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Vegetational History, Floral Preference of Honeybees (Apis mellifera var. adansonii) and Biodiversity Conservation Inferred from Recent Honey Pollen Analysis in Hawul Local Government Area of Borno State, Nigeria

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Abstract:
Pollen analytical examination was conducted using honey samples from four randomly selected localities within Hawul Local Government Area of Borno State, Nigeria with the aim of ascertaining the species of plants that were utilized by honeybees in the course of honey production; vegetational history and biogeographical origin of honey as well as the taxa most preferred by honeybees. The samples were treated using standard palynological techniques and results showed that a total of 27,852 pollen grains count of 4665, 9513, 5669 and 8005 was recorded for Ngwa, Timpil, Peta and Bantali respectively. Study revealed that eighty- eight (88) pollen types belonging to forty-one (41) plant families were encountered. One (1) was identified to family level, seventy-four (74) to generic level, twelve (12) to species level and one (1) unidentified. The predominant pollen types in the four samples were those of *Syzygium guineense*, *Psidium gaujava*, *Mangifera indica*, *Parkia biglobosa*, *Combretum* spp., *Vitellaria paradoxa*, *Elaeis guineensis*, and *Trichillia prieureana*. Findings revealed that the period of major honey production were between dry season to early raining season (October-April). The pollen assemblage reflects the vegetation of Hawul in Borno State to be Sudan Savanna type despite high level of human impact on the environment. Pollen weight was between 0.40 to 0.45 grams indicating that the honey samples were unadulterated. Adequate conservation of these indicator species is recommended for safety health and environmental sustainability using appropriate biotechnological interventions.

Keywords: Biodiversity, Floral preference, Honey, Pollen analysis, Vegetation history,

INTRODUCTION

The use of pollen grains and spores in environmental studies is primarily in its application to the study of vegetational history (Traverse, 1988). The relevance of pollen content to the vegetation of a region is related to the palynomorphs produced *in situ* and those supplied from the surrounding ecological zones (Ige & Essien, 2019). Conclusion about climate and human disturbances could be deduced from such analysis and they are termed secondary deductions (Erdtman, 1969). Fact gathered from such analysis could be useful to climatologists and oil explorationists among others (Moore & Webb, 1978). Basically, pollen analysis is a technique for reconstruction of former vegetation by means of the pollen grains recovered from sediments. Since the pollen grain exine is resistant, it may have a long geological life once it is incorporated into sediment, but only if the grains avoid mechanical attrition and chemical changes such as oxidation (Hopping, 1967).

The vegetation of an area is an integral and basic component of the ecosystem and is sensitive to changes in the ecosystem. Consequently, vegetation changes are themselves a response to and a reflection of variation in one or more of the factors of the environment, particularly climate

(Essien, 2019). A close relationship exists between vegetation and the rest of the environment, particularly climate and soil. Thus, the flora of an area provides a good reflection of the major climatic regime of the area. The influence of climate on other components of the environment is so great that every other climatic zone has its own characteristic vegetation type (Ige, 2017). Plants are therefore among the best indicators of the environment especially of the climate, soil and fauna. Certain individual or assemblages of plants are known to be characteristic of specific ecological zone and the occurrence of the fossil pollen of such ecological indicator species in sediments is considered a reflection of contemporary ecological conditions. For example, the tropical rainforest is characterized by broad-leaved species, the savanna characterized by grasses, the desert by ephemeral and sclerophyllous plants and the cold regions of the world characterized by evergreen conifers (Essien, 2019).

The study of vegetation and the way in which it has been altered and developed in the course of time indicates past changes that have occurred in our terrestrial environment. Variations in climate and in the intensity of human activities in historic and prehistoric times have made their mark upon the vegetation, and the plants themselves have left a record of these changes in the form of vast quantities of pollen grains which have survived in contemporary sediments (Roberts, 1989). In Quaternary, however, the pollen grains can be directly referred to extant vegetation due to the proximity of Quaternary period with the present, proving "Present is key to the past". Pollen analysis, therefore, is an extremely powerful tool for the investigation of floristic and climatic changes that took place in the recent past (Ige, 2017).

Co-evolution and mutualism have been cited as examples of relationships between honeybees and flowering plants. Honeybees and flowering plants are mutually dependent; honeybees need flowering plants for food in the form of pollen and nectar, whereas plants need honeybees for pollination. Honey contains pollen grains which are collected by honeybees while foraging the flowers for nectar (Essien, 2020). The bee is the most valuable insect on planet earth. This is not because of the value of its direct products as they represent only 0.5% of the total agricultural production, but because of the enormous benefits accruing from the cross pollination of plants. This cross pollination ensures the improved quality and quantity of produce, fruits and seeds, improved species of self-germinating plants and also maintain the eco-balance on earth (Sivaram, 1995).

The honey bees (*Apis mellifera var. adansonii*), the pollinators of plants the world over; play a crucial role for wild and cultivated plants, especially in the tropics where insect pollination is vital (Winfree, 2010; Ollerton *et al*., 2011). Honeybees are one of the world's most essential pollinators capable of sustaining biodiversity and food security. Honey, which is produced by honeybees, is one of the most consumed foods with very high nutritional, pharmaceutical and medicinal value. It is made from nectar and pollen primarily through the action of digestive enzymes by a careful mixture, compression, dehydration and maturation processes in the beehive (Shubharani *et al*., 2013). For quality assurance purpose, the color, pollen diversity and abundance are a determinant of the nutritional richness and originality of honey. The pollen grains also reflect the honeybee preferred plants for pollen and/or nectar, geographical and organoleptic properties (Bogdanov & Martin, 2002; Anidiobu, 2016). As a matter of urgency, plants foraged by honeybees must be conserved for continuity if honey production is to be sustained and one of the ways to determine these plants is through pollen analytical studies (Kayode & Oyeyemi, 2014; Byrant, 2018; Adekanmbi & Ogundipe, 2009). A combination of the insect and wind pollinated taxa found in a honey gives a unique understanding of the particular geographical location where the honey was produced and the plant communities in that region. This could shed more light on the important plants foraged by honeybees (Essien *et al*., 2022a).

