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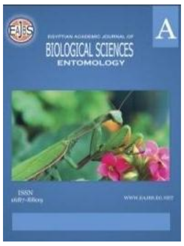

Insect Pollinator Diversity and Distribution on Selected Sites in Yobe State, Nigeria

Yusuf Abdullahi[1] and Kabir M. Umar[2]*
[1]Department of Biological Sciences, Yobe State University, Damaturu, Yobe State, Nigeria
[2]Centre for Dryland Agriculture, Bayero University, Kano, Kano State, Nigeria
*E-mail: kmumar.cda@buk.edu.ng

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ABSTRACT

Pollinators play vital ecosystem services to crops and wild plants, supporting agricultural land and producing worldwide food crops. This study aimed to assess insect pollinators' biodiversity in Yobe State, Nigeria. Using the line transect method, a field Survey was conducted fortnightly for one year in Dachia, Amshi, Kazir, Karage, Paga, and Damaturu communities. Four Temporary Sample Plots (TSP) of size 50×50 m were laid along each transect at a 250 m interval. A total of 349 insect pollinators belonging to 7 orders, 9 families and 13 species were collected and recorded during the sampling period, with Order Hymenoptera being the most dominant (74.83 %) in the dry season and (45 %) in the rainy season while Hemiptera represent the least (2.73 %) in dry seasons and (1.48 %) in the raining seasons, respectively. Similarly, more insect pollinators were observed in Amshi communities (20.30 %) in the rainy season and (17.00 %) in the dry season, while in Dachia (19.80 %) in the rainy season and (21.09 %) in the dry season, respectively. There was no significant difference (3.15) in insect distribution and diversity between sampling sites and species in the rainy season and (4.17) in the dry season in Amshi, while (3.08) in the rainy season and (5.17) in the dry season in Dachia, respectively. The results could be helpful for baseline information for further research on insect diversity, the relative abundance of beneficial and harmful insects, and the control of insect pests in the study areas.

INTRODUCTION

Pollinators provide a vital link with nature, supporting human life and subsistence. The main areas of concern for pollinators' decline are land-use intensification, habitat destruction and fragmentation, disease, the use of agrochemicals, and climate change. Although the importance of each of these and the extent to which they are interrelated is less well known (Vanbergen, 2013). Jaweria *et al.* (2020) reported that using agrochemicals such as pesticides, fertilizers, and heavy metal pollutants drives the decline in insect pollinators' diversity in the ecosystems. The use of biomarkers to evaluate pollution has noticeably increased in the past few years. It has been proposed as a sensitive 'early warning' tool for biological effect measurement in environmental quality assessment (Hamza-Chaffai, 2014). Several different mechanisms lead to fragmentation, many of which are influenced by anthropogenic activities like clearing land for agriculture and logging (Aguirre, 2014).

Insects are essential components of ecosystems, especially those found in forests. Some bug species are significant indicators in ecosystem management and serve as effective pollinators and biological pest control agents. Due to their small size, which enables them to occupy niches unavailable to larger organisms, insects are a remarkably diverse collection of organisms (Kyerematen, 2014; Okrikata & Yusuf, 2017).

Pollinators are a key component of global biodiversity, providing vital ecosystem services to crops and wild plants (Potts *et al.,* 2010). About ninety percent of flowering plants depend upon pollinators for their pollination (Ollerton, 2011). Pollinators affect 35 percent of global agricultural land, supporting the production of 87 percent of the leading food crops worldwide (Klein, 2007; Mumyuli, 2014). A decline in pollinator abundance and diversity can result in a loss of pollination services that could significantly affect the maintenance of wild plant diversity, wider ecosystem stability, crop production, food security, and human welfare (Regan, 2015). Due to the removal of food sources, nesting, oviposition, resting, and mating locations, habitat destruction impacts insect pollinators. In agricultural settings with severe habitat loss or greater distance from natural habitat, there is currently a well-documented decline in the abundance and richness of wild pollinators (Siregar *et al.,* 2016). Food security is a priority in many developing countries, including Nigeria. