22.	*Amaranthus* sp.	8	6	11	3	4	2	4	1	9	33	2	3	86	3.85
23.	*Mimosa* sp.	0	0	0	0	1	1	0	0	7	1	0	0	10	0.45
24.	Asteraceae	8	0	0	0	0	0	0	0	37	2	0	7	54	2.42
25.	Convolvulaceae	0	0	0	0	0	0	0	0	0	1	0	0	1	0.05
26.	Cyperaceae	141	0	0	0	6	1	1	1	0	1	0	1	152	6.80

Table 2 continued

S. no	Pollen types	July 2015	August 2015	September 2015	October 2015	November 2015	December 2015	January 2016	February 2016	March 2016	April 2016	May 2016	June 2016	Total	%
27.	Poaceae	83	118	148	20	53	47	55	35	330	86	14	206	1195	53.47
28.	Pollen Indeterminate	0	0	0	0	0	0	0	0	0	0	0	2	2	0.09
Total pollen count		336	144	181	63	148	84	106	211	447	180	23	312	2235	
%		15.03	6.44	8.10	2.82	6.62	3.76	4.74	9.44	20.00	8.05	1.03	13.96		
Fern spores														Total	
30.	*Nephrolepis* sp.	1	1	0	0	1	0	0	2	2	0	0	0	7	

some of these abundant pollen types could be attributed to the prolific production and anemophily of their parent plants. Also, some of the pollen identified in this study have been similarly reported by previous workers: Poaceae and *Elaeis guineensis* (Agwu and Osibe 1992; Njokuocha 2006; Essien and Agwu 2013; Ezike et al. 2016), *Alchornea* sp. (Njokuocha 2006; Essien and Agwu 2013; Adeniyi et al. 2014; Ezike et al. 2016), *Syzygium guineense* and *Terminalia* sp. (Essien and Agwu 2013), *Pinus caribaea* (Singh and Dahiya 2008) and Cyperaceae (Adeniyi et al. 2014).

In this study, the concentration of airborne Poaceae pollen was observed throughout the study period and varied considerably in the study locations (Fig. 4). This is supported by Latorre and Belmonte (2004) who stated that Poaceae pollen was observed during all the year in Catalonia Spain, especially in Spring when most grass species bloom. This is also buttressed by Essien and Aina (2014) who cited the work of Suphioglu et al. (1992), in which they affirmed that Poaceae pollen grains contain antigens capable of dispersing microscopic particles into the air after dehiscence. From the clinical point of view, Poaceae pollen is considered one of the most important aeroallergens in Europe (Sanchez-Mesa et al. 2003; Garcia-Mozo et al. 2010) and a major cause of pollinosis in several regions of the world (D'Amato et al. 2007). Poaceae pollen has been found as an important allergen associated with pollinosis, as reported by workers including D'Amato et al. (2007) and Taketomi et al. (2008).

The representation of Asteraceae in this study is consistent with the findings of D'Amato (1998) who observed that this family comprises an important allergenic taxon, Artemisia (mugwort), occurring in both urban and suburban areas and in the Mediterranean area, flowering between September and October. The recovery of *Amaranthus* sp. is consistent with Lombardero et al. (1992) who reported that many members of Amaranthaceae family have been involved in inducing allergic diseases. Galan et al. (2016) also reported that Artemisia and Amaranthaceae pollen types are common in the Mediterranean area. They stated that some of their species are adapted to low water availability, being more abundant in semi-arid climates of the south-eastern Iberian Peninsula. The recovery of *Pinus caribaea* pollen corresponds with the findings of Adekanmbi and Alebiosu