Recently, there are evident cultural, agricultural, unscientific and uncontrolled practices threatening the flora of several part of Hawul Local Government Area, Borno State. The indiscriminate destruction of plants may lead to the loss of important honey plants. Information on pollen analysis in Hawul Local Government Area, Borno State is almost non-existent, limited or somewhat scarce. This expanding destruction of flora could lead to loss of biodiversity and important bee plants. Honeybees (*Apis mellifera* var. *adansonii*) forage on plants for nectar and pollen for the production of honey. Due to the loss of flora and long duration of production, adulteration of honey has also become rampant in Nigeria. Adulteration of honey simply means glucose, dextrose, molasses, corn syrup and invert sugar have been added into an original honey to probably increase quantity or add to the taste. The component (physical and chemical properties) confers the uniqueness of each honey and to be sure of its authenticity, it is vital to perform extensive honey compositional analysis like pollen analysis. Seeking to reveal the relative weight of pollen could be used in differentiating pure from adulterated honey.

This study, therefore, intends to ascertain among other things; the originality of honey produced and sold in Hawul, Borno State as well as the important bee plants that need to be conserved. Knowing the bee plants could be used as the basis of legalized protection and propagation of bee plants and farms. Pollen analytical studies have been found useful in deciphering such plants. The objectives, therefore, are to physico-chemically quantify the honey samples, carry out qualitative and quantitative analysis of pollen grains to determine the vegetational history and biogeographical origin of the honey samples; major season of honey production; floral preference of honeybees (*Apis mellifera* var. *adansonii*), and originality status of the honey samples.

MATERIALS AND METHOD

Study Area

Ngwa, Timpil, Peta and Bantali are localities within Hawul Local Government Area of Borno State. Borno State lies in North Eastern Nigeria. Hawul geographical coordinates- Latitude: 10° 25′ 59″ North, and Longitude: 12° 14′ 49″ East. It has an area of 2,098km² and Altitude 328 m (1,076 ft). Hawul Climate has a Tropical savanna climate and a population of about 120,000 as at the 2006 census. The land of Hawul Local Government Area is covered with volcanic soil and have a rainfall concentration between May to November. 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°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.

Sample Collection

Four honey samples were collected from vendors who sources from the wild at the study area between the months of September and December, 2022. The honeys were extracted by pressing and squeezing the combs, filtered into a bottle through fine mesh-copper gauze to avoid introduction of debris. Once collected the samples were labelled and transported to the Laboratory, Department of Biology, Nigerian Army University Biu, for pollen analysis.

Determination of pH

Honey (10 g) was dissolved in 75 ml of distilled water in a beaker and vigorously mixed using a glass rod, pH electric meter was immersed in the honey and values were taken.

Honey Colour

The Munsell Soil Color Chart was used.

Pollen Analysis

Three basic procedures were followed; honey quantification/dilution, pollen acetolysis and microscopy. All procedures followed the recommendation and techniques reported in Louveaux *et al*. (1978), Agwu *et al*. (2013) and Erdtman (1969). Mounting and microscopic examination was carried out using two drops of pollen suspension in microscope slide sealed off with 18 x 18 mm glass cover slip. Counting was done using Olympus microscope at x400 magnification while detailed pollen morphological studies to aid identification was done using Leica microscope at x 1000 magnification. Reference slides, pollen atlas and photomicrographs (Sowunmi, 1978; 1995; Agwu & Akanbi, 1985; Agwu *et al*., 2013; Shubharani *et al*., 2013; Essien *et al*., 2022b) was used for identification.

Weight of Pollen Grains

Honey (50 ml) and beaker (71.65 g) was weighed using the weighing balance. The honey was diluted with 1000 ml of distilled water and the formular below was applied

Weight of pollen x factor of 20 = weight of beaker/liter of honey samples.

Data Analysis

The data 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) for expressing pollen grain frequencies: Very frequent (over 45%), frequent (16-45%), rare (3-15%) and sporadic (> 3%).

RESULTS AND DISCUSSIONS

Table 1 showed the physicochemical properties of the four honey samples while Table 2 showed the pollen types recovered from the four honey samples. Absolute pollen counts are shown in Figure 1. Pollen counts of 4665, 9513, 5669, and 8005 were recorded for Ngwa, Timpil, Peta and Bantali respectively. The classification recorded by Louveaux *et al*. (1970) for expressing pollen grains frequencies was adopted: very frequent (over 45%), frequent (16-45%), rare (3-15%) and sporadic (less than 3%). Results showed that Bantali honey sample had forty-five (45) pollen types which was the highest while Peta had the lowest number of pollen types; that is twenty-seven (27), clearly an indication of the high diversity of pollen in Hawul, Borno State. Table 3. showed the floral source of the honey samples and findings revealed that all the honey samples were multifloral in nature and they belonged to category I. There were no very frequent pollen types in any of the samples, and there was only frequent pollen type in the sample from Ngwa. In Table 4; a detailed analysis of the vegetation types inferred from the pollen types and count showed that Hawul is a Guinean savanna type that is anthropogenically disturbed. According to the physicochemical properties of the four honey samples, the color ranged from light brown to dark brown. For the pollen weight; results showed that Timpil honey sample had the highest (0.45 g) while that of Ngwa was lowest (0.40 g). The pH values showed that Bantali honey had the highest pH value of 4.06 while Ngwa was lowest (3.44).

