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Original Research Article

Diversity, Morphology and Comparative Study of Season of Airborne Pollen Grains Abundance in Four Local Government Areas in Akoko Division, Ondo State, Nigeria

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Abstract: The study of atmospheric pollen content of an area is useful in providing vital information on environmental change, vegetation type, species composition and their utilization for safety health and sustainable development. The current study examined the diversity, morphology and comparative study of airborne pollen grains from four Local Government Areas in Akoko division, Ondo State, Nigeria. This study was carried out in fourty randomly selected locations to examine the temporal and spatial relationship between the atmospheric pollen content and its vegetation. The airborne pollen grains were collected with Modified Tauber Sampler using simple random sampling technique and analyzed palynologically. Results showed 50,661 pollen grains comprising of 182 pollen types belonging to 74 angiospermic plant families were encountered. Three (3) of these pollen types were identified to family level, 57 to species level, 121 to generic level and one (1) unidentified. The predominant pollen types belong to the family Poaceae, *Elaeis guineensis*, *Alchornea cordifolia*, *Aspilia africana*, *Casuarina equisetifolia*, and *Tridax procumbens*. The presence of *Empetrum nigrum*, *Linnea borealis*, *Linum* sp., *Stereospermum kunthianum* and *Vitellaria paradoxa* pollen indicates evidence of long distance transport. Airborne pollen grains were most abundant between September and January. Rainfall and relative humidity had more negative effect on pollen concentration. The effects of temperature and light intensity varied considerably with time and location because their effects are influenced by other meteorological factors. Continuous environmental monitoring through pollen rain analysis is recommended in order to produce a pollen calendar for the studied area.

Keywords: Airborne-pollen; Season of abundance; Diversity; Pollen morphology

INTRODUCTION

Airborne pollen grains, which are atmospheric particles of biogenic origin, is a common cause of allergy-related diseases such as asthma, bronchitis, rhinitis, and upper respiratory tract infection [1, 2]. The study of pollen grains of plant species reveals great diversity in their sizes, shapes, sculpture, density and abundance among other attributes [3].

Pollen identification, the basis of palynology, is based exclusively on pollen morphology [4, 5]. Pollen morphology is also important in understanding the functional aspects of pollen such as pollination biology and pollen- pistil interaction [5]. Pollen morphology is of great significance in taxonomy, phylogeny, palaeobotany, aeropalynology and pollen allergy [1, 6]. 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 [7].

The release, distribution and sedimentation of these airborne pollen grains 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 that are released into the atmosphere [8-10]. Also, the flowering pattern of individual plants play important role in determining the abundance and taxa of pollen circulating in the atmosphere [11]. Airborne pollen grains generally travel short distances; however, when they are blown into the upper strata of the atmosphere, pollen grains travel long distances, before they are deposited [12]. Meteorological factors, in particular temperature, precipitation, humidity and wind speed strongly influence airborne pollen counts [13, 7]. 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. Even though sometimes, some of them are blown into these areas from distant places, experienced palynologists are most of the time able to detect these re-deposited pollen and spores by differences in preservation (e.g. colour, corrosion, wear), ecological or stratigraphical inconsistencies and other associated evidences of being re-deposited [14].

Some factors that aid in the dispersal are the size, shape and density of the pollen and spores, the position of the parent plants (that produce them) in the vegetation and the prevailing climatic conditions [15]. The distinctive surface sculptures of pollen grains aid in the identification of their parent plants to at least family level [16]. Their other qualities such as small size, abundance and high resistance to degradation have made them an invaluable evidence of vegetation as well as environmental changes [17]. Because of the transitional location of Akoko division, Ondo State, Nigeria between the tropical rainforest in the South and the true savanna in the North; the area receives particles moving from the South to the Northern part of Nigeria and vice versa. Equally, the movements of the South-West Monsoon and North-East Trade winds across the latitudinal zones of Nigeria carrying along with them large quantities of particles which are deposited along their routes depending on the strength of the winds during the major seasons of the year. The aim of this study is to determine the taxa of airborne pollen grains circulating in the study area and to ascertain the pattern of seasonal variation in the distribution of the prevalent pollen types.

MATERIALS AND METHODS

Fourty locations were randomly selected within the four Local Government Areas of Akoko division, Ondo State, Nigeria as sampling sites. The sampling sites for the study was purposely selected to reflect (represent) as far as possible the Local Government Area of the study. In choosing the sites, consideration was also given to urbanization, accessibility, and safety of the sampling (experimental materials) instruments among others [18].

At each site, a pollen trap (Modified Tauber Sampler) was mounted according to the methods of Tauber [19, 20], Pardoe *et al*. [21] and Giesecke *et al*. [22]. Prior to this, a mixture of glycerol (65 ml), formalin (30 ml) and phenol (5 ml) was poured into each of the trap. The positions of the traps at various locations were recorded using a Global Position System (GPS). The solutions in the trap prevented the palynomorphs from drying up, kill insects and also prevented the decay of dead organisms. The trap was left to stand throughout the duration of the study period. 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 solution. This procedure was repeated bi-monthly from October 2016 to December 2017 (dry season and rainy seasons' samples) for one year. The palynomorphs were recovered through centrifugation at 2000 r.p.m (revolution per minute) for 5 minutes and supernatant decanted each time. The precipitates were washed twice with distilled water and recovered through centrifugation. The sediments were treated with glacial acetic acid to remove water before acetolysis [23, 24]. The recovered precipitates were washed with glacial acetic acid, and finally washed twice with distilled water, centrifuged each time and decanted. The recovered palynomorphs were stored in a plastic vials in glycerin and ethanol solution (2:1).

The palynomorphs were analysed palynologically and microscopically with Olympus microscope at x400 magnification for counting and Leica microscope at x1000 magnification for detailed morphological studies. Palynomorphs identification, counting and classification were done with the help of reference descriptions and photomicrographs from Agwu and Akanbi [24], Bonnefille and Riollet [25], Sowunmi [26] and Shubharani *et al*. [4]. In addition, prepared slides of pollen samples in the Palynological Research Unit; Department of Plant Science and Biotechnology, Adekunle Ajasin University, Akungba- Akoko, Nigeria were used.

RESULTS AND DISCUSSIONS

A total of 182 pollen types were identified across the study locations. These pollen types belong to 74 angiospermic plant families, 1 gymnosperms and 4 pteridophytes (Table 1). Out of these 74 plant families encountered, 66 families belong to the dicotyledonous plants, 6 to monocotyledonous plants, 1 to the gymnospermous plants and 1 was unidentified (Indeterminata).

However, the cumulative monthly pollen record showed that a total of 50661 pollen grains were recorded with the highest monthly pollen counts of 9,023 recorded in November, followed by December (8,750), October (5,789), September (5,600) and the least recorded in August (1,926) and July (1,530) respectively (Table 1).