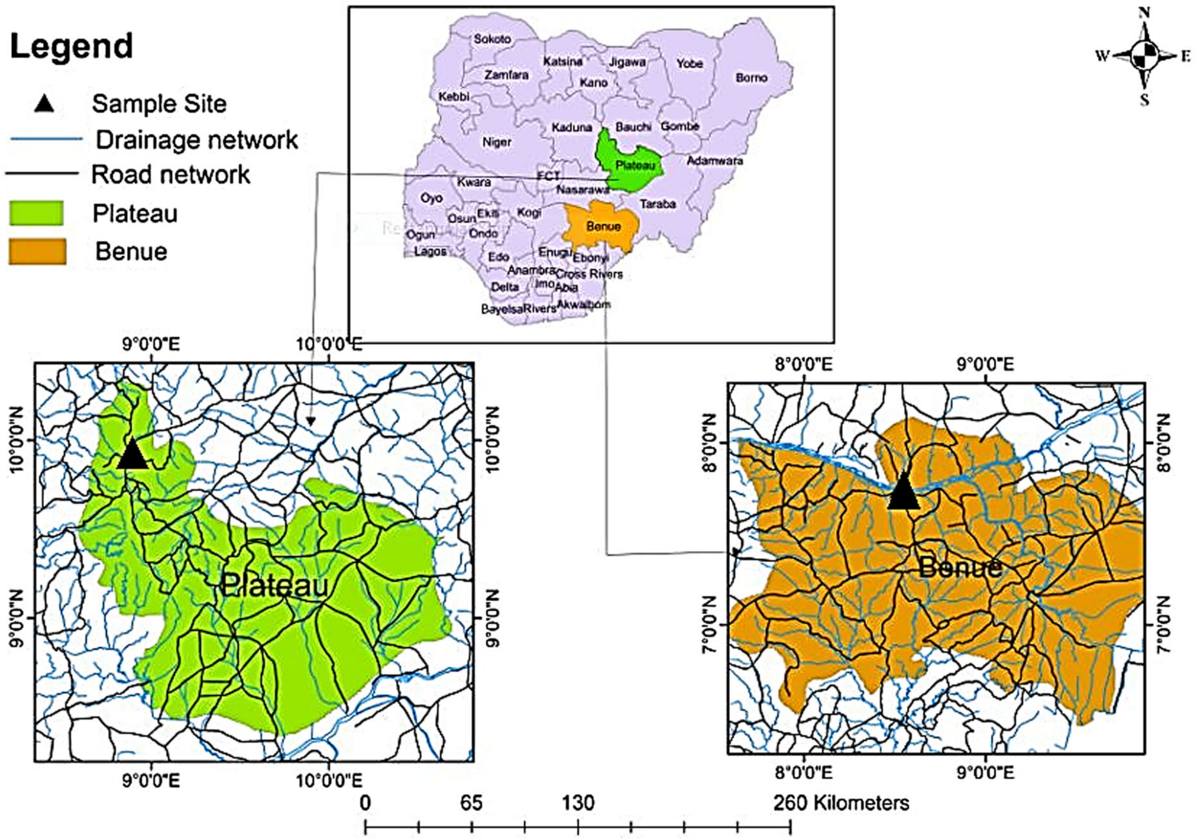

Fig. 3 Map of Nigeria showing the study locations in Plateau and Benue states, respectively

(2016) who reported special significance in the recovery of a bisaccate pollen produced by *Pinus* sp. type from a forensic palynological study in Lagos, Nigeria. They attributed this occurrence to their long dispersal through anemophily. Esch et al. (2001) also recorded that the genus Pinus is found from the Arctic to the southern hemisphere and is occasionally implicated in allergic reactions, owing to their pollen size and weight.

Variations were observed in the flowering periodicity of parent plants, including Poaceae and *Syzygium guineense* (Figs. 4, 5) and also their atmospheric pollen distribution during rainy and dry seasons in both locations (Tables 1, 2). This might have resulted from differences in the amount of prevailing meteorological parameters including rainfall, air temperature, wind speed and relative humidity available to support plant growth, pollen production and dispersal during these respective seasons (Table 3). Atmospheric distribution of pollen has been attributed to the considerable effects of meteorological parameters, through earlier aeropalynological studies of Huang (1998) and Kizilpinar et al. (2011). This corresponds with the findings of Ajikah et al. (2017) who affirmed the significant effect of flowering periodicity and density of parent plants on airborne pollen levels. This view is also supported by Kaplan (2004) who affirmed that a considerable variation exists in the distribution of airborne pollen from one country to another, in different regions of a country and also among cities of the same region. It is important to note that there was a striking similarity in the airborne pollen spectra recovered from the two study locations, with a total number of 22 same pollen types identified (Tables 1, 2). This might have been influenced by a similarity in the diversity of plants present in the neighbouring vegetation types of both locations.