Table 1: Physicochemical properties of the four honey samples

Localities	Colour	Honey Weight collected (g)	Weight of pollen (g)	pH Value	Weight of honey (gram/litre)
Ngwa	Light-brown	10	0.40	3.44	1376
Timpil	Dark-brown	10	0.45	3.47	1301
Peta	Light brown	10	0.41	3.71	1290
Bantali	Dark-yellow	10	0.44	4.06	1355

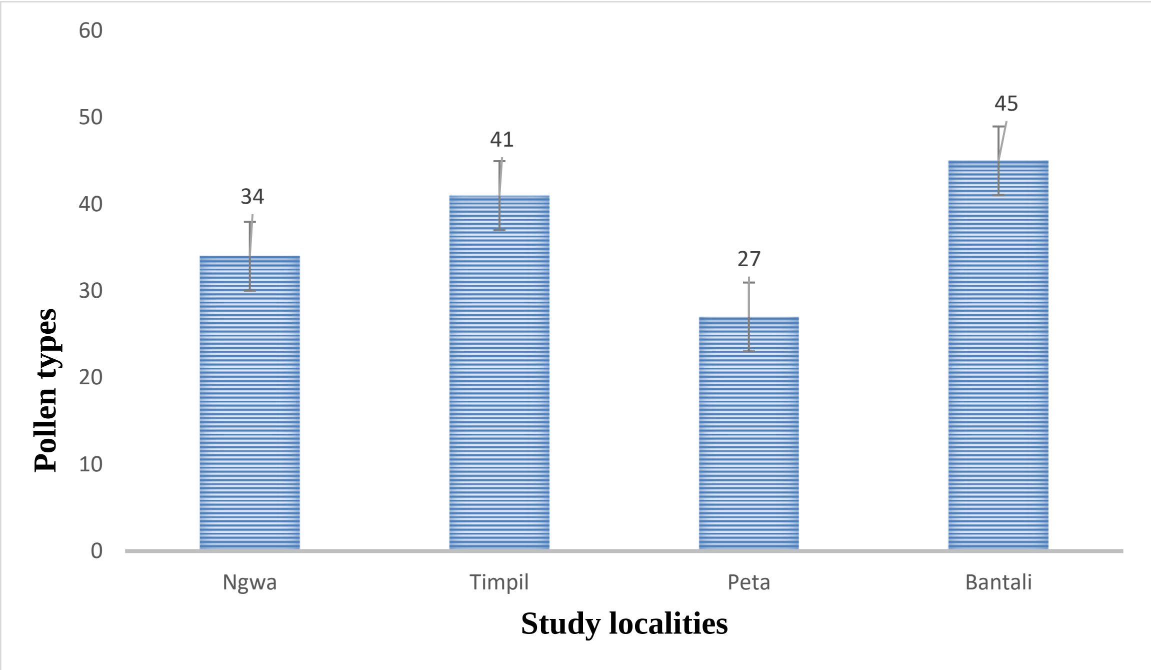

Fig. 1: Bar chart showing the number of identified pollen types in the four honey samples

The percentage of pollen representation based on plant families are shown in Fig 2. Results showed that the plant family Sapotaceae had (7.86 %), Bombacaceae (7.34 %), Solanaceae (4.84 %), Rubiaceae (3.22 %), Myrtaceae (5.56 %), Euphorbiaceae (5.15 %), Combretaceae/ Melastomataceae (4.03 %), Asteraceae (3.60 %), Aracaceae (5.50 %), Anacardiaceae (4.20 %). While the least abundant were Capparidaceae (0.15 %), Cyperaceae (0.19 %), Magnoliaceae (0.27 %), Rosaceae (0.25 %) and Aizoaeceae (0.28 %).

Study revealed that eighty- eight (88) pollen types belonging to forty-one (41) plant families were encountered. One (1) was identified to family level, seventy-four (74) to generic level, twelve (12) to species level and one (1) unidentified (Tabel 2). The predominant pollen types in the four samples were those of *Syzygium guineense*, *Psidium gaujava*, *Mangifera indica*, *Parkia biglobosa*, *Combretum* spp., *Vitellaria paradoxa*, *Elaeis guineensis*, and *Trichillia prieureana*.

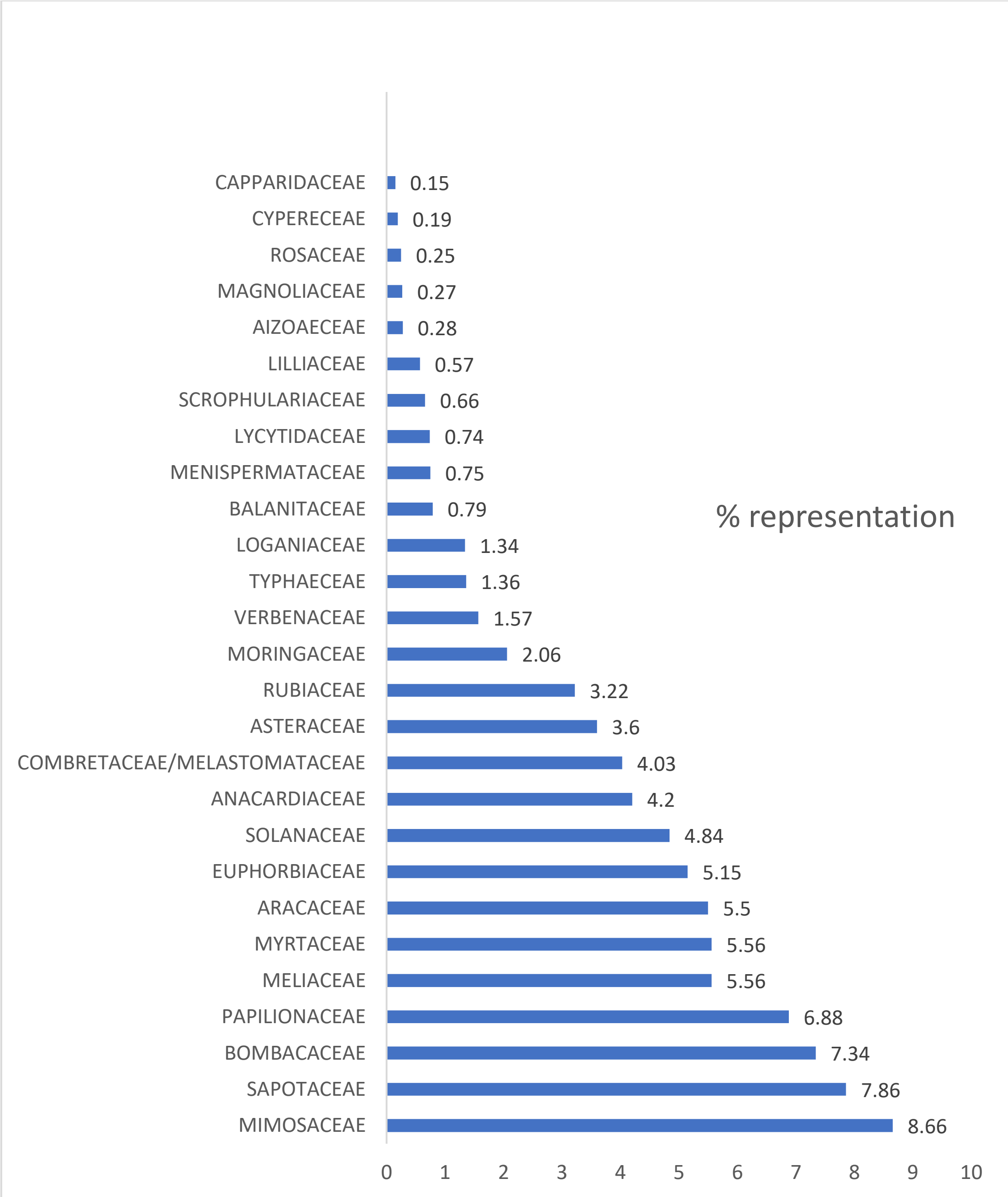

Fig 2: Percentage representation of plant families in the four pollen samples from the study area

Table 2: Absolute pollen counts from the four honey samples studied

	Pollen types/families	**Localities in Hawul**									
		Ngwa	**%**	**Timpil**	**%**	**Peta**	**%**	**Bantali**	**%**	**Total**	**%**
1	**ACANTHACEAE**										
	Crossandra nilotica.							200	2.5	200	0.72
	Hypoestes elliottii			431	4.53					431	1.55
	Justicia spp.			209	2.20					209	0.75
2	**AIZOAECEAE**										

	Corbichonia decumbens	106	2.27							106	0.38
3	**ANACARDIACEAE**										
	Curronia volubilis							60	0.75	60	0.22
	Herria reticulata							65	0.81	65	0.23
	Mangifera indica					589	10.39	405	5.06	994	3.75
4	**ARECACEAE**										
	Elaeis guineensis			430	4.52	555	9.79	546	6.82	1531	5.50
5	**ASCLEPIADACEAE**										
	Curroria volubilis					57	1.01	113	1.41	170	0.61
6	**ASTERACEAE**										
	Aspilia africana	305	6.54			127	2.24			423	1.55
	Bidens pilosa	168	3.60							168	0.60
	Synedrella nodiflora	27	0.58	229	2.41					256	0.92
	Tridax procumbens	147	3.15							147	0.53
7	**BALANITACEAE**										
	Balinite orbicularis							221	2.76	221	0.79
8	**BOMBACACEAE**										
	Bombax buonopozense					417	7.36	105	1.31	522	1.87
	Bombax malabarieum					183	3.23			183	0.66
	Bombax spp.			57	0.60					57	0.20
	Ceiba pentandra			450	4.73	508	8.96	325	4.06	1283	4.16
9	**BORAGINACEAE**										
	Cordia africana	200	2.29							200	0.72
	Cordia sinensis	206	4.42							206	0.74
	Cordia vignei					48	0.85			48	0.17
	Heliotropium spp.							80	1.00	80	0.29
10	**CAESALPINACEAE**										
	Acacia rubida			50	0.53					50	0.18
	Brachystegia eurycoma			53	0.56					53	0.19
	Daniella oliveri							182	2.27	182	0.65
	Delonix elata							10	0.12	10	0.04
	Delonix regia			200	2.10					200	0.72
	Paramacrolobium coeruleum			36	0.38					36	0.13
	Senegalia mellifera	4	0.10							4	0.01
	Tephrosia purpurea							32	0.4	32	0.11
	Vauchellia reficiens	12	0.26	22	0.22					34	0.12
11	**CAPPARIDACEAE**										
	Capparis tementosa	29	0.62							29	0.10
	Cleome angustifolia	13	0.28							13	0.05
12	**COMBRETACEAE/ MELASTOMATACEAE**										
	Combretum spp.	309	6.62			474	8.36	340	4.25	1123	4.03
13	**CONVOLVULACEAE**										
	Ipomoea cordifolia							307	3.84	307	1.10
	Ipomoea spp.	156	3.34							156	0.56
14	**CUCURBITACEAE**										
	Coccinia grandis	37	0.79	43	0.45			24	0.3	104	0.37
	Luffa echinata			328	3.45			7	0.09	335	1.20
15	**CYPERACEAE**										
	Cyperus crassipes							54	0.67	54	0.19
16	**EUPHORBIACEAE**										
	Alchornea cordifolia	109	2.35			43	0.79			154	0.55
	Euphorbia grandicornis	189	4.05					361	4.51	550	1.97
	Euphorbia hirta							164	2.05	164	0.59
	Euphorbia hypericifolia							5	0.06	5	0.02
	Euphorbia spp.	58	1.24					205	2.56	263	0.94
	Ricinus communis							302	3.77	302	1.08
17	**GENTIANACEAE**										
	Crawfurdia lanceolata	160	1.68							160	0.57

18	**LILIACEAE**										
	Aleo turkenensis							160	2.00	160	0.57
19	**LOGANIACEAE**										
	Strychnos spinosa			240	2.52			132	1.65	372	1.34
20	**LYCYTIDACEAE**										
	*Crateranthu***s** *letesturi*	207	4.44							207	0.74
21	**MAGNOLIACEAE**										
	Magnolia coco			56	0.59	20	0.35			76	0.27
22	**MELIACEAE**										
	Trichillia prieureana	906	19.42	582	6.12	22	0.49	39	0.49	1549	5.56
23	**MENISPERMACEAE**										
	Cuculus hirsutus							209	2.61	209	0.75
24	**MIMOSOIDEAE**										
	Acacia spp.			224	2.35			130	1.62	354	1.27
	Adenanthera pavonina			255	2.68	97	1.71			352	1.26
	Mimosa pigra					28	0.49			28	0.10
	Mimosa spp.	47	1.01			18	0.32	304	3.80	369	1.32
	Parkia biglobosa			809	8.50	520	9.17			1329	4.77
	Pentaclethra macrophylla	12	0.26							12	0.04
25	*Xylia* spp.					5	0.10			5	0.02
	MORINGACEAE										
26	*Moringa oleifera*			507	5.33			67	0.84	574	2.06
	MYRTACEAE										
	Eucalyptus globus			182	1.91					182	0.65
	Euginea nodiflora	20	0.43	147	1.55	30	0.53			197	0.71
	Psidium guajava	234	5.02	504	5.30			7	0.01	745	2.67
	Syzygium guineense			571	6.00	191	3.37	772	9.64	1534	5.51
27	**PAPILIONACEAE**										
	Bauhinia champonionii	102	2.17							102	0.37
	Flemingia strobilifera			270	2.84			9	0.11	279	1.00
	Macrotyloma africanum	15	0.32							15	0.05
	Milletia pinnata							5	0.06	5	0.02
28	**PHYLLANTHACEAE**										
	Phyllanthus spp.			520	5.47					520	1.87
29	**POACEAE**	22	0.47	7	0.07			41	0.51	70	0.25
30	**PROTEACEAE**										
	Protea elliottii			285	3.00					285	1.02
31	**ROSACEAE**										
	Rosa pricei	30	0.64	75	0.79	51	0.90			156	0.56
	Rubus pinnatisepaus			6	0.06					6	0.02
32	**RUBIACEAE**										
	Cephallanthus occidentalis			532	5.60					532	1.91
	Morellia senegalensis					161	2.86	137	1.71	298	1.04
	Sacrocephalus latifolius			52	0.55	6	0.11	18	0.22	76	0.27
33	**RUTACEAE**										
	Citrus spp.	72	1.5	122	1.28	139	2.45			333	1.20
34	**SAPINDACEAE**										
	Cordospermum halicacabum	104	2.23					116	1.45	220	0.79
	Paullinia pinnata	90	1.93	134	1.41					224	0.80
35	**SAPOTACEAE**										
	Mimusops warneckii	137	2.94							137	0.49
	Northia spp.							124	1.55	124	0.45
	Vitellaria paradoxa	584	12.52	421	4.43	430	7.59	492	6.15	1927	6.92
36	**SCROPHULARIACEAE**										
	Stemodia serrata							184	2.30	184	0.66
37	**SOLANACEAE**										
	Solanum melongena			136	1.43	689	12.15	522	6.52	1347	4.84
38	**TYPHACEAE**										
	Typha latifolia	6	0.13	10	0.11	256	4.52	107	1.34	379	1.36
39	**VERBENACEAE**										

	Phylla nodiflora			121	1.27			315	3.94	436	1.57
40	**VITACEAE**										
	Cissus quadrangularis			45	0.47					45	0.16
41	**INDETERMINATA**	2	0.04	2	0.02	3	0.05	2	0.02	9	0.03
	Total pollen count	**4665**	**100**	**9513**	**100**	**5669**	**100**	**8005**	**100**	**27852**	**100**

Table 3: Floral sources of the honey samples from Hawul

Samples	Pollen type				Remark on floral origin	Pollen count/ Category
	Very Frequent (> 45%)	Frequent (16 – 45%)	Rare (3 – 15.9%)	Sporadic (< 3%)		
Ngwa	-	*Trichillia prieureana* (19.42).	*Psidium guajava* (5.02), *Cordia sinensis* (4.42), *Aspilia africana* (6.54), *Tridax procumbens* (3.15), *Cordia sinensis* (4.42), *Ipomoea* spp. (3.34), *Euphorbia grandicornis* (4.05), *Vitellaria paradoxa* (12.52).	*Synedrella nodiflora* (0.58), *Vauchellia reficiens* (0.26), *Capparis tementosa* (0.62), *Alchornea cordifolia* (2.35), *Mimosa* spp. (1.01), *Eugenia nodiflora* (0.43), *Rosa pricei* (1.50), *Typha latifolia* (0.13), Poaceae (0.47). *Coccinia grandis* (0.45), *Crawfurdia lanceolate* (1.68), *Eugenia nodiflora* (1.55), *Rosa pricei* (0.79).	Multifloral	4,665/ **I**
Timpil	-	-	*Elaeis guineensis* (4.52), *Psidium guajava* (5.30), *Syzygium guineense* (6.00), *Vitellaria paradoxa* (4.43). *Parkia biglobosa* (8.50), *Phyllantus* spp (5.47), *Ceiba pentandra* (4.75), *Trichillia prieureana* (6.22).	*Rubus pinnatisepalus* (0.06), *Sarcocephalus latifolius* (0.55), *Citrus* spp. (1.28), *Solanum melongena* (1.42), *Typha latifolia* (0.11), Poaceae (0.07).	Multifloral	9, 513 /**I**
Peta	-	-	*Elaeis guineensis* (9.79), *Mangifera indica* (10.39), *Ceiba pentandra* (8.96), *Syzygium guineense* (3.37), *Parkia biglobosa* (9.17), *Vitellaria paradoxa* (7.59), *Solanum melongena* (12.15), *Typha latifolia* (4.52).	*Alchornea cordifolia* (0.79), *Trichillia prieureana* (0.49), *Mimosa* spp. (0.32), *Mimosa pigra* (0.49), *Eugenia nodiflora* (0.53), *Rosa pricei* (0.90), *Sarcocephalus latifolius* (0.11), *Citrus* spp. (2.45).	Multifloral	5,669 / **I**
Bantali	-	-	*Mangifera indica* (5.06), *Elaeis guineensis* (6.82), *Ceiba pentandra* (4.06), *Combretum* spp. (4.25), *Ipomoea cordifolia* (3.84), *Mimosa* spp. (3.80), *Syzygium guineense* (9.64), *Vitellaria paradoxa* (6.15), *Solanum melongena* (6.52), *Phyla nodiflora* (3.94).	*Heliotropium* spp. (1.00), *Delonix elata* (2.27), *Coccinia grandis* (0.30), *Luffa echinata* (0.09), *Euphorbia hirta* (2.05), *Trichillia prieureana* (0.49), *Moringa oleifera* (0.84), *Psidium guajava* (0.01), Poaceae (0.51), Daniella oliveri (2.27), *Morellia senegalensis* (1.71), *Sarcocephalus latifolius* (0.22), *Typha latifolia* (1.34).	Multifloral	8,005/ **I**

