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Pollination Ecology Of Some Selected Tree Species In Bagale Hills Forest Reserve And Jos Wildlife Park, Nigeria

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Abstract:
Background: *This study assessed the pollination ecology of some selected trees in Bagale Hills Forest Reserve (BHFR) in Adamawa State and Jos Wildlife Park (JWLP) in Plateau State. The objectives were to: assess angiosperm diversity; determine polinator diversity; compare the flowering of angiosperms between the two studied locations and investigate plant-pollinator interaction in between the studied locations.*
Materials and Method: *The systematic line transect method was deployed for laying out transects. Four transects of 1 km were laid in the two geolocations and four sampled plots of 50 m x 50 m was laid alternately along each of the transect. Three angiosperms were selected randomly and were used for collection of data on phenology, pollination and plant-pollinator interactions. The two locations were traversed for three months and the appearance of flowering buds and presence of pollinators on targeted tree species were observed. Data were analysed and presented using the Descriptive statistics but Shannon-Wiener's diversity index was used to determine diversity. The diversity of the pollinators of BHFR and JWLP were compared using the paired simple t-Test.*
Results: *The result of the Shannon-Wiener Diversity Index indicates pollinator species diversity of 2.686 in BHFR, while pollinator species diversity in JWLP was 2.589 respectively. There was no significant difference between the pollinator's diversity of BHFR and JWLP ($p > 0.05$). The result of phenological scoring showed that 3.25 % of the tree species were flowering during the wet season in both studied locations. Plant-pollinator interactions showed that the pollinators encountered during the study were invertebrates that were not evenly distributed. Additionally, all sampled tree species encountered were generalist. Despite variation in ecological features of the two locations, plant species and pollinator diversity were similar.*
Conclusion: *It was concluded that conservation education for the communities surrounding the two study sites must be given due priority.*
Key Word*: Pollinators, Phenology, Ecology, pollination syndromes, conservation education.*

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I. Introduction

Pollination, often transferred through the help of pollinator agents, forms the basis of reproduction in angiosperms. These pollinator agents can be wind, water, animal, gravity or growth contact by overcrowded plant population[1,2]. Several scientists analyzed some animal pollinators as: butterflies, bees, humming birds and bats. Others are: ants, beetles, rodents, possums, lizards, moths and flies[2,3,4].

Plants and their pollinators have jointly and gradually developed physical characteristics that make them more likely to interact successfully and these results to a great diversity of flowers in nature. Plants benefit from attracting a specific consortium of pollinators to its flowers, ensuring that its pollen will be carried to another flower of the same species and hopefully resulting in successful reproduction[3,4]. They further stated that the colour, fragrance, nectar, structure and shape of the flower vary by the type of pollinator that visits them. These characteristics are referred to as pollination syndromes; a group of symptoms consistently occurring together. This syndrome can be used to predict the type of pollinator that will aid the flower in successful reproduction. The more specific the relationship between the flower and pollinator, the more likely the pollen of that species will be successfully transferred and that the plant's pollen will not be wasted on the flower of a different species. Accordingly, that the hypothesis of co-evolution is explained by plant-pollinator interaction, such as how mutualism or antagonism can alter plant morphology or pollinator behaviour and morphology.

Sexually reproduced plants and their pollinators could either be generalist or specialist depending on their morphology[5]. A fundamental aspect of any ecological interaction involving pollination

mutualism is the degree to which the interactants are generalized or specialized. Plants that are generalists can be pollinated by a wide range of pollinators[6,7]. Three pristine pine rocklands site in Everglades National Park southern Florida, recorded a total of 22 species of flower visitors on the native trees. For example: *Chamaecrita keyensis* (partridge pea) are pollinated by three pollinator carpenter bee, and two species of Melisssodes bees. Specialist plants are only pollinated by animals that evolved with suitable characteristics that are capable of carrying out reproductive functions, for example: *Byrsonima lucida* has a specialized pollination system, it is pollinated by andrenid bees in the genus Centris[6].