Statistical analysis of the mean monthly pollen counts showed that there was a significant difference ($P<0.05$) in the monthly pollen abundance. The multiple comparison using DMRT showed that the quantity of pollen counts recorded in November was significantly different ($P<0.05$) from those recorded in the months of March, April, May, June, July, August, September, October, January and February, but not significantly different from the pollen counts recorded in December. There was no significant difference between the quantity of pollen recorded in December and other months (Table 4). Equally, statistical analysis of pollen record at the study locations showed that there was significant difference ($P<0.05$) between the abundance of pollen grains recorded at the study locations (Table 5). Photomicrographs of some selected palynomorphs are shown in Figure 3.

The study also showed that the airborne pollen grains were unevenly distributed throughout the year with many sporadically dispersed monthly and at the study locations. Similar findings were reported by [12, 13, 16].

Table-1: Pollen grains and fern spore spectra classified to family level for the study period (October 2016- September 2017)

S/N	Plant Family	OCT.	NOV.	DEC.	JAN.	FEB.	MAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	TOTAL
1	Acanthaceae	4	13	0	3	0	4	1	8	6	2	2	5	48
2	Amaranthaceae/ Chenopodiaceae	26	28	24	16	11	158	35	53	26	9	3	26	415
3	Anacardiceae	1	129	236	4	0	92	192	87	2	35	51	197	1026
4	Annonaceae	1	0	2	3	0	3	15	0	0	8	3	0	35
5	Apocynaceae	3	283	0	224	26	20	8	8	2	2	0	7	583
6	Arecaceae	350	1411	1153	400	258	639	600	330	148	123	187	379	5978
7	Asteraceae	678	955	66	155	38	15	41	80	583	85	208	152	3056
8	Bignoniaceae	3	41	41	25	0	41	0	13	8	11	0	8	191
9	Bombacaceae	25	14	6	5	4	2	19	18	13	0	3	17	126
10	Boraginaceae	0	0	0	0	0	0	0	3	0	0	0	0	3
11	Burseraceae	1	12	10	0	0	7	22	38	7	0	0	1	98
12	Caesalpinoideae	117	143	133	91	76	52	91	49	19	30	92	247	1140
13	Cannabaceae	0	0	0	15	0	7	3	1	0	0	2	1	29
14	Capparaceae	1	0	4	0	0	0	9	1	0	0	0	0	15
15	Caprifoliaceae	3	5	2	2	0	0	0	0	0	5	2	0	19
16	Caricaceae	0	0	0	0	0	0	0	0	0	0	11	31	42
17	Casuarinaceae	719	14	23	27	17	61	31	110	34	33	90	33	1192
18	Celastraceae	0	0	0	4	9	0	0	0	0	0	0	0	13
19	Chrysobalanaceae	0	0	0	0	0	31	5	11	9	0	0	0	56
20	Clusiaceae	4	2	5	0	0	8	15	5	25	29	0	2	95
21	Cochlospermaceae	0	0	0	0	0	5	0	0	30	1	0	0	36
22	Colchicaceae	0	0	0	0	0	5	7	4	2	0	3	0	21
23	Combretaceae	11	42	30	24	47	40	31	42	42	12	20	35	376
24	Commelinaceae	0	0	0	0	0	3	7	0	0	0	0	0	10
25	Connaraceae	0	0	0	0	0	4	1	11	0	0	0	0	16
26	Convolvulaceae	0	6	0	0	6	7	0	0	12	0	0	4	35
27	Costaceae	0	2	0	1	0	0	0	3	2	5	0	0	13
28	Cucurbitaceae	0	0	0	0	0	4	12	3	0	0	0	5	24
29	Cyperaceae	19	13	12	10	9	17	10	116	42	25	22	26	321
30	Dichapetalaceae	0	0	0	0	0	0	0	2	3	0	0	0	5
31	Dilleniaceae	0	3	0	0	0	1	2	4	0	0	0	0	10
32	Dioscoreaceae	0	0	0	0	0	8	3	1	0	0	0	2	14
33	Diptilomiodeae	0	0	0	0	0	6	9	0	0	0	0	0	15
34	Ebanaceae	0	0	0	0	0	0	3	6	18	88	237	0	352
35	Euphorbiaceae	25	518	851	200	104	229	140	148	67	9	16	68	2375
36	Fagaceae	0	4	1	7	0	0	0	0	0	0	0	0	12
37	Gentianaceae	0	1	2	3	0	0	0	0	2	2	0	0	10
38	Hypericaceae	35	0	0	2	8	5	21	20	25	27	31	0	174
39	Irvingiaceae	-	7	4	123	15	202	29	31	2	3	3	7	426
40	Lamiaceae	113	56	91	28	31	27	9	12	35	59	34	267	762
41	Leeaceae	0	3	0	0	0	0	0	0	2	0	0	0	5
42	Linaceae	12	0	0	3	5	8	6	12	12	23	8	0	89
43	Loganiaceae	5	0	18	3	3	2	2	5	2	1	0	2	43
44	Malvaceae	35	311	60	49	164	8	9	3	19	1	34	30	723
45	Melastomataceae	41	0	0	0	0	0	0	0	11	26	21	13	112
46	Meliaceae	4	22	21	10	7	31	76	10	8	13	17	7	226
47	Mimosoideae	91	342	390	458	372	177	182	277	79	63	29	94	2554
48	Moraceae	0	50	143	161	0	277	17	12	5	0	0	19	684
49	Myristicaceae	0	61	21	32	0	0	0	0	0	0	0	10	124
50	Myrtaceae	80	72	3	9	5	49	49	253	28	17	60	30	655
51	Ochnaceae	4	9	41	6	10	15	14	14	2	0	4	4	123
52	Olacaceae	2	0	5	7	7	2	0	0	0	0	2	4	29
53	Pandaceae	1	5	13	11	0	36	21	10	0	0	1	2	100
54	Papilionoideae	11	15	16	0	3	29	19	12	13	0	0	6	124
55	Passifloraceae	0	0	0	0	0	0	1	4	2	0	0	0	7
56	Pedaliaceae	0	72	15	15	0	0	0	0	0	0	0	125	227
57	Phyllanthaceae	44	61	435	122	41	60	69	247	59	28	28	36	1230
58	Pinaceae	9	0	7	4	0	1	4	4	1	2	5	2	39
59	Plumbaginaceae	11	0	0	0	0	0	0	0	0	0	3	7	21
60	Poaceae	3109	3892	4145	1679	594	551	567	889	699	703	565	3418	20811
61	Polygalaceae	5	21	15	18	0	0	0	0	0	0	8	10	77
62	Portulacaceae	18	12	8	0	0	0	0	0	0	0	5	5	48
63	Proteaceae	1	1	0	3	3	0	0	0	0	0	1	0	9
64	Rhamnaceae	0	1	2	1	0	9	7	0	0	0	0	0	20
65	Rosaceae	7	11	3	8	0	48	22	159	12	4	12	14	300
66	Rubiaceae	73	171	162	193	5	269	37	106	21	13	48	45	1143
67	Rutaceae	4	9	41	6	10	15	14	14	2	0	4	4	123
68	Sapindaceae	2	0	5	7	7	2	16	47	24	0	2	4	116
69	Sapotaceae	1	11	5	7	0	27	18	10	0	0	1	2	82
70	Solanaceae	28	4	406	4	2	10	12	4	33	6	5	16	530
71	Sterculiaceae	16	129	44	133	39	50	57	243	26	22	23	145	927
72	Urticaceae	26	25	20	18	0	0	0	0	0	0	14	19	122
73	Verbenaceae	9	9	3	3	3	0	0	0	0	0	3	3	33
74	Indeterminata	1	2	7	1	6	1	4	4	1	5	3	4	39
	SUB TOTAL	**5789**	**9023**	**8750**	**4343**	**1945**	**3380**	**2594**	**3557**	**2225**	**1530**	**1926**	**5600**	**50661**
1	Aspidiaceace	0	0	0	0	0	0	22	0	0	2	4	0	28
2	Davalliaceae	0	0	0	0	0	0	11	31	0	0	0	0	42
3	Hymenophyllaceae	0	0	0	0	0	0	2	3	0	0	0	0	5
4	Pteridaceae	127	25	114	22	19	22	40	49	54	23	22	422	939
	SUB TOTAL	**127**	**25**	**114**	**22**	**19**	**22**	**75**	**83**	**54**	**25**	**26**	**422**	**1014**
	GRAND TOTAL	**5916**	**9375**	**8537**	**4365**	**1964**	**3402**	**2669**	**3640**	**2279**	**1555**	**1952**	**6022**	**51675**