***Floral origin:** selected based on most represented (frequently and rare occurring) plant species
Categories: I (<20,000), II (20,000 – 100,000), III (100,000 – 500,000), IV (500,000 – 1,000,000) and V (>1,000,000)

Table 4: Vegetation inference from pollen types recovered from the four honey samples from Hawul

Vegetation type represented from absolute pollen counts						
		Lowland rainforest	**Open forest**	**Savanna**	**Human impacted**	**Suggestive inference on biogeographical origin of honey**
Selected pollen types		*Brachystegia eurycoma, Ceiba petandra, Pentaclethra macrophylla*	*Acacia* spp., *Combretum* spp., *Elaeis guineensis, Alchornea cordifolia*	*Bauhinia champonionii, Daniella oliveri Cordia africana., Cordia sinensis, Cordia vignei, Parkia biglobosa, Acacia rubida, Parkia biglobosa, Sarcocephalus latifolius, Morellia senegalensis,* Poaceae, *Vitellaria paradoxa,*	*Solanum melongena, Mangifera indica, Protea elliottii, Justicia* spp., *Delonix regia, Euphorbia* spp., *Euphorbia hirta, Moringa oleifera,*	
Total pollen count		**2645**	**7,305**	**9,500**	**9,102**	
Localities	Ngwa (%)	18. 56	21.46	37.38	22.50	- Sudan savanna
	Timpil (%)	30.12	20.50	37.15	12.23	- Sudan savanna
	Peta (%)	20.77	13.52	28.98	36.73	-Human impacted
	Bantali (%)	26.11	28.60	32.72	12.57	- Sudan savanna
Total pollen indicator of the vegetation (%) of Hawul		**10.57**	**26.22**	**34.11**	**29.10**	**Hawul in Borno State is largely Sudan Savanna type**

Total pollen count = 27,852

Vegetation History and Biogeographical Origin of Honey

The determination of a biogeographical origin of honey is based on the entire spectrum being consistent within the flora of that particular region (Louveaux et al., 1978). The abundance of *Acacia rubida*, *Combretum* spp., *Cordia africana*, *Cordia sinensis*, *Cordia vignei*, *Cyperus crassipes*, *Daniella oliveri*, *Heliostropium* spp., *Parkia biglobosa*, *Sarcocephalus latifolius*, *Strychnos spinosa*, *Senegalia mellifera*, and *Vitellaria paradoxa* reflects the vegetation of sudan savanna. The occurrence of the pollen of the above listed plants in the pollen spectrum of the studied samples confirms their biogeographical origin reflecting Sudan savanna ecovegetation type that is anthropogenically disturbed. Similar findings on other vegetation zones were reported by Agwu & Okeke (1997); Essien et al. (2022c) as well as Essien & Olaniyi (2023).

According to pollen analysis of these honey samples, savanna taxa were the highest pollen contributor (34.11%) followed by human impact taxa (29.10%), open forest taxa (26.22% and lowland rainforest taxa (10.57%). The suggestive vegetational inference inferred from this honey pollen analysis revealed that Hawul in Borno State is Sudan savanna vegetation type that is human impacted (anthropogenically disturbed). For example, the plant *Senegalia mellifera* whose pollen grains are present in the pollen assemblage of the honey samples studied is used as fencing, livestock feed and building material for huts. The wood is prized also for fuel and making charcoal. All these are predominant indigenous occupations/ cultural lifestyle and heritage of the inhabitant of the study area.

The pollen analysis shows a fairly similar floral composition for the entire honey samples studied which is in line with the work of Sowunmi (1976) in Southeastern Nigeria and the high floral diversity of the forested-savanna ecozone by Agwu et al. (2013) in Northcentral Nigeria. The percentage of human impact indicator species could be attributed to anthropogenic activities in this region such as the activities of herdsmen (livestock grazing, annual bush burning, etc.), deforestation, urbanization, and agricultural activities in line with Essien et al. (2022a) reports. From Table 4, there were clear indications that the region of Hawul is largely Sudan savanna which is been impacted by humans although with little variation with respect to the different study localities.

