International Journal of Innovative Healthcare Research 12(2):59-74, April-June, 2024

© SEAHI PUBLICATIONS, 2024 www.seahipaj.org ISSN: 2354-2950

Aeropalynomorphs, Environmental and Public Health Assessment of Mai Mustapha Aliyu International College of Health Science and Technology, Biu, Borno State, Nigeria

[*1]Essien, B. C.; [2] Adamu, M. [3] Tsoho, S. B, & [4]Ibrahim, G.A.

[*1,2,3,4]Department of Biology,
Faculty of Natural & Applied Sciences,
Nigerian Army University Biu, Borno State, Nigeria
***Corresponding Author's Email: benjaminessien8@gmail.com**

ABSTRACT
Analysis of the atmospheric pollen content of an area is important in providing standard baseline information on environmental change, vegetation type, species composition and their utilization for food and resource production, safety, health and sustainable development. The current study examined the aeropalynomorphs, environmental and public health assessment of Mai Mustapha Aliyu International College of Health Science and Technology, Biu, Borno State, Nigeria. This study was carried out to examine the temporal and spatial relationship between the atmospheric pollen content and their vegetation. The aeropalynomorphs were collected with Modified Tauber Sampler using simple random sampling technique and analyzed palynologically. Results showed 29,281 pollen grains counts of which 77 pollen types belonging to 35 plant families were encountered. Three (3) of the aeropollen types were identified to family level, 18 to species level, 55 to generic level and one (1) unidentified. The predominant pollen types belong to the family Poaceae, *Casuarina equisetiifolia*, *Apilia africana*, and Cyperaceae while the fungal spores belong to the species of *Nigrospora*, *Dreschelia*, *Ustilago*, *Botryodiplodia*, *Curvularia*, *Corynespora* and *Pithomyces*. The presence of *Empetrum nigrum* pollen indicates evidence of long-distance transport. Airborne pollen grains were most abundant between September and October while the fungal spores were from August to September. Furthermore, the occurrence of pollen from *Azadirachta indica*, *Carica papaya*, *Casuarina equisetiifolia*, *Delonix regia*, and those of the families Asteraceae, Cyperaceae and Poaceae indicates the availability of allergenic taxa in the atmosphere. Pollen assemblages confirmed the vegetation of the study area to be tropical Sudanean vegetation type despite high level of anthropogenic activities. Adequate conservation measures through afforestation and prevention of annual bush burning; environmental monitoring through pollen rain analysis; and avoidance of exposure to allergens during their season of prevalence are recommended for safety, health and environmental sustainability in the study area.
Keywords: Aeropalynomorphs, Aeroallergens, Allergic taxa, Borno State, Public health.

INTRODUCTION
Aeropalynology, a branch of palynology studies the release, dissemination, deposition and allergic effects of pollen grains and spores present in the air (Njokuocha, 2012). Essien and Agwu (2013) described

aeropalynology as the scientific study of biological particles such as pollen, fungal spores, dust mites, insect debris and organic dust present in the air.

It has been reported that airborne palynomorphs are widely distributed in the atmosphere and they vary in concentration and diversity from place to place and season to season (Essien, 2019). Some components of this palynomorphs such as pollen grains, fungal spores as well as animal hairs and arthropods parts constitute health problems to susceptible or immune-compromised individuals (Essien, 2019). They contain some chemical compounds such as proteins, glyco-protein, enzymes and protease enzymes that elicit or exacerbate respiratory related illnesses. Some invasive fungal spores such as those of *Aspergillus* sp. cause nosocomial infections (hospital infection) to patients that have undergone major surgery (Rhame, 1991).

Therefore, a good knowledge of the pattern of distribution of these palynomorphs, the identification and season of high abundance becomes very important in resolving some of these health and other issues (Hicks, 1992; Njokuocha and Ukeje, 2006; Essien and Aniama, 2014; Essien and Ige, 2019). Secondly, since meteorological factors play a significant role in the reproduction, release, concentration and precipitation of some of these palynomorphs, it become pertinent to understand the relationship between these airborne palynomorphs and meteorological factors (Essien *et al*., 2014).

Numerous investigations conducted all over the world indicate that the atmosphere is filled with abundant and diverse minute particles of both biological and non-biological origin (Essien and Aina, 2014; Essien *et al*., 2016; Adeonipekun *et al*. (2016), Adeniyi *et al*. (2017), Adeniyi *et al*. (2018a); Adeniyi *et al*. (2018b) and Ige and Essien, 2019a). The airborne particles of biological origin (pollen, fungal spores, charred plants and animal materials, diatoms frustules, zooclasts) serve useful interpretation purposes in palaeo-vegetation and extant vegetation analysis, as well as study of the changes in the dynamics of genotypes, flowering phenology, plant pathology, human aeroallergy, anthropogenic impact and particles movement in the air (Essien, 2014). Pollen grains and spores are part of the life cycles of the plant and in particular, lend themselves to these applications because they are the most abundant biological parameter consistently present in the air masses. Since they are direct products of plants, their abundance and distribution respond naturally to the environmental factor affecting their parent sources (Essien and Agwu, 2013).

The release, distribution and sedimentation of these aeropalynomorphs are influenced by a number of factors such as the type and floristic composition of the vegetation which determine the abundance and types of pollen and fungal spores that are released into the atmosphere (Burge and Rogers, 2008; Agwu, 2001). Also, the flowering pattern of individual plants play important role in determining the abundance and taxa of pollen circulating in the atmosphere (Jato *et al*., 2002).

Aeropalynomorphs are the major cause of respiratory ailments of humans, causing allergies, asthma, and pathogenic infections of the respiratory tract (Blackley, 1873; Cashel *et al*., 2004; Essien and Aina, 2014). Aeropalynomorphs for example, fungal spores, are also important causative agent of plant disease, their sources and the means for dissemination of many common saprotrophic fungi (Agashe, 1994).

Aeropalynomorphs usually travel short distances; however, when they are blown into the upper strata of the atmosphere, pollen grains travel long distances, before they are deposited (Essien, 2014). Pollen dispersal is facilitated by dry weather and high wind velocity. Pollen count is reduced after precipitation. The widely dispersed pollen and spores provide a broad picture of the surrounding vegetation of the areas in which they are produced.

The atmosphere contains a lot of aeropalynomorphs (pollen grains and spores, etc.). These aeropalynomorphs usually generate hazy dust or clouds that are carried by the wind when they are discharged. On a local, regional, and global scale, human activities have impacted many aspects of our environment, including the climate, biodiversity, vegetation, and air quality. Changes in land use, agriculture, the burning of fossil fuels, smoke emissions from vehicles, and the release of industrial emissions, and etc. all contributes to some of these anthropogenic effects. Currently, the prevalence of aeropalynomorphs allergy is increasing with increase in air pollution and climate change. The spread of biologically derived atmospheric particles has been linked to adverse effects on public health in densely populated urban areas, including the emergence of allergy related diseases such as allergic rhinitis, conjunctivitis and the aggravation of asthma and other related diseased conditions.

During recent past, it has been well documented that air-borne pollen grains and spores widely cause various allergic complaints such as hay fever, eczema and asthma (Burge and Rogers, 2008). About 10-20% of the population is known to suffer allergic disorders caused by aeropalynomorps (Singh and Singh, 1994). In hay fever and asthma responses, pollen grains enter the nose and lands on the mucous membrane of the upper and/or lower respiratory tract. Pollen grains get hydrated by the mucus secretion and release pollen allergens which penetrate the mucous tissues (Foster and Clark, 2001). Hay fever has assumed enormous proportions in many parts of the world. The treatment involves use of pollen directly or in the form of pollen extract. The role of air-borne pollens in the etiology of respiratory allergy is well established. That is why aeropalynomorphs abundance and incidence flora has been exhaustively studied all over the world (Essien *et al*., 2024).