The phenology of plants such as: bud-burst, leaf-expansion, abscission, flowering, fertilization, seed set, fruiting, seed dispersal and germination take place in due season[8]. For the most part, these events are too familiar to attract any special attention. Only when the expected pattern is broken, for example by out-of-season flowering or the loss of fruit due to a late frost, is attention drawn to the importance of timing of growth and reproduction in the life of plants. Phenological studies are as important as the spatial aspects are to understanding species interactions and community function[9,10]. To this end, this research focus on the plant phenology and biodiversity of pollinators in the study area with the objectives to: assess angiosperm diversity in the study area; determine pollinator diversity in the study area; compare the period of flowering of angiosperms between the two locations; and investigate plant-pollinator interaction in both study sites.

II. Material And Methods

Study Area

The study of was carried out in two locations: Bagale Hills Forest Reserve (BHFR) in Girei Local Government Area of Adamawa State and Jos Wildlife Park (JWLP) in Jos North Local Government Area of Plateau State (Figure 1). Bagale Hills Forest Reserve (Figure 2) covers an approximately 179.746 Km^2 of land. It is situated between latitude 9º 15' and 9º 23' North and longitude 12º 31' and 12º 41' East[11]. The Jos Wildlife Park (Figure 3) lies within latitude 09° 52' and longitude 08° 53' It cover approximately 8 km^2 of unspoiled savanna bush, about 4km from Jos[12]. The annual rainfall in Bagale Hills Forest Reserve is 1030 mm per annum[13] while Jos receives about 1,400 millimeters of rainfall annually (Climate-charts.com., 2013). The maximum temperature in Bagale can reach 40ºC particularly in April[13] while minimum temperature can be as low as 18ºC between December and January while in Jos average monthly temperatures range from 21–25ºC.

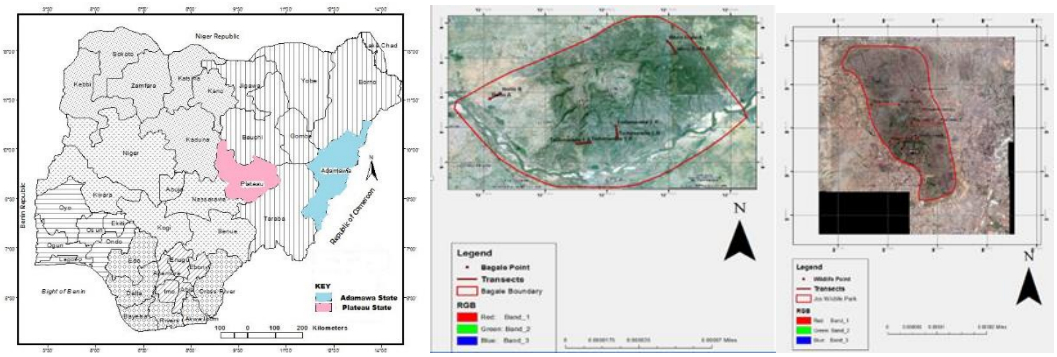


Fig. 1: Map of Nigeria: Adamawa/Plateau State
Fig. 2: Map of Bagale Hills Forest Reserve.
Fig.3: Map of Jos Wildlife Park
Source: Federal College of Forestry, Jos GIS Laboratory, 2015

Sampling Techiniques

The design used for this study was the systematic sampling in which four transects of 1 km was laid at intervals of atleast 500m between each transect (Figure 4). Also, Sample plots of 50 m X 50 m were laid alternately at 200 m interval as adopted by Adekunle, 2010.