In this study, it was also observed that some of the plants identified in the surrounding vegetation are represented in the airborne pollen spectra of the study

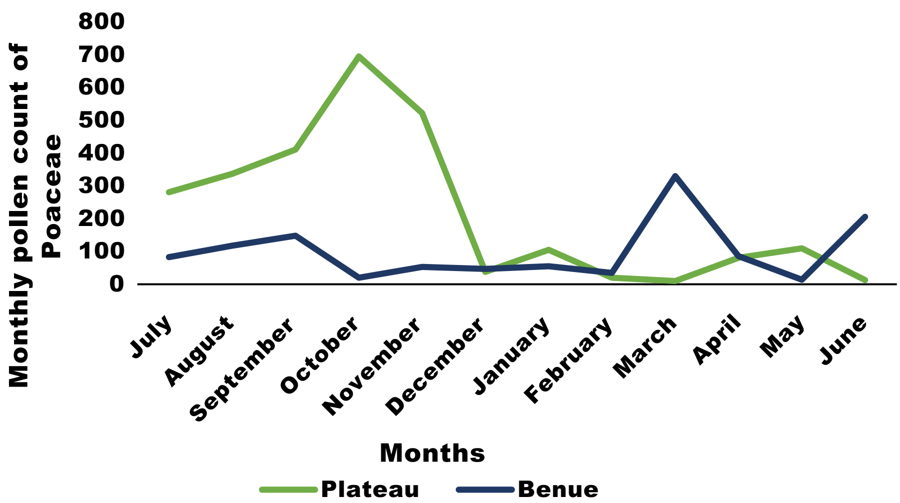

Fig. 4 Monthly atmospheric pollen count of Poaceae at the two study locations

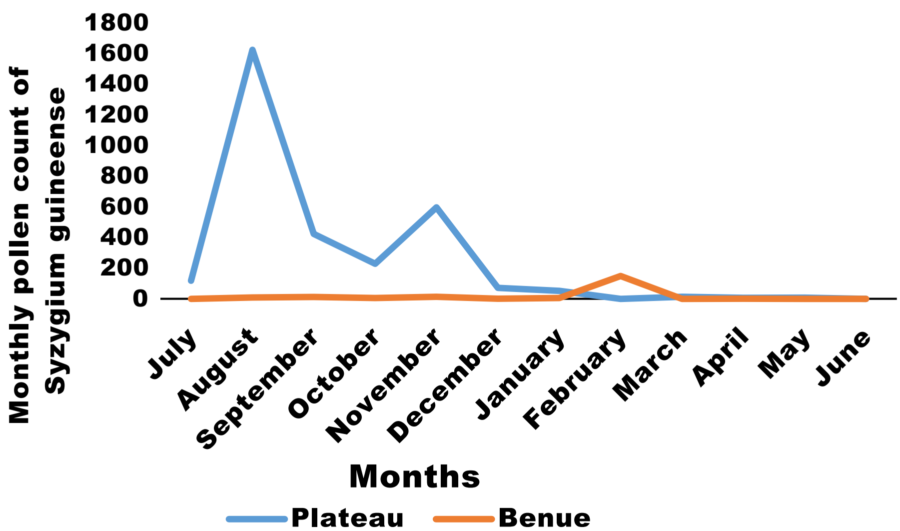

Fig. 5 Monthly atmospheric pollen count of *Syzygium guineense* at the two study locations