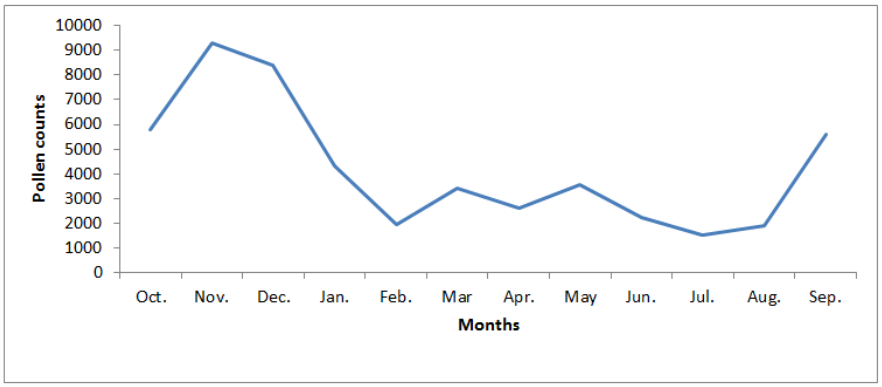


Fig-1: Variation in cumulative monthly pollen counts recorded during the study period

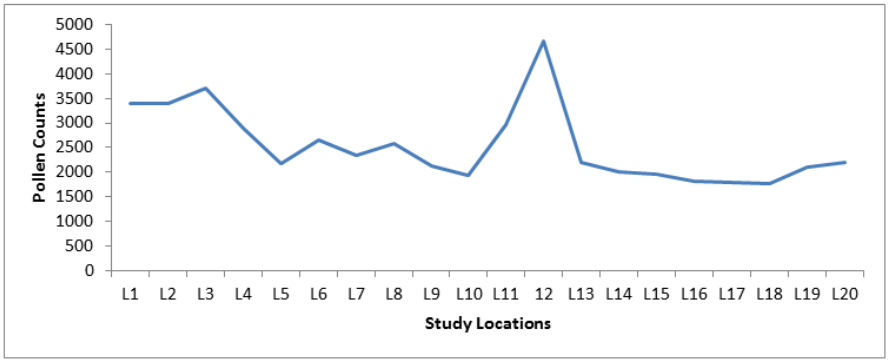


Fig-2: Variation in cumulative pollen counts recorded across the study locations

LEGEND: L1=Ifira, L2=Ipe, L3=Ipesi, L4=Isua, L5=Sosan, L6=Akunnu, L7=Auga, L8=Iboropa, L9=Ikare, 10=Ise, L11=Akungba, L12=Ayegunle, L13=Oba, L14=Oke-Oka, L15=Supare, L16=Arigidi, L17=Ogbagi, L18=Oke-Agbe, L19=Ikaram, L20=Irun.

Among the classified plant families, the maximum mean number of pollen counts of 86.71±5.74 was recorded for Poaceae followed by (8.29±0.66) Arecaceae, (4.97±0.99) Casuarinaceae and (2.12±0.29) Asteraceae and the least by (0.02±0.01) Proteaceae, (0.02±0.01) Hymenophyllaceae as well as (0.01±0.01) Boraginaceae and (0.01±0.01) Pteridaceae. Of the individual plant species *Elaeis guineensis* contributed the maximum mean number of pollen counts (24.65±1.52) followed by (9.25±1.21) *Alchornea cordifolia*, (5.19±1.06) *Aspilia africana*, (4.97±0.99) *Casuarina equisetifolia*, (4.55±1.26) *Tridax procumbens*, (4.06±0.55) *Lannea acida* and the least by (0.01±0.01) *Heliotropium* sp., (0.01±0.01) *Capparis* sp., (0.01±0.01) *Protea madiensis*, (0.01±0.01) *Tectona grandis* and (0.00±0.00) *Anopteris hexagona* .

With respect to the monthly pollen abundance in the atmosphere, the results showed that the concentration of pollen grains in the atmosphere fluctuates considerably with the seasons. The monthly airborne pollen concentrations showed three discernible periods of pollen variability in the atmosphere; (1) February - June (dry season to early rainy season); (2) July - August (mid rainy season) and (3) September – January (late rainy season to early dry season) (Fig. 1). The three periods of pollen abundance in the atmosphere showed that the highest mean concentration occurred during the late rainy season to early dry season, followed by the period of dry season to early rainy season and the least occurred during the mid-rainy season (Table 2).

Table-2: Seasonal Pollen Abundance in Akoko Environment

S/N	Seasons	Months	Absolute counts	Mean
1	Late rainy season to early dry season	September to January	33,444	6688.8
2	Dry season to early rainy season	February to June	13,761	2752.2
3	Mid rainy season	July to August	3,456	1728.0
4	Cumulative total pollen counts		50,661	

There were noticeable monthly increase and decrease in the quantity of pollen grains and other palynomorphs counted. The pollen load of the entire study area varied quantitatively and qualitatively not only from month-to-month but also from location-to-location (Table 3). At the study locations, the highest pollen counts was recorded in Ayegunle (4,665) followed by Ipesi (3,710), Ifira (3,404), Ipe (3,389), and in Akungba (2,955) while the least were in Ogbagi (1,790) and Oke- Agbe (1,763) (Table 3). The analysis of variance showed that there was significant difference in the mean pollen counts recorded across the study locations. Multiple comparisons using Duncan Multiple Range Test (DMRT) showed that the highest mean pollen counts was recorded in Ayegunle (2.07±0.45^{d}) and was significantly different from those recorded for all other study locations except Ipesi, Ifira and Ipe (Table 5). Findings corroborated favourably with the report of Latorre and Belmonte [27].

Table-3: Summary of the Pollen types identified at the study locations

S/N	Study Locations (L1-L20)	Total No. of pollen types counted	Total No. of pollen counted	Total No. of Plant Families	Total No. classified to Family level	Total No. classified to Generic level	Total No. classified to Species level	Total No. of Plant family Unidentified
1	Ifira	125	3404	59	3	81	40	1
2	Ipe	110	3389	55	3	80	27	0
3	Ipesi	108	3710	53	3	76	28	1
4	Isua	91	2895	54	3	63	24	1
5	Sosan	80	2180	45	3	58	18	1
6	Akunnu	106	2664	58	3	70	32	1
7	Auga	110	2338	54	3	76	30	1
8	Iboropa	96	2587	53	3	66	26	1
9	Ikare	86	2130	51	3	61	21	1
10	Ise	75	1923	43	3	51	20	1
11	Akungba	78	2955	50	3	51	23	1
12	Ayegunle	89	4665	50	3	61	24	1
13	Oba	81	2187	47	3	56	21	1
14	Oke-Oka	81	2008	43	2	57	21	1
15	Supare	73	1955	43	2	49	21	1
16	Arigidi	71	1821	42	3	53	15	0
17	Ogbagi	66	1790	38	3	44	18	1
18	Oke-Agbe	64	1763	42	3	46	14	1
19	Ikaram	67	2111	42	3	51	12	1
20	Irun	78	2186	43	3	56	19	0
	TOTAL	**1735**	**50661**	**965**	**58**	**1206**	**454**	**17**

Table-4: Mean monthly pollen counts recorded during the study period

S.L No	Month	Mean Pollen grains±S.E
1	October	1.55 ± 0.21^{d}
2	November	2.46 ± 0.27^{e}
3	December	2.23 ± 0.28^{e}
4	January	1.18 ± 0.12^{cd}
5	February	0.52 ± 0.05^{ab}
6	March	0.89 ± 0.08^{abc}
7	April	0.70 ± 0.07^{abc}
8	May	0.96 ± 0.14^{bc}
9	June	0.59 ± 0.12^{ab}
10	July	0.42 ± 0.09^{a}
11	August	0.51 ± 0.07^{ab}
12	September	1.48 ± 0.24^{d}
13	p Value	0.000*

Means not followed by the same letter are significantly different at P<0.05 (DMRT). *-significant at p<0.05

Table-5: Mean pollen grains recorded at the study locations

Study Location	Mean Pollen grains±S.E
Ayegunle	2.07 ± 0.45^{d}
Ipesi	1.64 ± 0.25^{cd}
Ipe	1.54 ± 0.27^{bcd}
Ifira	1.51 ± 0.21^{abcd}
Akungba	1.31 ± 0.25^{abc}
Isua	1.28 ± 0.20^{abc}
Akunnu	1.19 ± 0.18^{abc}
Iboropa	1.14 ± 0.19^{abc}
Auga	1.05 ± 0.17^{abc}
Oba	0.97 ± 0.19^{abc}
Irun	0.97 ± 0.19^{abc}
Sosan	0.97 ± 0.17^{abc}
Ikare	0.94 ± 0.18^{abc}
Ikaram	0.94 ± 0.17^{abc}
Oke-Oka	0.89 ± 0.18^{ab}
Ise	0.86 ± 0.17^{ab}
Supare	0.86 ± 0.16^{ab}
Arigidi	0.80 ± 0.15^{a}
Ogbagi	0.79 ± 0.18^{a}
Oke-Agbe	0.78±0.15a
p Value	0.000*

Means not followed by the same letter are significantly different at P<0.05 (DMRT). *-significant at p<0.05.

The study also showed that the airborne pollen grains were unevenly distributed throughout the year with many sporadically dispersed monthly and at the study locations. Among the classified plant families, the maximum mean number of pollen counts of 86.71±5.74 was recorded for Poaceae followed by (8.29±0.66) Arecaceae, (4.97±0.99) Casuarinaceae and (2.12±0.29) Asteraceae and the least by (0.02±0.01) Proteaceae, (0.02±0.01) Hymenophyllaceae as well as (0.01±0.01) Boraginaceae and (0.01±0.01) Pteridaceae.

The abundance in monthly pollen concentration is also reflected in Figures 4 to 10. Among the major pollen contributing plants are *Elaeis guineensis*, *Alchornea cordifolia*, *Aspilia africana*, *Casuarina equisetifolia*, *Tridax procumbens*, *Lannea acida*, and those of the family Poaceae. The monthly abundance of their pollen is shown in Figures 4 and 5. Among the moderate pollen contributing plants are those of *Triplochiton scleroxylon*, *Parkia biglobosa*, *Milicia excelsa*, *Senna occidentale*, *Prosopis africana*, *Gutenbergia* sp., *Sida acuta*, *Periploca* sp., *Albizia zygia*, *Solanum melongena*, *Hymenocardia acida*, *Irvingia gabonensis*, *Hyptis suaveolens*, *Combretum* sp., and *Nauclea latifolia* (*Sarcocephalus latifolius*) among others.

With regards to the different species or families, Poaceae which is among the predominanat plant communities (including cultivated species) in the study area produces large quantities of pollen grains which are release into the atmosphere. The monthly pollen abundance of Poaceae showed that the frequency increased greatly from September, reached its peak in November and thereafter declined progressively to a relatively low level from February (Figure 4i). The pollen of *Elaeis guineensis* declined progressively from its second peak in March to July, after which it increased again reaching its peak in December. It subsequently declined from November to February (Figure 4ii). *Alchornea cordifolia* pollen also declined from its second peak in March to very low levels from July to September. From October the pollen abundance increased sharply and reached its highest peak in December and declined again from January to February (Figure 4iii).

Equally, the pollen abundance of of Amaranthaceae/ Chenopodiaceae increased sharply to its highest peak in March and declined sharply in April. From May, the pollen abundance declined again progressively up to August, and rose again in September, maintaining a relatively stable presence up to December before declining again to the lowest level in February (Figure 6ix) whereas *Periploca* sp., *Aspilia africana*, and *Tridax procumbens* pollen only showed a major peak of abundance in November (Figures 6x, 5vi and 4iv). For *Lannea acida* the pollen abundance showed three peaks of highest occurrence in the months of April, September and December (Figure 5vii), while those of *Combretum* sp. fluctuated considerably from February to June having high occurrences in February, May, June, and September to October (Figure 6xi). Although the pollen of *Triplochiton scleroxylon* was not relatively abundant in the atmosphere, the output was still high in May and September despite the fact that it was a time of heavy rainfall (Figure 9xxiii). *Hyptis suaveolens*, a farmland and roadside weed had its peak of pollen abundance in August, while *Nauclea latifolia* (*Sarcocephalus latifolius*) pollen increased considerably in March reaching its peak in May and declined between June and July (Figure 9xxi). The pollen of *Irvingia gabonensis* (an economic tree) had its major peak of abundance in May, and declined to a very low level from June to December and increased slightly in January (Figure 7xiii). That of *Parkia biglobosa* increased to its first peak of abundance in December and thereafter declined progressively up to March before rising to its second peak in May (Figure 8xvi), while the pollen grains of *Casuarina equisetifolia* had only one peak in October (Figure 5v). In the same way, there were notable variations in the period of maximum abundance of *Milicia excelsa* and *Hymenocardia acida* pollen grains (Figures 8xviii and 8xix).

Similarly, there were also noticeable variations in the quantity and quality of pollen grains recorded across the study locations. Possibly, differences in the density and distribution of the pollen–producing plants over the study areas may be one of the primary factors that contributed to the observed variations in pollen abundance. The pattern of pollen grains distribution across the locations is exemplified by the diagrams of pollen concentration of common plant sources shown in Figures 11 through 14. Also, the quantitative variations in monthly occurrence of pollen grains at each location are shown in Figures 4 to 10. While the monthly quantitative abundance of pollen grains at each location is highlighted in Figures 11 to 14, whereas the monthly pollen variation in the study locations is highlighted in Figures 15 to 19. Similar findings on the airborne pollen flora of Jabulur- the Central India were previously reported [28-29].

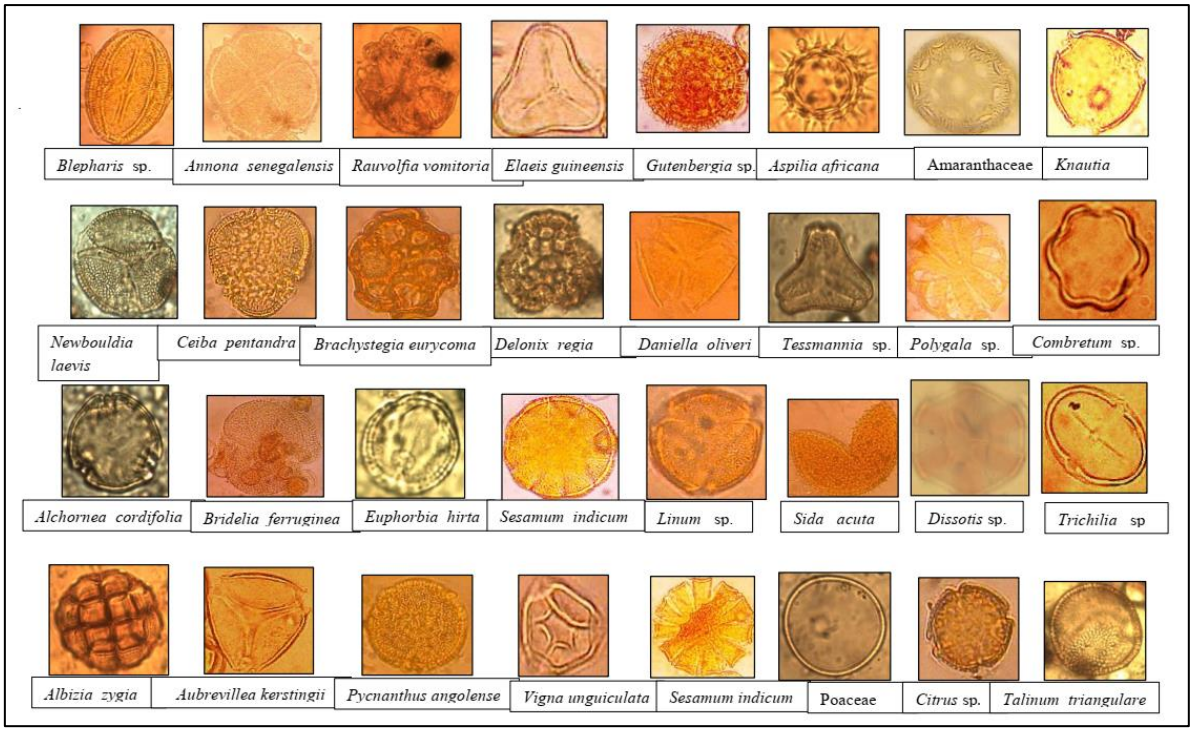


Fig-3: Photomicrograph of some selected pollen grains

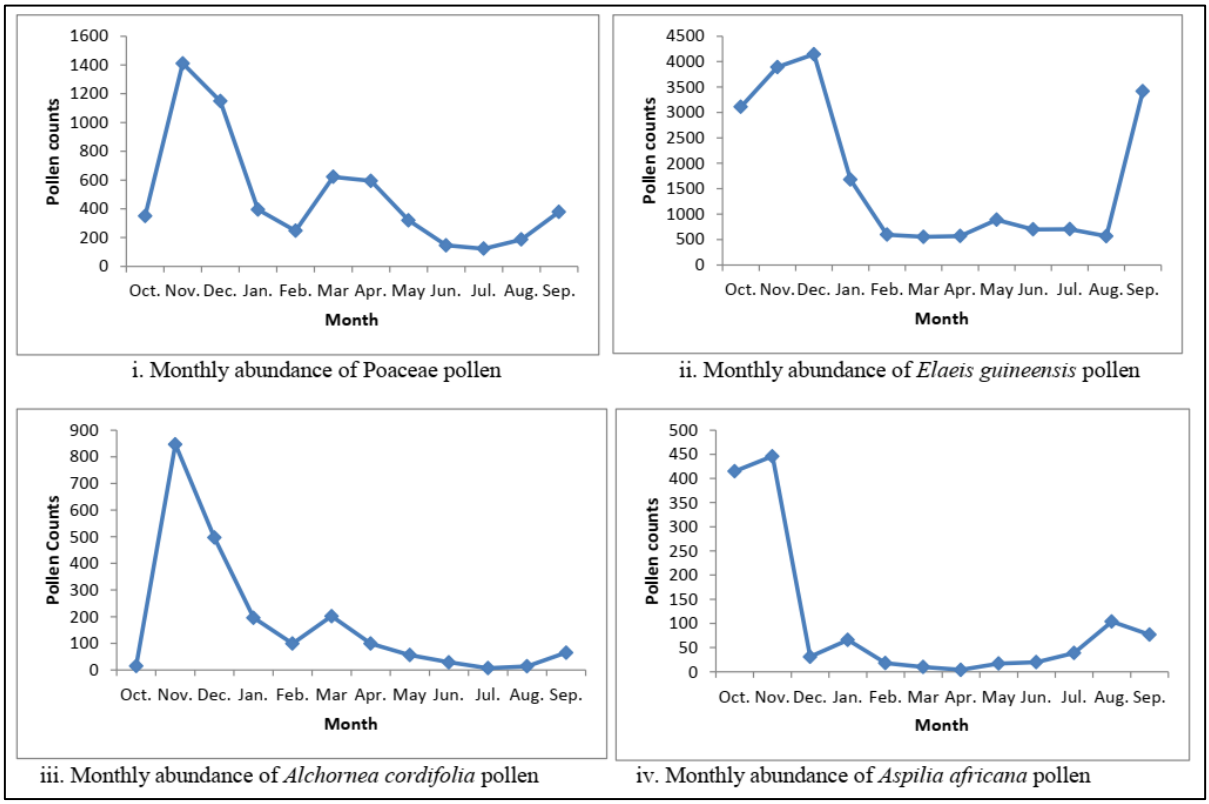


Fig-4: Monthly abundance of pollen of (i) Poaceae (ii) *Elaeis guineensis* (iii) *Alchornea cordifolia* (iv) *Aspilia Africana*

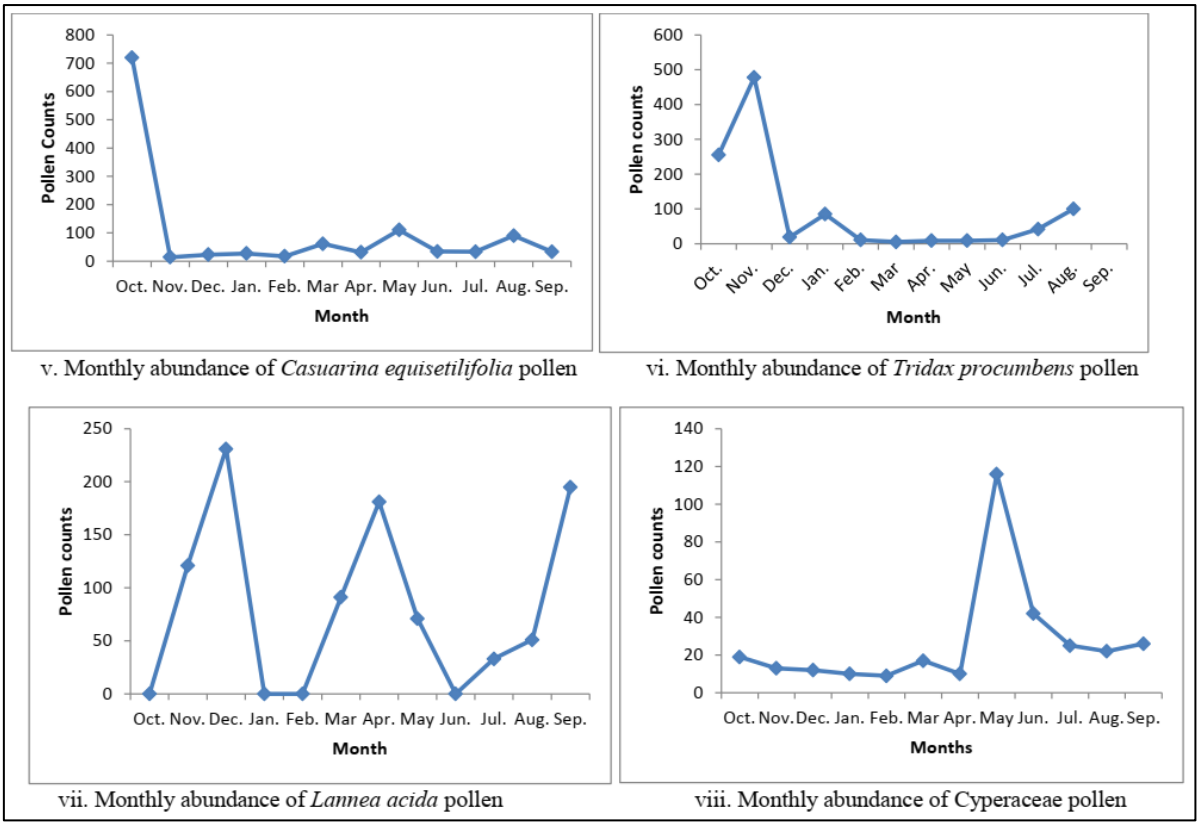


Fig-5: Monthly abundance of pollen of (v) *Casuarina equisetilifolia* (vi) *Tridax procumbens* (vii) *Lannea acida* (viii) Cyperaceae