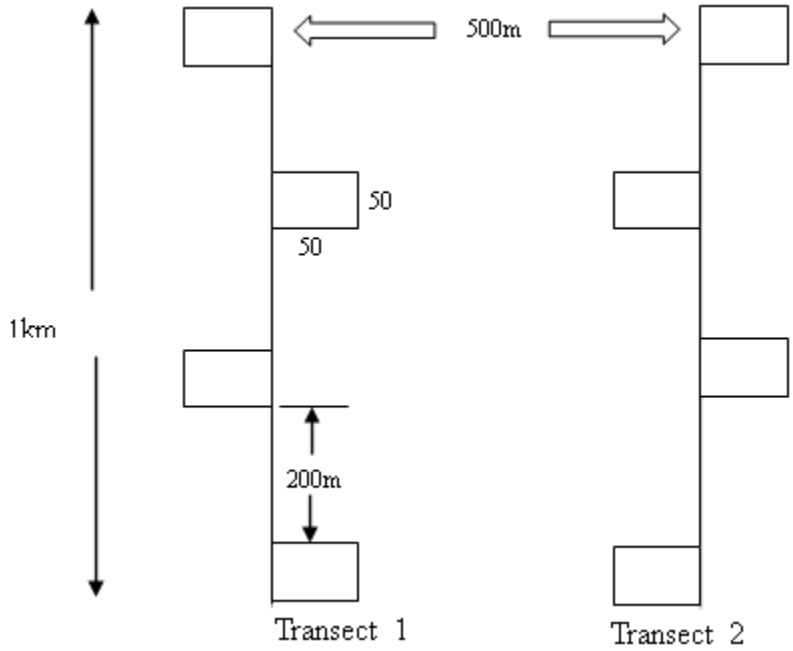


Figure 4: Plot Location using Systematic Line Transect

Data Collection

Data were collected by direct field observation with the aid of binocular, field guide book and recorded in data collection sheet. The study area was traversed on foot for three months and the appearance of flower buds and presence of pollinators (birds, butterflies, bees, ants, beetles, flies and rodents) on the targeted tree species was observed between the periods of 6:00 am to 10:00 am and 4:00 pm to 6:00 pm daily. The number of visitation of pollinators and the occurrence of reproductive parts of the flowers were also recorded.

In each plot, all living angiosperms with diameter at breast height (dbh) ≥ 10cm were numbered and identified. Out of these trees, three trees (focal trees) were selected at random and were used for collection of data on phenology and pollination. Plant-pollinator interactions were determined by visual observation of rates of visitations to a particular tree at flowering stage for a period of 10 minutes; these were used to identify the generalist (many pollinators) and the specialist tree (single pollinator) (Waser and Ollerton, 2006). The scoring system used for the Phenology of the identified trees were "0" (for "No bud") and "1" (for "flower bud").

Data Analysis

The data collected were subjected to descriptive (Frequency, Table and Charts) and inferential statistics (paired sample t-Test) which was used to compare the phenology of the two-study location. The formula is depicted in equation (1). Shannon-Wiener index was used to determine diversity of pollinators of the two locations as shown in equation (2).

$$t = \frac{\bar{X}_A - \bar{X}_B}{\sqrt{\frac{S_d^2}{n}}} \ldots\ldots\ldots\ldots\ldots (1)$$ [16]

Where $\bar{X}_A - \bar{X}_B$ = arithmetic means for group A and B
A = Bagale Hills Forest Reserve
B = Jos Wildlife Park
n = number of pairs of sample units
S_d^2 = variance of the individual differences between A and B.

$$H' = -\sum_{i=1}^{N} Pi \ \ln \ (Pi) \ldots\ldots\ldots\ldots\ldots\ldots (2)$$ [15]

Where H′= Shannon-Wiener diversity index
N = The total number of all individuals
Pi= The proportion of a species to the total number of individuals in the community.

III. Result

Summary Of Pollinators On Flowering Trees In BHFR And JWLP

The result displayed in Table 1 indicated that in all the 16 plots, BHFR had the highest pollinators (1147) while in JWLP few (961) were encountered. The average pollinator in BHFR and JWLP were 54.4 % and 45.6 % with mean of 71.6875 and 60.0625 respectively. Plot 4 had the highest visitation in both study locations (125 in BHFR and 165 in JWLP) while the least were encountered in BHFR plot 15 (23) and in JWLP plot 11 (8) respectively. The BHFR had 370 pollinators recorded in transect 1 (Girei Laide) which was followed by transect 3 (Holin) with 293 pollinators and by transect 2 (Girei Kolere) with 249 pollinators and transect 4 (Wuro-dole) with 235 pollinators respectively. On the other hand, JWLP had non-vertebrate and a caterpillar with observations as follows in each transect: 371 pollinators in transect 1 (Pine valley), 300 pollinators in transect 2 (Eastern gate), 170 pollinators in transect 3 (Vong-fwei) and 120 pollinators in transect 4 (L-wholshe) respectively.