locations. Different array of local plants contributed to the respective aeroflora of both locations (Tables 4, 5). In Plateau State, parent plants of the recovered airborne pollen types of *Sida acuta*, *Pinus caribaea*, *Sida* sp., *Citrus* sp., Cyperaceae, Poaceae and Fabaceae can be identified in the surrounding vegetation of the study site. Other enumerated plants such as *Zornia latifolia*, *Indigofera hirsuta* and *Desmodium scorpirus* belong to Fabaceae; *Dactyloctenium aegyptium*, *Chloris pilosa*, *Eragrostis* sp., *Brachiaria oleflexa*, *Brachiaria* jubuta and *Brachiaria* lata belong to Poaceae; *Cyperus* sp. belong to Cyperaceae. In Benue State, parent plants of the recovered pollen types of *Gomphrena celosioides*, *Tridax procumbens*, *Elaeis guineensis*, *Terminalia* sp., Poaceae and Cyperaceae can be identified in the surrounding vegetation of the study site. Enumerated plants such as *Andropogon* spp. and *Cyperus* spp. belong to Poaceae and Cyperaceae, respectively. These findings are in agreement with the works of Njokuocha (2006) and Adeonipekun (2012) who reported greater recovery of pollen from the local vegetation of their study areas, thereby confirming the importance of airborne pollen contribution from the immediate vegetation of an area. Agwu (1997) also recorded that dominant vegetation of the Nsukka Plateau contributed to the major

Table 3 Monthly mean values of weather parameters in the study locations (July 2015–June 2016)

Weather parameters	Study locations	July	August	September	October	November	December	January	February	March	April	May	June
Air temperature (°C)	Plateau State	20.6	20.3	20.5	22.2	20.5	17.1	18.5	21.8	24.9	24.5	22.5	21.3
	Benue State	28.0	27.8	27.9	29.1	29.8	28.5	29.8	33.0	32.2	31.6	30.3	28.9
Relative humidity (%)	Plateau State	88.0	91.0	87.0	78.0	45.0	38.0	30.0	28.0	55.0	69.0	81.0	87.0
	Benue State	82.0	85	79.0	79.0	69.0	27.0	25.0	31.0	64.0	68.0	73.0	75.0
Rainfall (mm)	Plateau State	263.4	331.7	195.0	21.7	0.0	0.0	0.0	0.0	21.7	24.0	192.2	198.0
	Benue State	139.5	337.9	126.0	83.7	18.0	0.0	0.0	0.0	52.7	90.0	238.7	84.0
Wind speed (knot)	Plateau State	9.9	9.0	8.5	7.6	9.4	15.5	13.6	10.6	9.1	10.3	10.5	10.6
	Benue State	3.5	3.7	3.0	3.0	2.2	6.2	5.1	3.8	3.8	3.9	3.4	3.9

component of aeroflora in Nsukka, South-eastern Nigeria.

In Plateau State, 23.33% of total fern spore count was observed as highest in the month of April and there was no record in July, November, March and June, respectively (Table 1). Among the three fern spore types recovered, *Nephrolepis* sp. was the most represented 20 (66.67%), followed by a trilete fern spore 8 (26.67%) and *Pteris* sp. 2 (6.67%). This finding is supported by Njokuocha (2006) who recorded the spore of *Nephrolepis biserrata* as one of the most preponderant in the atmosphere of Nsukka, Enugu State, Nigeria. Essien et al. (2014) also reported the recovery of *Pteris dentata*, *Pteris* sp. and a trilete spore in Kogi State, North-Central Nigeria. In Benue State, only *Nephrolepis* sp. was represented with a peak in February and March; no record was noted in September, October, December, January, April, May and June, respectively (Table 2). The peak months of fern spore count recorded in the study locations are in contrast to the findings of Njokuocha (2006) who observed more fern spores in the respective months of September and November. The recovery of fern spore types indicates that a fresh water swamp forest inhabiting their parent plants could be found in the immediate environment of the study locations.

The statistical analysis showed that there was no significant correlation between total pollen counts and mean monthly values of meteorological parameters in Benue State (Table 6). A significantly negative correlation was observed between total pollen counts and meteorological parameters, including air temperature and wind speed in Plateau State (Table 7). This is in contrast to the findings of Hu et al. (2008) who reported a positive correlation between the temperature and airborne pollen concentration in their study. They stated that a decline in atmospheric pollen load is usually influenced by higher rainfall or lower temperature and this may reduce the incidence of pollinosis. This also negates the findings of Abdulrahaman et al. (2015) who reported that total pollen counts were positively correlated with wind speed and temperature.