An allergy is a specific immunologic reaction to a normally harmless substance (allergen). This reaction can be triggered off by a number of factors common among which are aeropalynomorphs (for example, pollen grains and fungal spores). Pollen grains are among the earliest known allergens and the taxa that trigger allergic reactions are produced by wind pollinated plants (herbs and grasses) that produce large quantities of pollen grains which are carried over long distances (Essien and Aina, 2014). The protein, glycoprotein and proteases enzymes present in the pollen and spores were reported to be responsible for the chemical irritant effects of these aeropalynomorphs (Gallup *et al*., 1987; Burge and Rogers, 2008; Essien *et al*., 2024).

In allergic individual, these substances, which in a normal person would be destroyed by antibodies, stimulate the release of histamine, leading to inflammation and other characteristic symptoms of the allergy, for example asthma or hay fever (Thomas and Leuschner, 2006). The essential information for the pollinosis or allergenic pollen is not the quantity of pollen, but the number of allergens or at least antigens they bear (Chakraborty *et al*., 1999). Exposure to the starch granules from pollen grains has been shown to elicit severe bronchial constriction (Suphioglu *et al*., 1992). A study carried out on patients with seasonal asthma and rhinitis showed that grass (Poaceae) pollen immunotherapy reduced seasonal asthma symptoms and bronchial hyper-responsiveness (Walker *et al*., 2001). Also, Cashel *et al*. (2004) found a significant correlation to asthmatic symptoms and rhinitis with *Ambrosia* pollen (Asteraceae) concentration and other pollen types. Aeropollen grains have been proved to be responsible for causing allergic symptoms such as runny nose, itchy eyes, nasal congestion and sneezing (Nielsen *et al*., 2002).

Allergic diseases may involve any part of the body; the most frequently involved being the nose, eye and chest with resultant symptoms of hay fever, rhinitis or asthma. The skin and eyes also commonly show allergic symptoms.

Therefore, identifying the kinds and concentrations of aeropalynomorphs is essential and beneficial for individuals with allergic disorders. Contrary to other nations like Spain, the United States of America, and India where substantial research has been conducted on aeropollen monitoring and its functions in allergy. Studies in Nigeria are just beginning and no Nigerian city has a standardized pollen calendar that can be used to predict the abundance and prevalence of aeropalynomorphs in the atmosphere.

The aim of this study is to appraise the vegetation in and around the Mai Mustapha Aliyu International College of Health Science and Technology, Biu, Borno State, Nigeria, and to find out the temporal and spatial relationship between the atmospheric aeropalynomorphs content of the study area and its vegetation. This would provide data for environmental studies related to the transport and provenance of the airborne biological particles.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in the Mai Mustapha Aliyu International College of Health Science and Technology, Biu, Borno State, Nigeria. The College is located in the heart of Biu town, Borno State, Northeastern Nigeria.

Biu is a town and a Local Government Area (LGA) in Southern Borno State of Nigeria. The town is the administrative center of the LGA and was once the capital of Biu kingdom, and is now the capital of the Biu Emirate. Biu lies on the Biu Plateau at an average elevation of 626 meters. The region is semi-arid. Biu kingdom became established around 1670 in the reign of Mari Watila Tampta. King Mari Watirwa (r. 1793-1838), whose capital was near Biu at Kogu, defeated Fulani invaders from the Gombe Emirate to the West. In 1878, Mari Biya became the first Babur king to rule from Biu. The name of Biu was initially called Viu which in Babur and Bura language means high. The Emir palace is now situated in the town. With British rule, Biu division was created in 1918. Mai Ari Dogo was acknowledged as the first Emir of Biu in 1920. The area became known as the Biu federation after 1957, when the districts of Shani and Askira were added to the Emirate. Maidalla Mustafadan Muhammad (b. 1915) became Mai Biu, also styled Kuthli, in 1959.

There is a small mining industry in Biu, with iron ore, Gravel, Magnesite, Uranium, Fedspar, Topaz, Mica, Granite, Aquamarine, Nephelite and salt being extracted. The land is rugged and consists of plains, gullies, seasonal streams, rock out crops, and dead grounds. It is partly covered with sparse vegetation and shrubs. During the Harmattan season, it is patched and dry but becomes soggy and wet during the rainy season. Main ethnic group of Biu include the Baburawa, Fulanis, Hausas and other non-indigenous groups. The Biu Local Government Area has a large number of communities in addition to Biu, which include: Balbaya, Mbulamile, Buratai, Mirnga, SabonLayi, Tum, Yamarkumi, Zara, Filinlirgi, Galdimare, Garundana, Kimba, Kogu, MainaHari, Mandafuma, Mandagirau, Mangada (Amaza, *et al*., 2007). It is inhabited by the indigenous Hausas and other multi-ethnic groups and the languages spoken are Hausa, Fulani, English, Igbo and Yoruba, with Hausa as the common medium of communication and English language which is the conventional means of communication (Ali, 1995). Biu climate has a Tropical savanna climate and a population of about 176,072 as at the 2006 census. The land of Shani Local Government Area is covered with volcanic soil and the mean annual rainfall is 510-1150 mm, the dry season last 5 to 7 months. Increased seasonality and irregularity of rainfall impose semi-arid condition on the study area. The harmattan season between December and January is basically influenced by the North-East Trade winds. It has mean annual temperature of between 25 and 38^{o}C. There is extensive area of seasonal swamps. The vegetation is typically mixed Combretaceous woodland with *Vitellaria paradoxa*, *Acacia senegal*, *Acacia albida*, *Zizyphus* spp., *Adansonia digitata*, and *Piliostigma reticulatum* being the dominant trees. The common grasses in the zone, Aristida, *Brachiaria*, *Panicum*, *Chloris*, *Digitaria*, and *Eragrostis* are mostly short. Cultivation is intense and together with heavy grazing, bush burning and cutting for firewood/ charcoal, and browse, has contributed to extensive desertification in the study area (Essien *et al*., 2023).

The economy of Biu Local Government Area is mixed agricultural based on herding cattle, goats, sheep, horses and donkeys and farming activities which include; Sorghum, Rice, Maize, Cowpea and Cotton. Agriculture consists mostly of small farms using traditional methods. About 70% of the populations in the study area engage in farming.

3.2 Study Design and Sampling Techniques

Eight locations were randomly selected within the Mai Mustapha Aliyu International College of Health Science and Technology, Biu, Borno State, Nigeria as sampling sites. The sampling sites for the study were purposively selected to cover a wide range of the study area (Patton, 1990). In choosing the sites, consideration was also given to urbanization, accessibility, and safety of the sampling (experimental materials) instruments among others. At each site, a pollen trap (Modified Tauber Sampler) was buried in the ground in such a way that the collar was about 4cm above the ground level according to the methods of Tauber (1974; 1977; Pardoe *et al*., 2010, and Giesecke *et al*., 2010).