Table 1: Summary of Pollinators on Flowering Trees in BHFR and JWLP

Plot No	BHFR	JWLP
1	95	88
2	68	51
3	82	67
4	125	165
5	108	101
6	24	72
7	56	75
8	61	52
9	101	57
10	57	39
11	58	8
12	77	66
13	51	28
14	110	56
15	23	16
16	51	20
TOTAL	1147	961

The Interactions between Plant and Pollinator in the Study Area

The result of plant-pollinator interaction in both Table 2 and Table 3 showed that pollinators were not evenly distributed among the angiosperms in the two study locations. In BHFR, three (3) pollinators were sometimes seen on the flowers of some trees and at other times, eight (8) pollinators or even more were seen. On the other hand, for JWLP, the least number of pollinators observed on flowering trees was two (2) while the highest number of pollinators observed was nine (9).

Table 2: Plant-Pollinator Interaction in Bagale Hills Forest Reserve

S/N	Tree species	Number of pollinators	Species of pollinator	Rate of visitation
1	*Acacia senegal*	4	Wasp	**
			Mud dauber	*
			Honey bee	*
			Butterfly-	**
2	*Annona senegalensis*	4	Beetle	**
			Ants	*
			Honey bee	*
3	*Anogeissus leiocarpus*	3	Butterfly- swallowtail	**
			Tiny flies	*
4	*Combretum molle*	4	Butterfly	*
			Bug	*
			Wasp	**
			Honey bee	**
5	*Detarium microcarpum*	9	Beetles	*
			Honey bee	*
			Flies	*

			Butterfly	**
6	*Dichrostachys cinerea*	3	Butterfly -brown	**
			Tiny fly	**
7	*Entada africana*	4	Bee	**
			butterfly	*
8	*Piliostigma thonningii*	4	Honey bee	**
			Flies	*
9	*Prosopis africana*	4	Bee	**
			Butterfly	*
10	*Securidaca longepedunculata*	3	Wasp	*
			Butterfly	**
			Others: Lizard, honey bee	*
11	*Strychnos spinosa*	3	Mint green butterfly	**
			Brown butterfly	*
12	*Tamarindus indica*	8	Honey bee	**
			Wasp	*
			Soldier ant	**
			Flying bug	*
			Butterfly	*
			Small ants	*
			Flies	*
13	*Uvaria chamae*	3	Butterfly-swallowtail	*
			Glossina-tsetse fly	**
			Bee	**
	Total			

*= Occasionally visited, ** Frequently visited

Table 3: Plant-Pollinator Interaction in Jos Wildlife Park

S/N	Tree species	Number of pollinators	Species of pollinator	Rate of visitation
1	*Allophylus africanus*	12	Honey bee	*
			Wasp- (mud dauber, bee-like wasp)	**
			Caterpillar	*
			Butterfly	**
			House-fly (*Musca domestica*)	**
			Glossina- tsetse fly	**
			Small ants	*
2	*Annona senegalensis*	4	Bee	*
			Small ants	*
3	*Anogeissus leiocarpus*	4	Butterfly- (swallowtail, mint green)	**
			Tiny insects	*
4	*Carissa edulis*	3	Butterfly	*
			Honey bee	**
5	*Combretum molle*	2	Butterfly	**
			Bug	*
			Wasp	**
			Ants	*
6	*Detarium microcarpum*	2	Flies	*
			Honey bee	**
7	*Dichrostachys cinerea*	3	Soldier ants	**
			Small ants	*
8	*Piliostigma thonningii*	2	Bee	**
			Flies	*
9	*Prosopis africana*	4	Bee	**
			Mint green butterfly	**
10	*Securidaca longepedunculata*	3	Wasp	*
			Butterfly- (swallowtail, mint green)	**
11	*Strychnos innocua*	4	Butterfly	*
			tiny red ants	**
			Tiny insect	*
12	*Strychnos spinosa*	5	butterfly	**
13	*Tamarindus indica*	6	Wasp-	**
			Butterfly	*
			Soldier ant	**
			Honey bee	**
			Small ants	**
			Others: tiny Flies	*
14	*Uvaria chamae*	4	Bee	*

			Glossina-tsetse fly	**
			Butterfly- brown	*
	Total			

*= Occasionally visited, ** Frequently visited

Diversity of Pollinators in the Study Area

The result of the Table 5 and Table 6 showed the Shannon-Wiener Diversity Index of the two study locations. The Shannon-Wiener Diversity Index for pollinators in BHFR was 2.686285 while that of JWLP was 2.589587.

Phenological scoring in the study area

During the course of the study, the number of flowering and non-flowering trees were observed and presented in Fig. 5. In BHFR the result was in the following order: in June the flowering trees were 235 while the non-flowering trees were 192 trees. In July, the number of flowering trees were 244 while the non-flowering trees were 183. In August, number of flowering trees were 189 while the non-flowering trees were 238.

The result of phenological scoring presented in Fig.6 for JWLP showed that in June, the number of flowering trees were 157 while non flowering trees recorded were 337. In July, number of flowering trees observed were 184 while the non-flowering trees were 310. In August, number of flowering trees were 133 while 361 trees had no flower.

Table 5: Diversity of Pollinators on Flowering Trees in BHFR

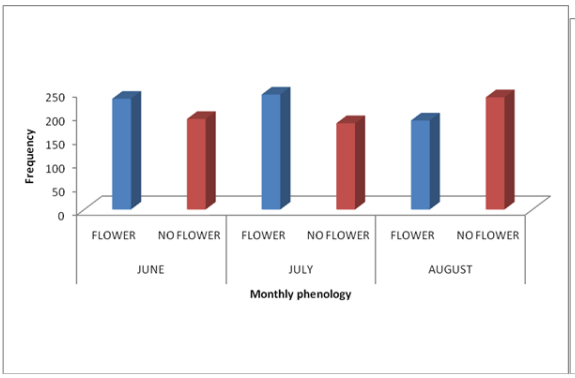
Plot No	Frequency	Pi	LnPi	PiLnPi
1	95	0.082825	-2.49103	0.206319
2	68	0.059285	-2.8254	0.167504
3	82	0.071491	-2.63819	0.188606
4	125	0.10898	-2.21659	0.241564
5	108	0.094159	-2.36277	0.222476
6	24	0.020924	-3.86685	0.080911
7	56	0.048823	-3.01955	0.147424
8	61	0.053182	-2.93403	0.156038
9	101	0.088056	-2.42978	0.213957
10	57	0.049695	-3.00185	0.149177
11	58	0.050567	-2.98446	0.150914
12	77	0.067132	-2.7011	0.181329
13	51	0.044464	-3.11308	0.138419
14	110	0.095902	-2.34442	0.224836
15	23	0.020052	-3.90941	0.078393
16	51	0.044464	-3.11308	0.138419
	1147			2.686285

Source: Field Survey, 2015

Table 6: Diversity of Pollinator Visitors on Flowering Trees in JWLP

Plot No	Frequency	Pi	LnPi	PiLnPi
1	88	0.091571	-2.39064	0.218914
2	51	0.05307	-2.93615	0.155821
3	67	0.069719	-2.66328	0.185681
4	165	0.171696	-1.76203	0.302534
5	101	0.105099	-2.25285	0.236772
6	72	0.074922	-2.59131	0.194146
7	75	0.078044	-2.55049	0.199049
8	52	0.05411	-2.91673	0.157825
9	57	0.059313	-2.82492	0.167555
10	39	0.040583	-3.20441	0.130044
11	8	0.008325	-4.78853	0.039863
12	66	0.068678	-2.67832	0.183943
13	28	0.029136	-3.53577	0.103019
14	56	0.058273	-2.84262	0.165647
15	16	0.016649	-4.09539	0.068185
16	20	0.020812	-3.87224	0.080588