5 Conclusion

A mosaic of growth forms contributed to the aeroflora of the study locations, from their parent vegetation

Table 4 Occurrence of plants identified in the vegetation study around the sampling site in Plateau State

S.no	Scientific name	Family name	Plant type
1.	*Indigofera hirsuta* L.	Fabaceae	Subshrub
2.	*Desmodium scorpiurus* (Sw. Desv)	Fabaceae	Forb/herb
3.	*Zornia latifolia* (SM.)	Fabaceae	Forb/herb
4.	*Sida falax* Walp.	Malvaceae	Herb/subshrub
5.	*Sida acuta* Burm. f.	Malvaceae	Herb/subshrub
6.	*Sida corymbosa* R.E. Fr.	Malvaceae	Herb/subshrub
7.	*Pinus caribaea* Morelet.	Pinaceae	Tree
8.	*Eucalyptus camandullensis* Dehnh.	Myrtaceae	Tree
9.	*Boerhavia diffusa* L.	Nyctaginaceae	Herb
10.	*Brachiaria oleflexa* Schumach.	Poaceae	Grass
11.	*Brachiaria jubata* (Fig. & De Not.) Stapf.	Poaceae	Grass
12.	*Brachiaria lata* Schumach.	Poaceae	Grass
13.	*Dactyloctenium aegyptium* L.	Poaceae	Grass
14.	*Chloris pilosa* Schumach	Poaceae	Grass
15.	*Eragrostis* sp.	Poaceae	Grass
16.	*Portulaca oleracea* L.	Portulacaceae	Herb
17.	*Cyperus* sp.	Cyperaceae	Sedge
18.	*Spigelia* sp.	Loganiaceae	Herb
19.	*Diodia scandens* Sw.	Rubiaceae	Herb
20.	*Mitracarpus villosus* (Sw.) DC.	Rubiaceae	Herb
21.	*Duranta repens* L.	Verbenaceae	Shrub
22.	*Mangifera indica* L.	Anacardiaceae	Tree
23.	*Physalis* sp.	Solanaceae	Herb
24.	*Citrus* sp.	Rutaceae	Tree

Table 5 Occurrence of plants identified in the vegetation study around the sampling site in Benue State

S.no	Scientific name	Family name	Plant type
1.	*Mangifera indica* L.	Anacardiaceae	Tree
2.	*Albizia lebbeck* (L.) Benth.	Mimosaceae	Tree
3.	*Elaeis guineensis* Jacq.	Arecaceae	Tree
4.	*Tectona grandis* L. f.	Lamiaceae	Tree
5.	*Gmelina arborea* Roxb.	Verbenaceae	Tree
6.	*Terminalia randii* Baker f.	Combretaceae	Tree
7.	*Tridax procumbens* L.	Asteraceae	Herb
8.	*Gomphrena celosioides* Mart.	Amaranthaceae	Herb
9.	*Cyperus* sp.	Cyperaceae	Sedge
10.	*Andropogon* sp.	Poaceae	Grass

types during the period of study. This study has reported the first recovery of *Pinus caribaea* and *Podocarpus* sp. bisaccate pollen in the aeropalynology of Nigeria. The distribution of fern spores identified in this study would serve as additional information to the pteridology of these locations. The recovered pollen spectra corresponded with the identified plants in the immediate vegetation of the study sites, implying a considerable airborne pollen–vegetation relationship. One implication of a striking similarity in the

Table 6 Correlation coefficients between pollen count and meteorological parameters in Benue State at 95% confidence interval ($P < 0.05$)

Model	Unstandardized coefficients		Standardized coefficients	–	Sig.	Correlations		
	B	SE	Beta			Zero order	Partial	Part
(Constant)	− 1432.236	1063.142		− 1.347	0.220			
Air temperature	35.053	26.213	0.512	1.337	0.223	0.264	0.451	0.409
Wind speed	64.659	62.234	0.557	1.039	0.333	− 0.117	0.366	0.318
Relative humidity	6.080	3.704	1.134	1.642	0.145	0.167	0.527	0.503
Rainfall	− 0.618	0.501	− 0.543	− 1.232	0.258	− 0.156	− 0.422	− 0.377

Dependent variable: Benue pollen count

Independent variable: air temperature, wind speed, relative humidity and rainfall

Sig. significance

Table 7 Correlation coefficients between monthly total pollen counts and meteorological parameters in Plateau State at 95% confidence interval ($P < 0.05$)