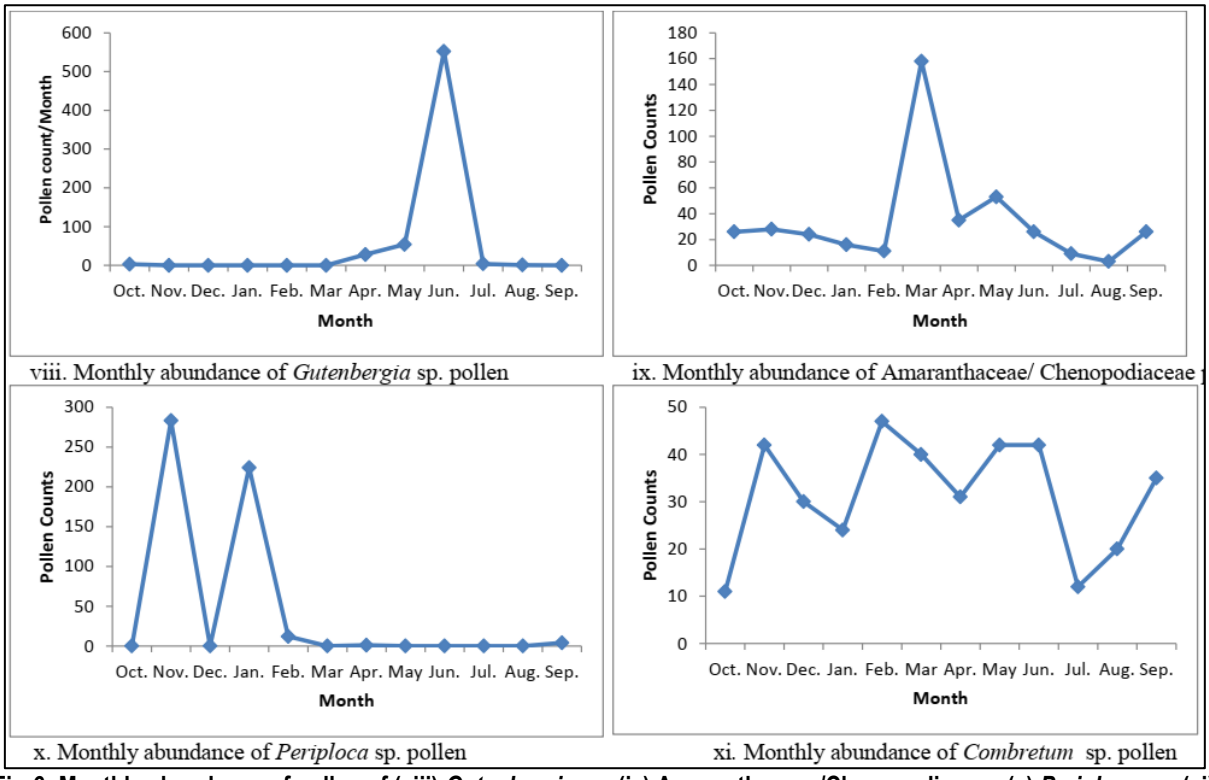


Fig-6: Monthly abundance of pollen of (viii) *Gutenbergia* sp. (ix) Amaranthaceae/Chenopodiaceae (x) *Periploca* sp. (xi) *Combretum* sp

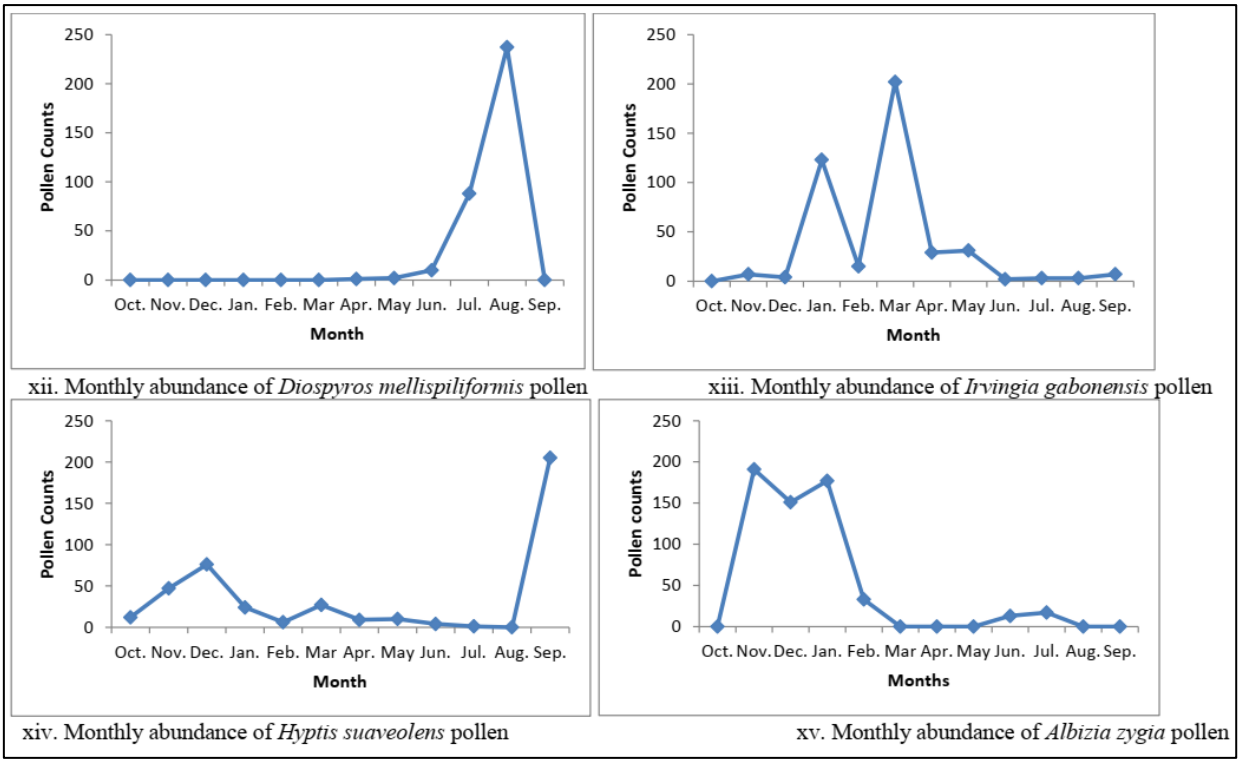


Fig-7: Monthly abundance of pollen (xii) *Diospyros mellispiliformis* (xiii) *Irvingia gabonensis* (xiv) *Hyptis suaveolens* (xv) *Albizia zygia*

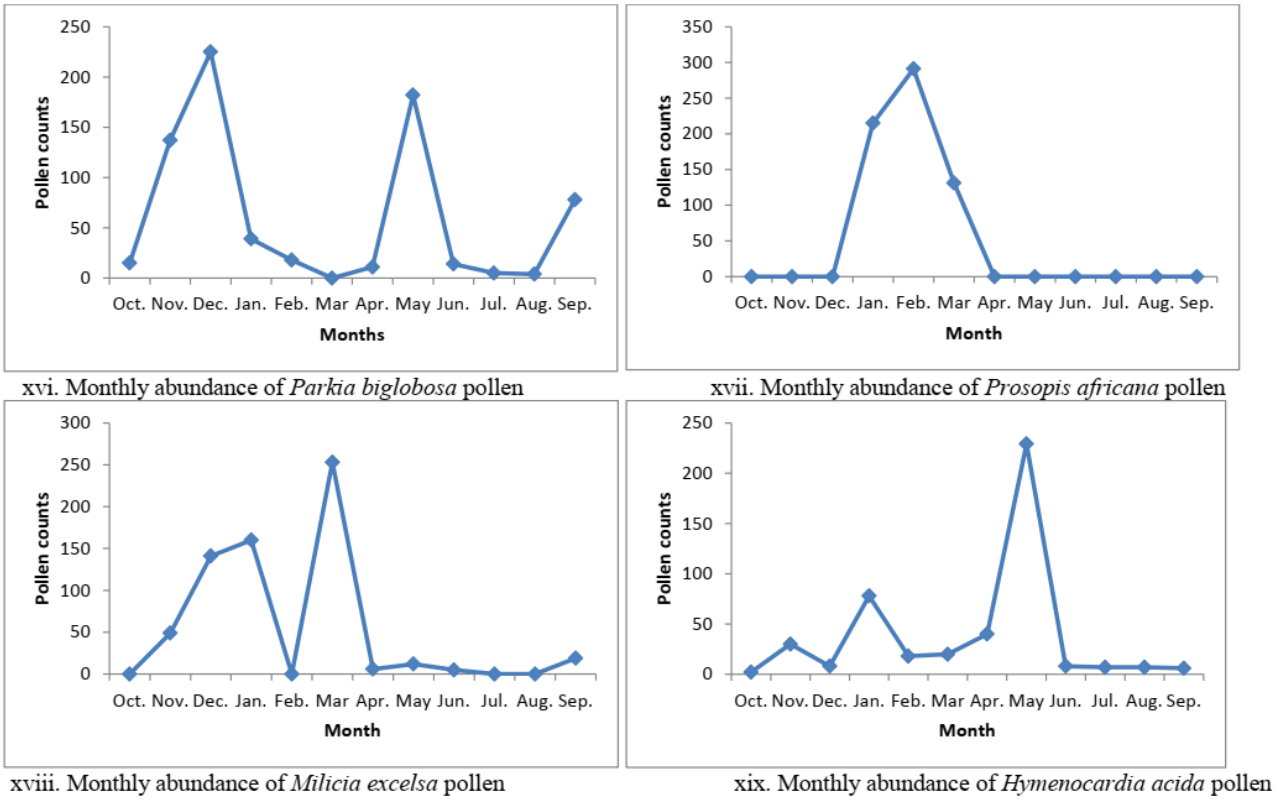
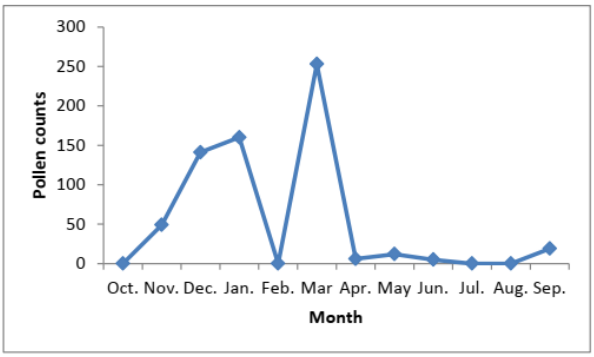
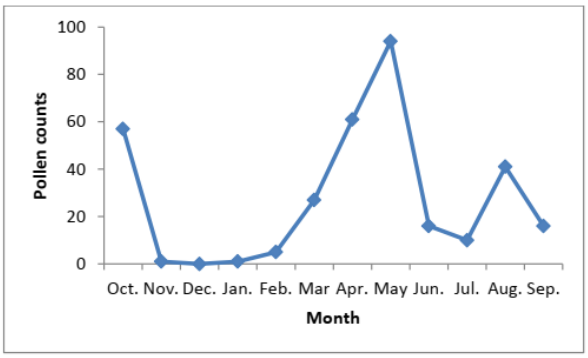