At the various locations, the sampler was mounted in an open field firmly secured to the ground by making a tripod stand where the sampler was seated at about six (6 m) meters above sea level to ensure its stability in the ground as well as to prevent flood from washing it away. Surrounding weeds were periodically cleared to minimize over representation of local pollen from such weeds. The immediate surroundings of the sampler were fenced with a cord and properly labeled to protect them from passerby. They were also painted blue to make them contrast with the surrounding environment.

The Modified Tauber Sampler is a gravimetric sampler or non-volumetric sedimentary passive sampler that relies on gravity to assess the composition of atmospheric content (Hicks and Hyvarinen, 1986). The device is used widely for long-term studies of airborne palynomorphs. In principle, the palynomorphs collected by these processes are believed to be analogous to incorporation of pollen into sediments. The Modified Tauber Sampler is shaped like a bucket measuring 3,606.8878cm^3 in volume. It consists of a receptacle and a lid (collar). The shape and capacity of the receptacle is large enough to accommodate the expected monthly rainfall and the reagents that are introduced into it. The conical shape collar has an apical opening measuring 5cm in diameter and covered with fine meshed wire gauze to prevent large insects and particles from entering it. The material from which the sampler was made is sufficiently resistant to corrosion in the field for the duration of the study without getting destroyed.

Prior to this, a mixture of glycerol (65ml), formalin (30ml) and phenol (5ml) were poured into each of the trap. However, during the dry season, the volume was increased to about 200ml (glycerol 130ml), formalin (60ml) and phenol (10ml). The positions of the trap at each location were recorded using Global Positioning System (Garuda GPS). The solutions in the trap prevented the palynomorphs from drying up, killed insects and also prevented the decay of dead organisms. The trap was left to stand throughout the duration of the study period (August to December 2023). Fortnightly of each month, solution collection was done. The traps were washed with water to remove any contaminants and were then recharged with the above-mentioned chemical solutions. The monthly collections were stored in plastic bottles and labeled accordingly.

3.3 Chemical Preparation and Recovery of Airborne Palynomorphs

After the periodic collection of samples from the pollen sampler (Tauber,1974) from the site, chemical preparation was done following a number of steps to recover the palynomorphs. The palynomorphs were recovered through centrifugation at 2000 r.p.m for 5 minutes and supernatant decanted each time. The precipitate was washed twice with distilled water and recovered through centrifugation. The sediment was treated with glacial acetic acid before acetolysis.

3.4 Acetolysis

Acetolysis mixture were freshly prepared in a ratio of 9:1 from acetic anhydride and concentrated sulphuric acid (conc. H_2SO_4). Acetolysis were carried out by boiling the palynomorphs in a water bath at 100^0C according to the methods of Erdtman (1969). This process removes all the protoplasmic content of the pollen, spores and all the exineous materials like tryphine and Ubisch bodies. The mixture was placed in water–bath at 100˚C for 5 minutes. At the end of this, the mixture was stirred and then centrifuged for 5 minutes and the supernatant decanted. The recovered precipitates were washed with glacial acetic acid, and finally washed twice with distilled water, centrifuge each time at 200 revolution per minute (rpm) for 5 minutes and the supernatant decanted. The recovered palynomorphs were stored in plastic vials in glycerin and ethanol solution (2:1).

3.5 Mounting and Microscopic Examination

The acetolysed pollen grains, spores, and other palynomorphs were transferred with about 2ml of glycerol (glycerol/alcohol) into specimen tubes for storage. One drop of thoroughly shaken palynomorphs suspension were mounted on microscope slide and covered with an 18×18mm cover slip. The mount was sealed off with colourless nail varnish to prevent drying up of the palynomorphs. The prepared slide was then be examined microscopically with Olympus microscope at x400 magnification for counting and Leica microscope at x1000 magnification for detailed pollen morphological studies. Pollen identification; counting and classification were done as far as possible with the help of reference pollen descriptions and photomicrographs from Kremp and Kawasaki (1972); Sowunmi (1973, 1978, 1995); Agwu and Akanbi (1985); Y'bert (1979); Bonnefille and Riollet (1980); Barnett and Hunter (1998); Zillinsky (1983); Shubharani*et al*. (2013) and Essien *et al*. (2023). In addition, prepared slides of pollen samples in the Palynology Research Laboratory, Department of Biology, Nigerian Army University, Biu was used. Photomicrographs were taken using a Fluorescent PEC Medical Microscope Model No.: OZJ088 at x1000 magnification.

3.6 Medical Records Data Collection

Medical data of patients with allergy-related cases such as naso-bronchial allergy, bronchitis, conjunctivitis, dermatitis, hay fever, rhinitis and upper respiratory tract infections was collected monthly from the Medical Records Department of Biu General Hospital, Biu, Borno State from January 2017 to November 2023.

3.7 Statistical Analysis of Data

All the data generated from this study was subjected to descriptive statistics of frequency counts and percentages only. The classification for representation of pollen types followed was the one recommended by Louveaux *et al.* (1978) as adopted by Essien *et al*. (2023) for expressing pollen grain frequencies: Very frequent (over 45%), frequent (16-45%), rare (3-15%) and sporadic (> 3%).

RESULTS AND DISCUSSIONS

The results of this aeropalynomorphs study showed that the following particulate entities: pollen grains, spores of pteridophytes and fungi, diatom frustules, fungal hyphae, arthropods (insects and insect parts), plant tissues and bryophyte parts as well as charred plant particles were recorded at varying quantities and qualities. Cumulative monthly aeropollen counts across the study period are presented in Table 1. Results showed 29,281 pollen grains counts of which 77 pollen types belonging to 35 plant families were encountered. Three (3) of the aeropollen types were identified to family level, 18 to species level, 55 to generic level and one (1) unidentified. The predominant pollen types belong to the family Poaceae, *Casuarina equisetiifolia*, *Apilia africana*, and Cyperaceae while the fungal spores belong to the species of *Nigrospora*, *Dreschelia*, *Ustilago*, *Botryodiplodia*, *Curvularia*, *Corynespora* and *Pithomyces*.

Table 1: Cumulative monthly aeropollen counts across the study period (2023)

S/N	Pollen type / Month	August	September	October	November	December	TOTAL
A	DICOTYLEDONS						
1	**ACANTHACEAE**						
	Hypoestes spp	3	8	5	7	21	44
	Justicia spp	5	5	3	8	11	32
2	**AMARANTH.ACEAE**	26	28	24	16	11	105
3	**ANACARDIACEAE**						
	Lannea acida	19	13	12	10	9	63
	Mangifera indica	0	17	7	11	5	40
4	**ANNONACEAE**						
	Annona senegalensis	5	7	2	3	34	51
5	**APOCYNACEAE**						
	Calotropis procera.	2	8	23	11	7	51
	Rauvolfia vomitoria	0	9	4	23	14	50
6	**ASTERACEAE**						
	Aspilia africana	74	121	231	87	347	860
	Bidens pilosa	3	21	11	4	2	41
	Emilia sonchifolia	7	3	12	47	7	76
	Gutenbergia sp.	3	5	0	5	10	23
	Tridax procumbens	255	478	19	85	11	848
	Vernonia amygdalina	2	7	5	9	16	39
7	**CAESALPINOIDEAE**						
	Berlinia grandifolia	0	12	5	28	28	73
	Daniellia oliveri	34	31	19	67	45	196
	Delonix regia	3	17	27	29	11	87
	Dialium guineense	18	15	22	43	39	137
	Piliostigma thonningii	12	8	0	26	0	46
	Senna occidentalis	145	259	101	161	268	934
8	**CARICACEAE**						
	Carica papaya	6	14	9	25	42	96
9	**CASUARINACEAE**						
	Casuarina equisetiifolia	19	94	23	719	217	1072