Model	Unstandardized coefficients		Standardized coefficients	–	Sig.	Correlations		
	B	SE	Beta			Zero order	Partial	Part
(Constant)	9088.709	2818.275		3.225	0.015			
Air temperature	− 240.736	93.126	− 0.784	− 2.585	0.036	− 0.173	− 0.699	− 0.546
Wind speed	− 316.815	102.631	− 1.020	− 3.087	0.018	− 0.517	− 0.759	− 0.652
Relative humidity	− 2.573	13.402	− 0.092	− 0.192	0.853	0.418	− 0.072	− 0.041
Rainfall	0.766	2.395	0.138	0.320	0.758	0.452	0.120	0.068

Dependent variable: Plateau pollen count

Independent variable: air temperature, wind speed, relative humidity and rainfall

Sig. significance

recovered airborne pollen spectra of both locations is that pollen allergy sufferers within these two areas are exposed to virtually same array of pollen types, even though their respective seasons differ. In this case, they tend to respond to common allergenic pollen types in their respective seasons, thereby eliciting similar allergic conditions, such as allergic rhinitis, atopic dermatitis, conjunctivitis, exacerbation of asthma and acute sinusitis.

The results of our study have created baseline information about suspected pollen allergens in the study locations with a potential to guiding pollen hypersensitive individuals on prophylaxis against their negative effects. The allergenic effect of the abundant pollen types on humans should be further investigated. It is suggested that the impact of meteorological parameters on airborne pollen distribution of larger sampling areas over successive years should be considered.

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References

Abdulrahaman, A., Aruofor, O. S., Garuba, T., Kolawole, O. S., Olahan, G. S., & Oladele, F. A. (2015). Aeropalynological investigation of the University of Ilorin, Ilorin, Nigeria. *Journal of Applied Science and Environmental Management, 19*(1), 53–63.

Adekanmbi, O. H. (2009). Pollen grains of Asteraceae and Analogous echinate grains. *International Journal of Botany*. ISSN:1811-9700.

Adekanmbi, O. H., & Alebiosu, O. S. (2016). Palynological studies for forensic approach in three locations of Lagos, Nigeria. In *Human palaeoecology in Africa: Essays in honour of M. Adebisi Sowunmi*, Palynological Association of Nigeria (PAN) and University of Ibadan Press. pp. 120–129. ISBN:987-978-081-937-2.

Adekanmbi, O. H., & Ogundipe, O. T. (2009). Pollen grains of Lagos lagoon swamp and hinter-land vegetation-1. *International Journal of Botany, 5,* 270–278.

Adekanmbi, O. H., & Ogundipe, O. T. (2010). Aeropalynological studies of the University of Lagos Campus, Nigeria. *Notulae Scientia Biologicae, 2*(4), 34–39.

Adeniyi, T. A., Adeonipekun, P. A., Olowokudejo, J. D., & Idowu, S. A. (2014). Airborne pollen records of Shomolu Local Government Area in Lagos State. *Notulae Scientia Biologicae, 6*(4), 428–432.

Adeonipekun, A. P. (2012). Comparative aeropalynology of Ota, Nigeria. *Journal of Ecology and the Natural Environment, 4*(12), 314–320.

Agwu, C. O. C. (1997). Modern pollen rain in Nsukka: An indicator of the vegetation of Nsukka Plateau. *Wurzburger Geographie Arbied, 92,* 97–115.

Agwu, C. O. C., & Osibe, E. E. (1992). Airborne palynomorphs of Nsukka during the months of February–April, 1990. *Nigerian Journal of Botany, 5,* 177–185.

Ajikah, L. B., Alebiosu, O. S., Adekanmbi, O. H., Oshinlaja, E. O., & Ogundipe, O. T. (2017). Aeropalynological investigation of three local governments in Lagos, South West Nigeria. *Nigerian Journal of Botany, 30*(1), 107–119.

Ajikah, L., Ogundipe, O. T., & Bamgboye, O. (2015).). Palynological survey of airborne pollen and spores in the University of Lagos, Akoka campus, Southwestern Nigeria. *Ife Journal of Science, 17*(3), 643–655.