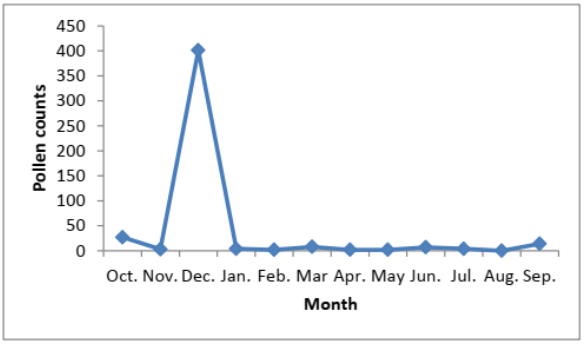
Fig-8: Monthly abundance of pollen of (xvi) *Parkia biglobosa* (xvii) *Prosopis africana* (xviii) *Milicia excels* (xix) *Hymenocardia acida*



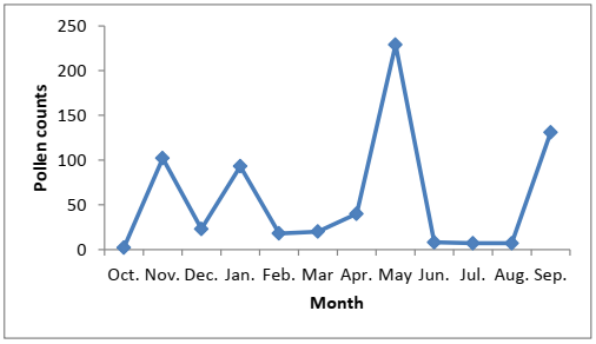
xx. Monthly abundance of *Morelia senegalensis* pollen



xxi. Monthly abundance of *Nauclea latifolia* pollen

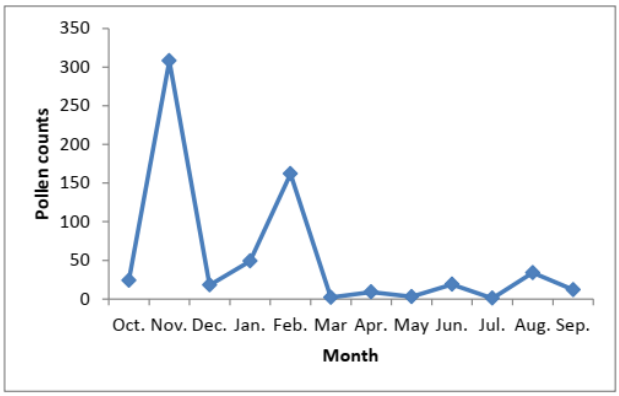


xxii. Monthly abundance of *Solanum melongena* pollen

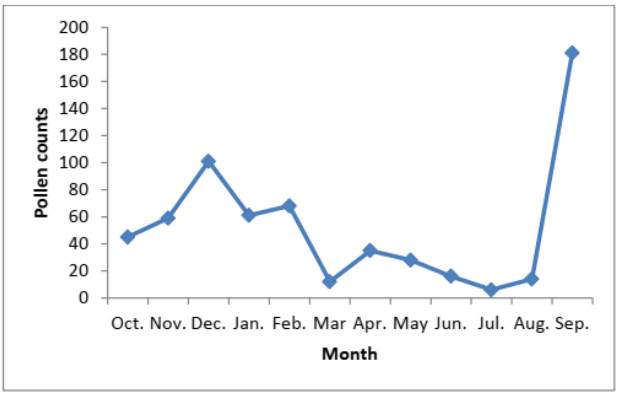


xxiii. Monthly abundance of *Triplochiton scleroxylon* pollen

Fig-9: Monthly abundance of pollen (xx) *Morelia senegalensis* (xxi) *Nauclea latifolia* (xxii) *Solanum melongena* (xxiii) *Triplochiton scleroxylon*



xxiv. Monthly abundance of *Sida acuta* pollen



xxv. Monthly abundance of *Senna occidentale* pollen

Fig-10: Monthly abundance of pollen (x) *Sida acuta* (y) *Senna occidentale*

CONCLUSION

The result of this study gives information on diurnal, seasonal and annual variations in the pollen types and their concentration in the air. A characteristic feature of pollen allergy is its seasonal occurrence associated with the prevalence of pollen of that particular species in the atmosphere. Information generated from this study on the pollen content in the air of the studied environment is necessary in order to forecast pollen incidence. Studies of this nature are useful in finding areas and periods that are comparatively safe for allergic patients. Adequate environmental monitoring through continuous pollen rain analysis and avoidance of exposure to allergic pollen types during their season of prevalence are recommended for safety health and environmental sustainability.

Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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