10	**COMBRETACEAE**						
	Combretum sp.	11	42	30	24	47	154
11	**EBANECEAE**						
	Diospyros spp.	14	5	18	38	33	108
12	**ERICACEAE**						
	Empetrum nigrum	5	14	16	7	17	59
	Sapium sp.	0	0	7	3	8	18
13	**EUPHORBIACEAE**						
	Acalypha sp.	15	847	497	196	99	1654
	Euphorbia hirta	8	58	23	9	17	115
	Euphorbia heterophylla	9	21	17	53	1	101
	Jatropha curcas	2	17	9	58	14	100
	Ricinus communis	14	2	6	2	18	42
14	**LAMIACEAE**						
	Hyptis suaveolens	12	47	76	24	6	165
	Leucas sp.	5	7	9	2	11	34
15	**LEEACEAE**						
	Leea guineensis	0	3	5	0	0	8
16	**LINACEAE**						
	Linum catharticum	4	7	0	2	2	15
	Linum sp.	12	0	42	1	3	58
17	**MALVACEAE**						
	Abelmoschus esculentus	5	7	21	30	11	74
	Sida acuta	24	308	18	49	162	561
18	**MELIACEAE**						
	Azadirachta indica	7	2	9	0	0	18
	Khaya ivorensis	0	2	7	3	16	28
	Khaya senegalensis	4	15	2	7	7	35
	Trichilia prieureana	0	13	35	18	34	100
19	**MIMOSOIDEAE**						
	Acacia senegal	0	3	8	37	0	48
	Acacia sp.	19	11	232	9	3	274
	Albizia sp.	54	16	61	0	11	142
	Albizia zygia	58	191	151	177	233	810
	Leucaena leucocephala	5	21	5	7	29	67
	Parkia biglobosa	15	137	225	39	18	434
	Prosopis africana	0	63	37	215	291	606
20	**MYRTACEAE**						
	Eucalyptus globulus	16	5	7	21	33	82
	Euginea sp.	57	61	5	1	3	127
	Syzygium guineense	72	11	36	81	122	322
21	**OCHNACEAE**						
	Lophira alata	4	9	41	6	10	70
22	**PAPILIONOIDEAE**						
	Indigofera sp.	7	8	5	9	17	46
	Vigna unguiculata	11	0	9	5	15	40
23	**PEDALIACEAE**						
	Sesamum indicum	36	72	15	15	113	251
24	P**ERIPLOCACEAE**						
	Periploca sp.	0	283	52	224	12	571
25	**PHYLLANTHACEAE**						
	Hymenocardia acida	2	30	8	78	18	136
	Phyllanthus sp.	4	0	9	24	10	47
	Securinega virosa	10	27	12	16	11	76
26	**PROTEACEAE**						
	Protea elliotii	1	1	6	3	13	24
27	**RUBIACEAE**						

	Borreria sp.	0	3	5	7	3	18
	Gaertnera paniculata	0	22	9	10	46	87
	Morelia senegalensis	9	49	141	160	12	371
	Sarcocephalus latifolius	57	71	117	41	59	345
28	**RUTACEAE**						
	Citrus sp.	4	107	35	6	10	162
29	**SAPINDACEAE**						
	Paullinia pinnata	2	21	74	1	3	101
30	**SAPOTACEAE**						
	Vitellaria paradoxa	12	51	11	7	82	163
31	**SOLANACEAE**						
	Physalis angulata	1	1	12	24	0	38
	Solanum melongena	27	38	401	41	27	534
32	**STERCULIACEAE**						
	Sterculia sp.	10	27	12	16	11	76
	Triplochiton scleroxylon	2	102	23	93	18	238
33	**VERBENACEAE**						
	Gmelina arborea	8	18	38	18	24	106
	SUB TOTAL	**1691**	**4489**	**3232**	**3397**	**2927**	**15736**
	2.MONOCOTYLEDONS:						
34	**CYPERACEAE**	415	446	31	66	18	976
35	**POACEAE**	3104	3892	4145	1679	594	13414
36	**INDETERMINATA**	1	2	7	1	6	17
	SUB TOTAL	**3124**	**3907**	**4164**	**1690**	**609**	**13494**
B	**GYMNOSPERMS**						
37	**PINACEAE**						
	Pinus caribaea	9	7	12	4	19	51
	Total pollen counts	**5788**	**9297**	**8416**	**4343**	**1945**	**29281**
C	**PTERIDOPHYTES:**						
1.	**ASPIDIACEAE**						
	Cystopteris fragilis	0	5	7	0	3	15
	Goniopteris vivipara	10	5	5	7	22	49
2.	**DAVALLIACEAE**						
	Nephrolepis exaltata	14	0	8	5	31	58
3.	**HYMENOPHYLLACEAE**						
	Callistopteris apiifolia	5	0	20	11	15	51
4.	**PTERIDACEAE**						
	Anopteris hexagona	23	5	0	5	9	42
	Pteris dentata	0	0	8	3	4	15
	Monolete	126	113	23	22	18	302
	Trilete	1	1	2	0	1	5
	SUB TOTAL	**179**	**129**	**73**	**53**	**103**	**537**
	GRAND TOTAL	**5967**	**9426**	**8489**	**4396**	**2048**	**29818**

The abundance of these airborne palynomorphs trapped in the present study may be attributed to the availability of their primary sources such as vascular plants (that release pollen grains and fern spores), fungi (that release spores and hyphae), non-vascular plants (algae, diatom frustules, etc.), arthropod (insects and insect parts) moults and parts as well as human activities (bush fire, exhaust fumes, sooths, etc.) among others (Agwu, 2001; Agwu *et al*., 2004, Essien and Aniama, 2014; Essien *et al*., 2015).
Fungal spores were the dominant component of the airborne palynomorphs recorded the study and constituted 46.71% of grand total palynomorphs (Tables 2 and 3). Fungal spores are of cosmopolitan distribution and constitute a large proportion of total airborne palynomorphs recorded in most aeropalynological studies.

Table 2: Cumulative monthly fungal spore and other aeropalynomorphs counts

S/N	Fungal Spore type	August	September	October	November	December	TOTAL
1	*Alternaria* sp.	32	18	32	11	21	114
2	*Aspergillus* sp.	0	21	0	32	0	53
3	*Beltrania* sp.	6	13	5	10	0	34
4	*Botryodiplodia* sp.	596	586	496	125	209	2012
5	*Cercospora* sp.	0	0	19	0	2	11
6	*Cladiosporium* sp.	17	31	0	22	5	75
7	*Cordana* sp.	0	18	0	0	0	18
8	*Corynespora* sp.	233	280	733	247	54	1547
9	*Curvularia* sp.	772	576	646	404	311	2709
10	*Dictyoarthrinium* sp.	0	0	17	24	0	41
12	*Dreschelia* sp.	1218	1202	2136	1200	793	6549
13	*Endophragmiella* sp.	52	17	48	32	51	200
14	*Epicoccum* sp.	0	0	8	0	0	8
15	*Exosporium* sp.	0	0	0	0	5	5
16	*Fusarium* sp.	29	0	5	0	0	34
17	*Ganoderma* sp.	14	7	33	2	8	64
18	*Glomastix* sp.	39	36	46	28	16	165
19	*Glomerularia* sp.	0	0	0	0	4	4
20	*Histoplasma* sp.	0	0	0	0	18	18
21	*Holerinema* sp.	0	0	0	0	37	37
22	*Murogenella* sp.	7	0	0	4	0	11
23	*Neurospora* sp	292	34	11	17	15	369
24	*Nigrospora* sp.	3933	1821	1141	320	175	7390
25	*Pithomyces* sp.	475	337	301	147	71	1331
26	*Puccinia* sp.	88	0	40	115	228	471
27	*Stemphylum* sp.	5	0	6	2	0	13
28	*Syncephalastrum* sp.	21	54	11	19	7	112
29	*Tetraploa* sp.	209	82	124	47	19	481
30	*Torula* sp.	102	25	12	5	1	145
31	*Uromyces* sp.	35	28	84	27	3	177
32	*Ustilago* sp.	1786	906	1839	918	399	5848
33	*Venturia* sp.	252	83	29	10	13	387
34	Unidentified	0	0	8	0	0	8
	Total Fungal Spore	**10213**	**6175**	**7830**	**3768**	**2465**	**30451**