Ama, I. I., Okeme, S., & Chia, J. I. (2015). Constraints faced by Farmers receiving primary healthcare service in the North-Eastern Zone of Benue State, Nigeria. *Journal of Agricultural Economics, Environment and Social Sciences, 1*(1), 151–154.

Ani, D. P., Chidebelu, S. A. N., & Enete, A. A. (2017). Structure of soyabeans markets in Benue and Enugu States, Nigeria. *African Journal of Agricultural Research, 12*(6), 435–449.

D'Amato, G. (1998). Pollen allergy in the Mediterranean area. *Revue Française d'Allergologie, 38*(suppl 7), S160–S162.

Dalziel, J. M. (1937). *The useful plants of West Tropical Africa* (p. 612). London: Crown Overseas Agents for the Colonies.

D'Amato, G., Cecchi, L., Bonini, S., Nunes, C., Annesi-Maesano, I., Behrendt, H., et al. (2007). Allergenic pollen and pollen allergy in Europe. *Allergy, 1111,* 1398–1413.

Danlami, M. S., & Onimisi, A. H. (2016). An analysis of soil physico-chemical properties of Kerang Volcanic Landscape Catena, Jos Plateau, Nigeria. *Resources and Environment, 6*(1), 9–15.

Erdtman, G. (1969). *Handbook of Palynology* (p. 209). Copenhagen: Munksgaard.

Esch, R. E., Hartsell, C. J., Crenshaw, R., & Jacobson, R. S. (2001). Common allergenic pollen, fungi, animals and arthropods. *Clinical Review of Allergy and Immunology, 21,* 261–292.

Essien, B. C., & Agwu, C. O. C. (2013). Aeropalynological Study of Anyigba, Kogi State, Nigeria. *Standard Scientific Research and Essays, 1*(13), 347–351.

Essien, B. C., Agwu, C. O. C., & Taiga, A. (2014). A Comparative analytical investigation of airborne palynomorphs within Kogi State University Teaching Hospital, Anyigba, Nigeria. *Journal of Applied Sciences and Research, 2*(1), 136–142.

Essien, B. C., & Aina, D. O. (2014). The role of airborne pollen grains of some angiosperms and fungal spores in allergic and pathogenic infections in Anyigba, Kogi State, Nigeria. *ASJ International Journal of Advances in Medical Sciences and Biotechnology, 2*(3), 23–28.

Ezike, D. N., Nnamani, C. V., Ogundipe, O. T., & Adekanmbi, O. H. (2016). Airborne pollen and fungal spores in Garki, Abuja (North-Central Nigeria). *Aerobiologia.* doi:10:1007/s10453-016-9443-5.

Galan, C., Alcazar, P., Oteros, J., Garcia-Mozo, H., Aira, M. J., Belmonte, J., et al. (2016). Airborne pollen trends in the Iberian Peninsula. *Science of the Total Environment, 550,* 553–559.

Garcia-Mozo, H., Galan, C., Alcazar, P., Diaz de la Guardia, C., Nieto-Lugilde, D., Recio, M., et al. (2010). Trends in grass pollen season in southern Spain. *Aerobiologia, 26,* 157–169.

Gosling, W. D., Miller, C. S., & Livingstone, D. A. (2013). Atlas of the tropical West Africa pollen flora. *Review of Paleobotany and Palynology, 199,* 1–135.

Hu, Y. Q., Ferguson, D. K., Bera, S., & Li, C. (2008). Seed hairs of poplar trees as native airborne pollen trap for allergenic pollen grains. *Grana, 47,* 241–245.

Huang. (1998). Aeropollen of the Pingtung area, South Taiwan. *Taiwania 43*(2), 73–100.

Hutchinson, J., & Dalziel, J. M. (1954). *Flora of west tropical Africa, vols. 1 and 2*. London: The White Friars Press Ltd.

International Study of Asthma and Allergies in Childhood. (1998). World wide variation in prevalence of symptoms of asthma, allergic rhino-conjunctivitis, and atopic eczema. *ISSAC Steering Committee, 351,* 1225–1232.

Kaplan, A. (2004). Airborne pollen grains in Zonguldak, Turkey, 2001–2002. *Acta Botanica Sinica, 46,* 668–674.