Season of Honey Production

Most plants flower during the dry seasons, allowing honeybees graze during those times. To produce honey in the study area efficiently, this study examined the numerous pollen types and their distinct flowering seasons. According to Dalziel (1937) and Keay (1959) studies, flowering seasons differ for different plants. For example, *Mangifera indica* (February-May), *Morellia senegalensis* (November to January; March to April), *Mimusops warneckei* (April to June), *Alchornea cordifolia* (October to November; June - August), *Bombax buonopozense* (January to March), *Brachystegia eurycoma* (April to May), *Daniella oliveri* (November to January; March to April), *Delonix regia* (April to August), *Elaeis guineensis* (October-April), *Parkia biglobosa* (December to April), *Paullinia pinnata* December to January), *Trichilia prieureana* (January to March), *Tridax procumbens* (June to September), *Vitellaria paradoxa* (April to June). According to Sowunmi (1976) and Agwu & Akanbi (1985), *Parkia biglobosa*, and *Phyllanthus* spp. all have flowering periods between January and October. These flowering seasons can be used by beekeepers to maximize the production of honey in the study area.

Most plants flower during the dry seasons, allowing honeybees graze during those times. For instance, the flowers of *Senegalia mellifera* are sources of nectar for honey-producing bees. To produce honey in the study area efficiently, this study examined the numerous pollen types and their distinct flowering seasons. According to Dalziel (1937) and Keay (1959) studies, flowering seasons differ for different plants. For example, *Mangifera indica* (February-May), *Morellia senegalensis* (November to January; March to April), *Mimusops warneckei* (April to June), *Alchornea cordifolia* (October to November; June - August), *Bombax buonopozense* (January to March), *Brachystegia eurycoma* (April to May), *Daniella oliveri* (November to January; March to April), *Delonix regia* (April to August), *Elaeis guineensis* (October-April), *Parkia biglobosa* (December to April), *Paullinia pinnata* December to January), *Trichilia prieureana* (January to March), *Tridax procumbens* (June to September), *Vitellaria paradoxa* (April to June). According to Sowunmi (1976) and Agwu & Akanbi (1985), *Parkia biglobosa*, and *Phyllanthus* spp. all have flowering periods between January and October. These flowering seasons can be used by beekeepers to maximize the production of honey in the study area.

Floral Preference of Honeybees (*Apis mellifera* var. *adansonii*)

Pollen analysis of honey samples examined indicates the presence of pollen types of different plants species, most likely a reflection of more species diversity characteristics of Human impacted Sudan Savanna vegetation type. The determination of the floral origin of honey is based on the relative frequencies of pollen types of various nectar producing plants species in the honey samples. Generally entomophilous plants were observed to be more abundant in the pollen spectrum of each honey sample studied and the honey from the source localities were rich in pollen types. In terms of floral sources, this study revealed that all the honey samples were multifloral (Table 3); suggesting that honeybees (*Apis mellifera* var. *adansonii*) collected honey by gathering a variety of pollen and nectar that they found to be most appealing. According to Agwu et al. (2013), Kayode & Oyeyemi (2014), Adeonipekun et al. (2016), Adekanmbi & Ogundipe (2019), and Essien et al. (2022c), the majority of Nigerian honeys fall into the type I description of Parades and Bryant (2019). The pollen types from the least abundant families may not have been fully domesticated, or their pollen does not rank among the top choices for honeybees.

The study showed that all honey samples were multifloral (Table 3), implying that honeybees (*Apis mellifera* var. *adansonii*) foraged for several preferred pollen and nectar sources to produce the honey. Agwu and Njokuocha (2004) reported that the differences which were observed in the number of contributing plant species in the honey samples may be attributed to the variation in edaphic factors, microclimate, lack of uniformity in the establishments of plants (including flowering period) and selective behaviors of bees during their foraging activities.

Originality of Honey

Deciphering the botanical or ecological origin and the authenticity of honey samples from Hawul, Borno State, Nigeria was the focus of this study. Complimentarily, knowing the best times for apiculture by understanding the flowering seasons of the plant was another objective. Having seen evident impact of humans in the study location, pollen analytical study shed more light on the important bee plants that may require preservation for continuous supply of quality honey in Borno State. The study found that all honey samples were acidic in nature (Table 1) and pollen weight revealed that the honey sample were not adulterated. Cases of honey adulteration have been reported in many cities in Nigeria. For example, Agwu *et al*. (2013) from Dekina; Aina *et al*. (2014) from Kogi East; Anidiobu (2016) from Kabba; Essien *et al*. (2022a) from Ijumu has been reported to be good. This study confirms those from Hawul, Borno State; that were randomly sampled are also of good quality. Honey quality can be measured by its pollen diversity and count (Ige & Modupe, 2010; Oyeyemi, 2017; Essien *et al*., 2022c). The high diversity of pollen types (Figure 1) further supports the originality of the honey samples (Bogdanov & Martin, 2002).

CONCLUSION

Pollen analysis is still an indispensable method for the determination of vegetational history and biogeographical origin of honey; major season of honey production; floral preference of honey bees, and purity status of honey based on its floral and geographical origin. It can to some extent, reflect the floristic characteristics of the area the honey was collected from. This study has revealed some important indicator species of vegetation types in Hawul as well as honey bees (*Apis mellifera* var. *adansonii*) preferred pollen and nectar sources. These plants include those of *Syzygium guineense*, *Psidium gaujava*, *Mangifera indica*, *Parkia biglobosa*, *Combretum* spp., *Vitellaria paradoxa, Elaeis guineensis,* and *Trichillia prieureana* worthy of conservation and their sustainable exploitation managed in the apiculture to enhance large scale production of honey in Hawul Local Government Area of Borno State, Nigeria. The study further revealed that the region of Hawul in Borno State is largely Sudan Savanna type and is currently being impacted by human activities of subsistence.

REFERENCES

Adekanmbi, O. & Ogundipe, O. (2019). Nectar sources for the honey bee (Apis mellifera adansonii) revealed by pollen content. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 37(2):211 – 217.

Adeonipekun, P.A., Adeniyi, T.A., Akinsoji, A. & Eden, D. (2016). Floral diversity and antibacterial properties of honey from three different eco-zones in Nigeria. Bee World, 93(3): 68 – 73.

Agwu, C.O.C. & Okeke, G.I. (1997). Pollen analytical and thin-layer chromatographic Study of honey from three savanna zones of northern Nigeria. Nigerian Journal of Botany, 10: 25-36.