	Other Palynomorphs						
1	Algal cysts	11	180	0	0	0	29
2	Arthropods/ parts	117	123	315	252	107	914
3	Bryophyte	15	0	3	0	0	18
4	Charred plant tissue	73	219	1441	602	163	2498
5	Diatom frustules	130	156	293	299	378	1256
6	Dinoflagellate cysts	60	12	2	0	0	74
7	Fungal hyphae	11	3	7	3	12	36
8	Plant tissue	5	7	33	2	42	89
	Total	**422**	**538**	**2093**	**1158**	**702**	**4914**
	Grand Total	**10635**	**6713**	**9923**	**4926**	**3167**	**35365**

On the basis of the present study, a very high concentration of fungal spores and few fungal hyphae were documented. The abundance of these airborne fungal spore genera is not only a reflection of the degree of abundance of the spores in the air, but an indication of the availability of host plants and other spore sources in the region. The high annual concentration record of fungal spores and their complete dominance over other biological particles in this study compare favourably with the findings of Khandelwal (1988), Calleja *et al*. (1993), Agwu *et al*. (2004), Konopinska, 2004, Njokuocha and Osayi (2005) and Essien *et al*. (2013b)..

The high number of spore genera (34) identified coupled with the numerous unidentified spores reflect to a large extent the diversity of spore-bearing fungi and that of the host plants.

Table 3: Summary of the aeropalynomorphs encountered in the study

S/N	Palynomorphs	Quantitative count	Percentage of grand total (%)
1	Algal cysts	29	0.04
2	Arthropods	914	1.40
3	Bryophyte remains	18	0.03
4	Charred plant tissues	2,498	3.83
5	Diatom frustules	1,256	1.92
6	Dinoflagellate cysts	74	0.11
7	Fungal hyphae	36	0.05
8	Fungal spores	30,451	46.71
9	Plant tissues	89	0.13
10	Pollen grains	29,281	44.92
11	Pteridophytes spores	537	0.82
	Grand Total	65,183	

Moreso, it has been reported that many fungi such as some species of mushroom, rusts and smuts are host-specific growing in close association with specific plant species and may not be found in the absence of the host (Burge and Rogers, 2008). Among the fungal spore types identified, those of *Corynespora* sp., *Curvularia* sp., *Endophragmiella* sp., *Nigrospora* sp., *Neurospora* sp., *Pithomyces* sp. and *Ustilago* sp. are the most common and dominant spore genera identified in this study. Studies have also shown that these spore genera belong to the dry air-spora (*Corynespora* sp., *Curvularia* sp., *Pithomyces* sp.) and wet air-spora (*Endophragmiella* sp., *Nigrospora* sp., *Neurospora* sp., *Ustilago* sp., *Venturia* sp.). Similar spore constitutions have been reported in airspora investigations in Nsukka and Anyigba by Agwu *et al*. (2004), Njokuocha and Agwu (2007), Essien *et al*. (2013b) and in related studies in other part of the world (Prince and Meyer, 1976; Vittal and Glory, 1985; Hurtado and Riegler-Goihman, 1987; Royes, 1987; Sterling *et al*., 1999, Troutt and Levetin, 2001; and Codina *et al*., 2008).

The highest period of fungal spores' abundance was recorded in July may be attributed to favourably environmental condition that promoted the release of both dry air spora and wet air spora in the area. The month of July recorded the highest number and amount of annual rainfall. This period actually favours the growth, production and release of abundant spores especially the wet-air spora. However, the wash out effect of rainfall reduces drastically the concentration of airborne spora and consequently the quantity trapped. Seasonal variation showed that the highest mean fungal spore abundance was more from June-July and October- December than from August – September and the dry period of January – April due to higher sporulation activities by the fungi. Similar findings have been reported by previous authors (Lyon *et al*., 1984; Burge, 1986; Royes, 1987; Troutt and Levetin, 2001).

Pollen Allergies, Allergens and Allergic Proteins in Dominant Aeropollen

Although this study does not involve allergenic protein characterization, aerobiological studies have revealed some dominant aeropollen in the atmosphere which could be allergenic due to their relative abundance and the plant families they belong to. Examples of these dominant aeropollen types documented in this study are presented in Table 4.

Table 4: Allergic aeropollen types dominant in the study area

S/N	Pollen type / Month	August	September	October	November	December	TOTAL	Plant form
1	*Acacia* sp.	19	11	232	9	3	274	Shrub
2	AMARANTH.ACEAE	26	28	24	16	11	105	Herb
3	*Aspilia africana*	74	121	231	87	347	860	Herb
4	*Azadirachta indica*	7	2	9	0	0	18	Tree
5	*Carica papaya*	6	14	9	25	42	96	Herb
6	*Casuarina equisetiifolia*	19	94	23	719	217	1072	Tree
7	CYPERACEAE	415	446	31	66	18	976	Sedges
8	*Delonix regia*	3	17	27	29	11	87	Tree
9	*Justicia* spp	5	5	3	8	11	32	Herb
10	POACEAE	3104	3892	4145	1679	594	13414	Herb
11	*Prosopis africana*	0	63	37	215	291	606	Tree
12	*Ricinus communis*	14	2	6	2	18	42	Shrub
13	*Tridax procumbens*	255	478	19	85	11	848	Herb
	TOTAL	3974	5173	4796	2940	1574	18430	

This dominance is due to the presence of a bioactive ingredient (histamine) in the pollen grains of these taxa as well as the cosmopolitan nature of these groups of plants in our environment. Ige and Essien (2019a) reported that the occurrence of pollen grains from *Acacia* sp., *Azadirachta indica*, *Bombax buonopozense, Carica papaya*, *Casuarina equisetiifolia*, *Ceiba pentandra, Cocos nucifera*, *Delonix regia*, *Ipomoea* sp., *Justicia* sp., *Prosopis africana*, *Ricinus communis* and those of the families Amaranthaceae/ Chenopodiaceae, Asteraceae, Cyperaceae and Poaceae during the months of June to July and September to January indicates the availability of allergenic taxa in the atmosphere. For instance, Poaceae (grass) pollen grains have been reported by Subiza *et al*. (1992) to be one of the most important factors for rhinitis and/or asthma in Spain, as well as in the other Western European countries. In Catalonia (NE Spain) Poaceae pollen grains showed symptoms in 35% of patients and are thus the highest-ranking taxa with allergenic significance (Belmonte *et al*., 2000).