	961			**2.589587**



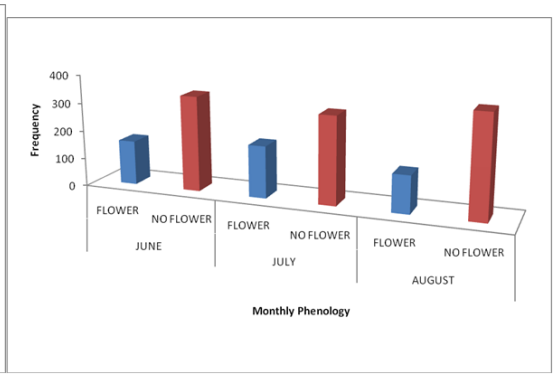


Fig. 5: Phenological Scoring in BHFR (Yola)
Fig. 6: Phenological Scoring in JWLP

Comparism of the Diversity of Pollinators in the two Study Areas

The t-Test result presented in Table 7 showed the comparism between the diversity of pollinators in BHFR and JWLP. The result showed that there were no significant differences in the diversity of the two studied locations (0.455801216) at $\alpha = 0.05$.

Table 7: Paired Sample t-Test for Mean Diversity of Pollinators

	Bagale Hills Forest Reserve	Jos Wildlife Park
Mean	0.167892843	0.161849
Variance	0.002291268	0.004465
Observations	16	16
Pearson Correlation	0.616413796	
Hypothesized Mean Difference	0	
Df	15	
T Stat	0.455801216	
t Critical one-tail	1.753050325	

df=degree of freedom

IV. Discussion

The Diversity of Pollinators in the Study Area

In comparism between the two study sites, the t-Test paired sample result revealed that there was no significant difference in diversity of pollinators in the two study locations. This implies that the species of invertebrate (pollinators) encountered in BHFR and JWLP were similar. While BHFR recorded the highest number of pollinators, it lacks some of the pollinators encountered in JWLP. The study showed that there were more bees and butterfly species than other pollinators in both study locations. It is a well-known fact that Bees pollinate a wide range of plants. This agrees with the results of some scientists[17,18].

The Interaction between Plants and Pollinators in the Study Area

The result of plant-pollinator interaction in BHFR and JWLP showed that pollinators were not evenly distributed in the two-study location. This may be as a result of fragmentation of habitat and may be detrimental to plant and pollinator interactions. The result agrees with [6] who reported different number of visitors for three sites in Everglades National Park in small fragments and that of [9,18] who also reported observed variations in the distribution of pollinators attributed to the physical and environmental factors (altitude, number of plant species, forest disturbance flowering trees, rainfall and temperature).

The study also revealed that the trees encountered in BHFR and JWLP were all generalist plants. The reason is because more than one pollinator was seen on the angiosperms in the two sites. In Bagale, only 2 pollinators (wasp and butterfly) were observed on *Securidaca longepedunculata*, but only the butterfly frequently visited the flowers. The highest number of pollinators were seen on *Detarium microcarpum* (9 insects) and *Tamarindus indica* (8 insects). The most frequent pollinators on *D. microcarpum* was butterfly and *T. indica* was soldier ant.

The plant-pollinator interaction in JWLP showed that 2 pollinators were seen on three (3) tree species namely: *Combretum molle*, *Detarium microcarpum* and *Piliostigma thonningii*. The highest number of

pollinators was observed on *Allophylus africanus* (12 insects). The pollinator that visited *A. africanus* more frequently include: wasp, butterfly, house-fly (*Musca domestica*) and tse-tse fly. The result of this investigation agrees with [6] in a similar study at Everglades National Park, Southern Florida, which observed that plants that are generalists can be pollinated by a wide range of pollinators.

V. Conclusion

Despite variation in ecological features of the two studied locations, plant species and pollinator diversity were similar. The diversity of pollinators in the study area is appreciable. The reason why pollinators were not very abundant during the research can be attributed to the fact that the research was conducted in raining season during which only few trees were flowering. Additionally, a wide range of pollinators were observed on a tree and this is an indication that such trees are generalist. It was concluded that conservation education for the communities surrounding the two study sites must be given due priority.

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