Keay, R. W. J. (1989). *Trees of Nigeria* (pp. 19–30). Oxford, London: Clarendon Press.

Keay, R. W. J., Onochie, C. F. A., & Standfield, D. P. (1964). *Nigerian trees* (Vol. 1, p. 348). Ibadan, Nigeria: Department of Forest Research.

Kizilpinar, I., Civelek, E., Tuncer, A., Dogan, C., Karabulut, E., Sahiner, U. M., et al. (2011). Pollen counts and their relationship to meteorological factors in Ankara, Turkey during 2005–2008. *International Journal of Biometeorology, 5*(4), 623–631.

Latorre, F., & Belmonte, J. (2004). Temporal and spatial distribution of atmospheric Poaceae pollen in Catalonia (NE Spain) in 1996–2001. *Grana, 43*(3), 156–163.

Lombardero, M., Duffort, O., & Carreira, J. (1992). Allergenic significance of chenopod pollen. In G. D'Amato, F Th M Spieksma, & S. Bonini (Eds.), *Allergenic pollen and pollinosis in Europe* (p. 240). Oxford: Wiley-Blackwell Scientific Publications.

Malu, K. N. (2014). Allergic conjunctivitis in Jos, Nigeria. *Nigerian Medical Journal*, *55*(2), 166–170.

National Population Census. (2006). Federal Republic of Nigeria Official Gazzete. *Lagos, Nigeria, 94*(4), 10–12.

Njokuocha, R. C. (2006). Airborne pollen grains in Nsukka, Nigeria. *Grana, 45,* 73–80.

Ohemu, T. L., Agunu, A., Olotu, P. N., Ajima, U., Dafau, D. G., & Azila, J. J. (2014). Ethnobotanical survey of medicinal plants used in the traditional treatment of viral infections in

Jos, Plateau State, Nigeria. *International Journal of Medicinal and Aromatic Plants, 4*(2), 74–81.

Ologunorisa, T. E., & Tersoo, T. (2006). The changing rainfall pattern and its implication for flood frequency in Makurdi Northern Nigeria. *Journal of Applied Sciences and Environmental Management, 10*(3), 97–102.

Olowolafe, E. A., Adepetu, A. A., Dung, J. E., & Osagbemi, M. O. (2004). Effect of application of different levels of nitrogen and phosphorus fertilizer on upland rice yield on the Jos plateau, Nigeria. *Journal of Environmental Sciences, 6,* 39–45.

Sanchez-Mesa, J., Smith, M., Emberlin, J., Allit, U., Caulton, E., & Galan, C. (2003). Characteristics of grass pollen seasons in areas of Southern Spain and the United Kingdom. *Aerobiologia, 19,* 243–250.

Singh, A. B., & Dahiya, P. (2008). Aerobiological Researches on Pollen and Fungi in India during the last fifty years: An Overview. *Indian Journal of Allergy and Asthma Immunology, 22*(1), 27–38.

Singh, A. B., & Kumar, P. (2004). Aerial pollen diversity in India and their clinical significance in allergic Diseases. *Indian Journal of Clinical Biochemistry, 19*(2), 190–201.

Singh, A. B., & Mathur, C. (2012). An aerobiological perspective in allergy and asthma. *Asia Pacific Allergy, 2*(3), 210–222.

Sowunmi, M. A. (1973). Pollen grains of Nigerian plants. *Grana, 13*(3), 145–186.

Sowunmi, M. A. (1995). Pollen of Nigerian plants. *Grana, 34*(2), 120–141.

Suphioglu, C., Singh, M. B., Taylor, P., Bellomo, R., Holmes, P., Puy, R., et al. (1992). Mechanism of grass-pollen induced asthma. *Lancet, 339*(8793), 569–572.

Taketomi, E. A., Sopelete, M. C., Vierra, P. F., & Moreira, F. M. C. (2008). Pollen allergenic disease: Pollen and its major allergens. *Revista Brasileira Otorrinolaringologia*. https://doi.org/10.1590/50034-7299200640004000.

Tauber, N. (1974). Investigation of aerial pollen transport in a forested area. *Dansk Bot-Ar.*, *32*(1), 1–12.