Although this study did not extend to clinical immunological or sensitivity tests, some of the dominant aeropollen grains identified in this study have been proven to be perennial or seasonal causes of allergy (Singh, 1987; Mishra *et al*., 2002). In this study, thirteen (13) allergic pollen types were documented. These allergic taxa contributed 18,430 out of 29,281 total pollen grains counts encountered in the study (Table 4). These pollen types have also been reported in previous aerobiological studies in Nsukka (Agwu, 1997; Agwu *et al*., 2004; Njokuocha and Osayi, 2005; Njokuocha, 2006), Port Harcourt (Agwu, 2001), Aguata (Njokuocha and Ezenwajiaku, 2010), Anyigba (Essien, 2014; Essien *et al*., 2016), Ayetoro (Adeonipekun *et al*., 2016); Abuja (Ezike *et al*., 2016); Gbagada (Adeniyi *et al*., 2018a); Jabalur, Bengal, India (Chakraborty *et al*., 2001; Mishra *et al*., 2002).

Allergies are a heavy socio-economic burden worldwide. There is a deficit in public awareness, education and training on allergies; therefore, efficient preventive strategies are urgently needed.

However, in allergenicity studies, a vegetation reconnaissance of the sampled area is conducted to determine the dominant species within the region as it is in the present study. For example, the allergenic aeropollen types identified in this study contains allergenic proteins and similar findings has been reported by Adeniyi *et al*. (2018b) to have a high allergenicity of 84% and this poses great risk to hypersensitivity individuals. Also, its abundant/ copious production of pollen grains, which are widely dispersed and often remain in the atmosphere throughout the calendar year, poses another major risk. Because of these properties, Adeniyi *et al*. (2018b) in Ige and Essien (2019a) suggested an integrated weed management approach for these allergenic taxa: these plant populations should be reduced to the barest minimum in urban areas, and such area should be re-vegetated; they should be allowed to remain in urban wetlands (where they certainly perform ecological functions but they should be pruned regularly to prevent flowering; cut/ thinned.

Allergic and Pathologic Effects of the Identified Fungal Spores

Much has been reported about the abundance and cosmopolitan nature of fungal spores and their associated allergenic reactions (runny nose, watery and itchy eye) and diseases of humans, domestic animals and plants. In fact, they constitute very serious danger to immune-compromised patients. Some of the fungal spores identified in this study (Table 2) have been reported by several authors to cause allergies such as rhinitis, pollinosis and exacerbation of asthmatic attack as well as pathogenic infections of the respiratory tract. Other spores identified are among the invasive airborne fungal spores that have been implicated in nosocomial (hospital) infection of patients with solid organ transplants, those treated for leukemia and recipients of allergenic stem cell transplants (Barnes and Rogers, 1989; Rhame, 1991; Richardson and Ellis, 2000; Sanchez and Bush, 2001; Chakraborty *et al*., 2001; Cashel *et al*., 2004; Spiewak and Dutkiewicz, 2004). Such spore genera identified included the species of *Alternaria*, *Aspergillus*, *Dreschelia*, *Cladosporium*, *Curvularia*, and *Nigrospora* among others.

Pathologically, many fungal species identified in this study have also been associated with diseases of many agricultural crops and wild plants in Nsukka and many other places (Njokuocha, 2006; Essien and Aina, 2014). Such diseases are loose smut of wheat, maize smut (*Ustilago* sp.), leaf blight and spots, purple blotch, damping-off and scab caused by *Alternaria* sp., *Dreschelia* sp., early leaf blight of tomato (*Cladosporium* sp.) and cassava blight (*Alternaria* sp.) among others (Adeoti and Marley, 1995; Onyeke *et al*., 2003; Konopinska, 2004). Most of these fungal pathogens show multiple and whole plant host ranges, while some others are saprophytic on agricultural produce. Their prevalence in the air is a reflection of their entrenchment and serious threats to agricultural crops, their produce as well as wild plants.

Most of the predominant aeropollen types and fungal aerospora identified in this study have been reported by several researchers to be among the invasive and prevalent aeropollen documented in most aeropalynological studies (Njokuocha, 2006; Adeonipekun and John, 2011; Essien and Aina, 2014; Adeniyi *et al*., 2017). Findings compare favourably with the report of Adeniyi *et al*. (2018b) who opined that dominant pollen grains in the air of Gbagada (Lagos State, Nigeria) are those of Amaranthaceae, Cyperaceae and Poaceae among others. These pollen types statistically have an impact on the health of hypersensitivity individuals, especially those with wheezing cough symptoms.

There were noticeable differences in the taxa and quantity of pollen counted at the locations (sites) with regards to the pollen contribution by trees, shrubs, herbs, sedges, lianas, and herbaceous climbers. This may be attributed to the divergent sub-type vegetations sporadically distributed in the study locations, the land use pattern that favour certain plants by selection or protection and the direction of wind relative to the bearing of the sampler.

CONCLUSION

The findings of the study showed that numerous aeropalynomorphs dominated by pollen grains and fungal spores was abundant in the atmosphere. The occurrence of pollen types from *Azadirachta indica*, *Carica papaya*, *Casuarina equisetiifolia*, *Delonix regia* and those of the families Asteraceae, Cyperaceae and Poaceae indicates the availability of allergenic taxa in the atmosphere. The various ecological indicators species identified confirmed their origin as coming from the Sudan- Savanna ecological zone that is anthropogenically disturbed. The presence of pollen types from exotic plants and charred plant particles as part of the content of the atmospheric palynomorphs indicates clearly the high impact of man on the environment. The presence of fungal, bryophyte and pteridophyte spores, dinoflagellate cysts and diatom frustule in the atmosphere confirm the great influence of anthropogenic activities on the local vegetation. This factor can be used to monitor the frequency and intensity of indiscriminate bush fire and other anthropogenic activities on the local vegetation. Though most of the pollen types encountered from the study reflected the flora of Biu environment, the presence of pollen grains from *Empetrum nigrum* indicates valid evidence of long-distance transport.

Disclosure of conflict of interest

The authors declares that there is no conflict of interest.

REFERENCES

Adeniyi, T.A., Adeonipekun, P.A., Olowokedujo, J.D. and Akande, I.S. (2017). Allergenicity of dominant aeropollen in Nigeria. Part 1. *Current Allergy and Clinical Immunology*, 30(4):264-269.

Adeniyi, T.A., Adeonipekun, P.A. and Olowokedujo, J.D. (2018a). Comparative study of aeropollen and pollinosis cases. *Environmental Monitoring and Assessment*, 190: 562-572.

Adeniyi, T.A., Adeonipekun, P.A., Olowokedujo, J.D. and Akande, I.S. (2018b). Allergenicity of dominant aeropollen in Nigeria. (Part 11). *Current Allergy and Clinical Immunology*, 31(3):178-183.

Adeonipekun, P.A. and John, M. (2011). Palynological investigation of haze dust in Ayetoro-Itele, Ota, Southwest Nigeria. *Journal of Ecology and the Natural Environment*, 3: 455-460.

Adeonipekun, P.A., Agbalaya, A.E. and Adeniyi, T.A. (2016). Aeropalynology of Ayetoro-Itele, Ota, South-West Nigeria: A preliminary study. In: R.Alabi and P.A. Adeonipekun (Eds.). human Palaeoecology in Africa: Essays in honour of M.Adebisi Sowunmi. University of Ibadan Press, Ibadan, Nigeria. Pp 130-153.