Agwu, C. O. C. & Akanbi, T. O. (1985). A Palynological Study of Honey Samples from four Vegetation Zones of Nigeria. Pollen et Spores, 25 (3-4): 335-348.

Agwu, C. O. C. & Njokuocha, R. C. (2004). Pollen analysis of honey and the biological effects of honey as a rooting medium. Nigerian Journal of Botany, 17: 74-81.

Agwu, C. O. C., Essien, B. C. & Badmus, S. A. (2013). Melissopalynological Study of Honey samples from four localities in Dekina Local Govt. Area of Kogi State, Nigeria. Journal of Biological and Chemical Research, 30 (2): 921-928.

Aina, D., Enefola, J.O., & Agwu, C.O.C (2014). Palynological study of honey samples from four localities in Kogi East, Nigeria. Journal of Biology and Life Science, 6(1): 29-36.

Anidiobu, V.O. (2016). Rheological characterization of honey: application as an index of quality. PhD Thesis, Faculty of Engineering, University of Lagos, Akoka.

Bogdanov, S. & Martin, P. (2002). Honey authenticity: A review, Mitt. Hyg, 93: 235-254.

Bryant, V.M. (2018). Melissopalynology: the science of using pollen to study honey. Bee Culture, 146(11),41 – 45.

Dalziel, J.M. (1937). Useful plants of tropical West Africa. London: Crown Agent for Overseas Government and Administration. Pp. 191 – 340.

Erdtman, G. (1969). Handbook of Palynology. An introduction to the study of pollen grains and spores. Hafnar Publishing Company, New York. 486pp.

Essien, B.C. (2019). The Study of Quaternary Airborne Palynomorphs in Akoko Environment, Ondo State, Nigeria. PhD Thesis, Department of Plant Science & Biotechnology, Adekunle Ajasin University, Akungba- Akoko, Ondo State, Nigeria. 493pp.

Essien, B.C. (2020). The study of floral activities and flowering calendar of some selected plant taxa in Akoko environment, Ondo Statw, Nigerian. GSC Advance Research and Review, 4(1): 59-68.

Essien, B.C., Obigba, S.O. & Falaye, I.S. (2022a). Floral preference of honeybees (Apis mellifera var. adansonii) in Ijumu, Kogi State, Nigeria: a melissopalynological and biodiversity conservation perspective. NABDA Journal of Biotechnology Research, 1(1): 126-136.

Essien, B.C., Atukpa, M.E., Anwana, E.D., Oni, A.S. & Fatoyinbo, S.O. (2022b). A palynological study of honey samples from four localities in Yagba West Local Government Area of Kogi State Nigeria. International Journal of Innovative Bioscience Research, 10(3): 1 – 14.

Essien, B.C.; Tsoho, S.B., Atukpa, M.E. and Medubi, O.M. (2022c). Pollen analytical examination of honey samples from some selected localities in Kabba/Bunu Local Government Area, Kogi State, Nigeria. Science Research Annals, 13(1): 39 - 54.

Essien, B.C. & Olaniyi, B.O. (2023). Pollen and Physicochemical Characterization of Honey Samples from Owo Local Government Area, Ondo State, Nigeria. Standard Scientific Research and Essays, 11(4): 114 – 123.
Hopping, C.A. (1967). Palynology and the oil industry. Review of Palaeobotany and Palynology, 2: 23-48.

Ige, O.E. & Modupe, T.O. (2010). Pollen characteristics of honey samples from North Central Nigeria. Journal of Biological Science, 10(1): 43 – 47.

Ige, O.E. (2017). Wanted dead and alive: palynomorphs as microscopic signal to the past and present. 11th inaugural lecture, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria. 74pp.

Ige, O.E. & Essien, B.C. (2019). The applications of pollen analysis in environmental monitoring in Akoko North-East Local Government Area of Ondo State, Nigeria. GSC Biological and Pharmaceutical Sciences, 8 (1): 64 - 77.

Kayode, J. & Oyeyemi, S.D. (2014). Physico-chemical study and analysis of pollen grains in some commercial honey samples found in Ondo State, Nigeria. International Journal of Basic and Applied Science, 3(2): 63 – 73.

Keay, R.W.J. (1959). An outline of Nigerian vegetation. Lagos, Nigeria: Federal Government of Nigeria.

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

More, P.D. & Webb, J.A. (1978). An illustrated guide to pollen analysis. Stronghton, London. 133pp.
Ollerton, J., Winfree, R. & Tarrant, S. (2011). How many flowering plants are pollinated by animals? Oikos, 120: 321-326.

Oyeyemi, S.D. (2017). Pollen analysis of honey samples from an apiary in Ado Ekiti, Ekiti State, Nigeria. Nigerian Journal of Botany, 30(2): 203 – 212.

Parades, S. & Bryant, V.M. (2019). Pollen analysis of honey samples from the Peruvian Amazon. Palynology, 44(2): 344-354.

Roberts, N. (1989). The Holocene: an environmental history. Basil-Blackwell. New York. 361pp.

Shubharani, R., Roopa, P. & Sivaram, V. (2013). Pollen Morphology of Selected Bee forage Plants, Global Journal of Bio-Science and Biotechnology, 2(1): 82-90.

Sivaram, V. (1995). Bee flora, Honey flow and Bee keeping in the plains of Karnataka. PhD Thesis, Bangalore University, Bangalore.

Sowunmi, M. A. (1976). The Potential values of Honey in Palynology and Archaeology. Review of Palaeobotany and Palynology, 21: 171-185.

Sowunmi, M.A. (1978). Pollen of Nigerian Plants I. Grana, 13: 145-186.

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

Traverse, A. (1988). Palaeopalynology. Unwin Hyman Press, London. 283pp.

Winfree R (2010). The conservation and restoration of wild bees. Annals of the New York Academy of Sciences, 1195:169–197.