Adeoti, A.A. and Marley, P.S. (1995). Mycoflora associated with cob rots of maize in Samaru, Zaria, northern Nigeria. *Nigerian Journal of Botany*, 8:57-64.

Agashe, S.N. (1994). *Recent Treads in Aerobiology and Immunology*. Oxford & IBH Publ. Company, New Delhi. 357pp.

Agwu, C.O.C. and Akanbi, T.O. (1985). A palynological study of honey from four vegetation zones of Nigeria. *Pollen et Spores*, 27:335-348.

Agwu, C.O.C. (2001). A Study of Niger Delta Environment through air-borne palynomorphs, Port-Harcourt, Nigeria. *Palaeoecology of Africa*, 27:191-205.

Agwu, C. O. C., Njokuocha, R. C. and Mezue, O. (2004). The study of airborne pollen and spores circulating at "head level" in Nsukka environment. *Bio-Research*, 2(2):7-14.

Barnett, H. L. and Hunter, B. (1998). *Illustrated Genera of Imperfect Fungi*. Fourth Edition. APS Press, Minnesota, USA. 218pp.

Barnes, R. A. and Rogers, T. R. (1989). Control of an outbreak of nosomial aspergillosis by laminar air-flow isolation. *Journal of Hospital infection*, 14:89-94.

Belmonte, J., Canela, M. and Guardia, R.A. (2000). Comparison between categorical pollen data obtained by Hirst and Cour sampling methods. *Aerobiologia*, 16: 177-185.

Blackley, C.H. (1873). Experimental Research on the cause and nature of *Catarrhus aestivus* (*Hay fever or Hay Asthma*). Bailliere, Tindall and Cox, London. (Reprinted: Bawson, London, 1959). 183pp.

Bonnefille, R. and Riollet, G. (1980). Pollen des savanna d'Afrique orientale. Anatole Press, Paris, France. 140pp.

Burge, H.A. and Rogers, C.A. (2008). Outdoor allergens. *Environmental Health Perspective*, 108: 655-368.

Calleja, M., Strick, R.M. and Duzer, D. (1993). Atmospheric pollen content of West Africa. *Review of Palaeobotany and Palynology*, 79:335-368.

Cashel, P., Newhouse, B. S. and Levetin, E. (2004). Correlation of environmental factors with asthma and rhinitis symptoms in Tulsa. *Annals of Allergy, Asthma and Immunology*, 92: 356-366.

Chakraborty, P., Gupta, S., Gupta-Bhattacharya, S. and Chanda, S. (1999). Airborne pollen of *Borassus flabellifer*: Quantification of allergen and antigen. *Aerobiologia*, 15: 49 - 55.

Codina, R., Fox, R.W., Lockey, R.F., DeMarco, P. and Bagg, A. (2008). Typical levels of airborne fungal spores in houses without obvious moisture problems during a rainy season in Florida, U.S.A. *Journal of Investigational Allergology & Clinical Immunology*, 18(3): 156-162.

Erdtman, G. (1969). *Handbook of Palynology*. Muntisguard, Copenhagen. 285pp.

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

Essien, B.C., Aniama, S.O. and Idachaba, S.O. (2013a). A study of Derived Savanna environment through airborne palynomorphs, Anyigba, Kogi State, Nigeria. *Scholars Academic Journal of Biosciences*,1(6): 313-317.

Essien, B.C., Taiga, A., Suleiman, M. N., Idachaba, S. O., Aniama, S.O. and Edegbo, E. (2013b). A study of airborne fungal spores of Anyigba, Kogi State, Nigeria. *American Journal of Biomedical and Life Sciences*,1(4): 70-74.

Essien, B.C. (2014). A comparative analytical study of airborne pollen grains, spores and other palynomorphs within Grimard Catholic hospital, Anyigba, Kogi State, Nigeria. *Scholarly Journal of Scientific Research and Essay*, 3(5): 56-60.

Essien, B.C. and 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. *International Journal of Advances in Medical Sciences and Biotechnol*ogy, 2(3): 23-28.

Essien, B.C. and Aniama, S. O. (2014). Environmental impact analysis through aeropalynology, Kogi State Nigeria. *Standard Scientific Research and Essays,* 2(3): 060-064.

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

Essien, B.C., Ige, O.E. and Ekeyi, D. (2016). Recent pollen rain in Anyigba: an indicator of the vegetation of Kogi State, Nigeria. *World Journal of Biology and Medical Sciences*, 3(1):82-92.

Essien, B.C. (2019). The environmental, ecological and medical impact of airborne pollen grains, spores of fungi and pteridophyte and other atmospheric palynomorphs in Akoko division, Ondo State, Nigeria. *IOSR Journal of Biotechnology and Biochemistry*, 5(5): 8-17.

Essien, B.C**.** and Ige, O.E. (2019). Diversity, morphology and comparative study of season of airborne pollen grains abundance in four Local Government Areas in Akoko division, Ondo State, Nigeria. *South Asian Research Journal of Biology and Applied Biosciences*, 1(1): 9-19.

Essien, B.C.**,** Tsoho, S.B., Obigba, S.O., Atukpa, M.E., Ademoh, O.F., Oladeji, T.C., Oluwajuyigbe, B.M. and Fatoyinbo, S.O. (2024). Investigation of the health implications, abundance and spatio-temporal distribution of bioaerosols in Akoko region of Ondo State, Nigeria. *Kashere Journal of Science & Education*, 2(1): 109-121.

Essien, B.C., Ige, O.E., Ibrahim, Y.O. and Fatoyinbo, S.O. (2023). Palynotaxonomical study of Honeybees (*Apis mellifera var. adansonii*) forage and/or preference plants in South-Western Nigeria. *Journal of Biological Research and Biotechnology (Bio-Research)*, 21(2): 1973–1994.

Ezike, D.N., Nnamani, C.V., Ogundipe, O.T. and Adekanmbi, O.H. (2016). Airborne pollen and fungal spores in Garki (North-Central Nigeria). *Aerobiologia*, 32: 697-707.

Foster, J. and Clark, P. (2001). "Corn pollen deposition on milkweeds in and near cornfields". *Proceedings of the National Academy of Sciences of the United States of America*, 98(21):11919-11924.

Gallup, P., Kozak, P., Cummins, L. and Gillman, S. (1987). Indoor mold spore exposure characteristics of 127 homes in southern California with endogenous mold problems. *Experimentia Supplementum*, 51:71-80.

Giesecke, T., Fontana, S.L., van der Knaap, W.O., Pardoe, H.S. and Pidek, I.A. (2010). From early pollen trapping to experiments to the Pollen Monitoring Programme. *Vegetational History and Archaeobotany*, 19:247-258.

Hicks, S. (1992). Aerobiology and Palaeoecology. *Aerobiologia*, 8:220-230.

Hicks, S. and Hyvarinen, V.P. (1986). Sampling modern pollen deposition by means of "Tauber traps": some considerations. *Pollen et Spores*, 28:219-242.

Hurtado, I. and Riegler-Goihman, M. (1987). Air sampling studies in a tropical area, four years result. *Experimentia Supplementum*, 51: 49-53.

Ige, O.E. and Essien, B.C. (2019). Monitoring environmental change in Akoko North-East Local Government Area of Ondo State, Nigeria through pollen analysis. A paper presented at the 10th Palynological Association of Nigeria (PAN) Conference. Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria. 5th to 9th May, 2019.

Jato, V., Mendez, J., Rodriguez-Rajo, J. and Seijo, C. (2002). The relationship between the flowering phenophase and airborne pollen of *Betula* in Galicia (N.W. Spain). *Aerobiologia*, 18:55-64.

Khandelwal, A. (1988). Vertical variation of aerospora concentration at Lucknow, India. *Geophytology*, 18(2): 173-185.

Konopinska, A. (2004). Monitoring of *Alternaria* Ness. and Cladosporium link airborne spores in Lublin (Poland) in 2002. *Annals of Agriculture and Environmental Medicine*, 11:347-349.

Kremp, G.O.W. and Kawasaki, T. (1972). *The spores of Pteridophytes. Illustration of the spores of the ferns and fern allies*. Hirokawa Publishing Company Incorporated. Tokyo, Japan. 398pp.

Louveaux, J. A., Maurizzio, A. & Vorwohl, G. (1978). Melissopalynology. *Bee World*, 51 (3): 125-138.

Lyon, F.L., Kramer, C.L. and Evermeyer, G.M. (1984). Variation of airspora in the atmosphere due to weather conditions. *Grana*, 23: 177-181.

Mishra, R.P., Singh, B. and Oommachan, M. (2002). Airborne pollen flora of Jabulur- the central India. *Aerobiologia*, 18: 73-81.

Nielsen, G.D., Hansen, J.S., Lund, R.M., Bergqvist, M., Larsen, S.T., and Clausen, S.K. (2002). IgE-mediated asthma and rhinitis I: a role of allergen exposure. *Pharmacology and Toxicology*, 90 (5): 231-242.

Njokuocha, R.C. and Osayi, E.E. (2005). Airborne pollen survey in relations to allergy and plant pathogens in Nsukka, Nigeria. *Nigerian Journal of Biological Research and Biotechnology*, 3(1):77-84.

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

Njokuocha, R.C. and Ukeje, H.O. (2006). The study of airborne pollen precipitation in the University of Nigeria (Nsukka) Botanic Garden. *Bio-Research*, 4(2):88-93.

Njokuocha, R. C. and Agwu, C. O.C. (2007). Airborne fungal spores in Nsukka municipality. *Nigerian Journal of Botany*, 20(2):349-359.

Njokuocha, R.C. and Ezenwajiaku, T.E. (2010). Airborne pollen flora in Aguata Local Government Area, Anambra State, Nigeria. *Nigerian Journal of Botany*, 23(2): 211-224.

Njokuocha, R. C. (2012). Factors affecting the distribution and variation of airborne palynomorphs in Enugu State, Nigeria. Unpublished Ph.D Dissertation, University of Nigeria, Nsukka. 163pp.

Onyeke, C.C., Maduewesi, J.N.C., and Ugwoke, K.I. (2003). Incidence of post- harvest fungal diseases of banana (*Musa sapientum Linn*.) fruits in South-Eastern Nigeria. *Nigerian Journal of Botany*, 16:7-15.

Pardoe, H.S., Giesecke, T., van der Knaap, W.O., Svitavaska-Svobodova, H., Kvavadze, E.V., Panajiotiotidis, S., Gerasimidis, A., Pidek, I.A., Zimney, M., Swieta-Musznicka, J., Latalowa, M., Noryskiewiez, A.M., Bozilova, E., Tonkov, S., Filipova-Marinova, M.V., vvan Leeuwen, J.F.N. and Kalnipa, L. (2010). Comparing pollen spectra from Modified Tauber Traps and Moss samples: example from a selection of woodlands across Europe. *Vegetational History and Archaeobotany*, 19:271-283.

Patton, M.Q. (1990). *Quantitative evaluation and research methods* (2nd Ed.). Sage Publications, Newbury Park, CA. 523pp.

Prince, H.E. and Meyer, G.H. (1976). An up-to-date look at mold allergy. *Annals of Allergy*, 37: 18-25.

Rhame, F.S. (1991). Prevention of nosocomial aspergillosis. *Journal of Hospital Infection*, 18(A): 466-472.

Richardson, M.D. and Ellis, M. (2000). Clinical and laboratory diagnosis of systemic fungi infection. *Hospital Medicine*, 61:61-614.

Royes, V.I.J. (1987). Some components of the air spora in Jamaica and their possible medical application. *Grana*, 26:151-157.

Sanchez, H. and Bush, R.K. (2001). A review of *Alternaria alternate* sensitivity. *Review of Iberoamericana Micology*, 18: 56-59.

Shubharani, R., Roopa, P. and Sivaram, V. (2013). Pollen morphology of selected bee forage plants. *Global Journal of Bio-Science and Biotechnology*, 2(1): 82- 90.

Singh, A.B. (1987). Airborne pollen types of allergic in India. *Experimentia Supplementum*, 51: 61-68.

Singh, A.B. and Singh, A. (1994). *Pollen allergy: a global scenario. In: recent trends in aerobiology and immunology*. S.N. Agashe (Ed.), Oxford & IBH Publishing Company, New Delhi. 170pp.

Sowunmi, M.A. (1973). Pollen of Nigerian plants I. *Grana*, 13:145-186.

Sowunmi, M.A. (1978). Polymorphism in the pollen of tropical plants. *IV International Palynology Conference*, *Lucknow*, 1:255-263.

Sowunmi, M.A. (1995). Pollen of Nigerian plants II. *Grana*, 34:120-141.

Spiewak, R. and Dutkiewicz, J. (2004). A farmer's occupational airborne contact dermatitis masqueraded by coexisting Rosaceae: delayed diagnosis and legal acknowledgement. *Annals of Agriculture and Environmental Medicine*, 11: 329-333.

Sterling, M., Rogers, C. and Levetin, E. (1999). An evaluation of two methods used for microscopic analysis of airborne fungal spore concentrations from the Burkard Spore Trap. *Aerobiology*, 15:9-18.

Subiza, J., Masiello, M., Subiza, J.L., Jerez, M., Hinojosa, M. and Subiza, E. (1992). Prediction of annual variations in the atmospheric concentrations of grass pollen. A method based on meteorological factors and grain crop estimates. Clinical and Experimental Allergy, 22: 540-546.

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

Tauber, H. (1974). A static non-overload pollen collector. *New Phytology*, 73:359-369.

Tauber, H. (1977). Investigations of aerial pollen transport in a forested area. *Dansk Botanisk Arkiv*, 32(1):1-121.

Thomas, F. and Leuschner, R.M. (2006). A change from grass pollen induced allergy to tree pollen induced allergy: 30 years of pollen observation in Switzerland. *Aerobiologia*, 16:407-416.

Troutt, C. and Levetin, E. (2001). Correlation of spring spore concentrations and meteorological conditions in Tulsa, Oklahoma. *International Journal of Biometeorology*, 45: 64-74.

Vittal, B.P.R. and Glory, A.L. (1985). Airborne fungus spores of a library in India. *Grana*, 24: 129-132.

Walker, S.M., Panjo, G.B., Lima, M.T., Wilson, D.R., and Durham, S.R. (2001). Grass pollen immunotherapy for seasonal rhimits and asthma: a randomized, controlled trial. *Journal of Allergy and Clinical Immunology*, 107:87-93.

Y'bert, J.P. (1979). *Atlas des Pollens de Cote d'Ivoire*. Office de la Research Scientifique et technique. *Outer Mer.*, Paris. 281pp.

Zillinsky, F. J. (1983). Common Diseases of Small Grain Cereals. A Guide to Identification. *American Phytopathological Society*, Minnesota, USA. 126pp.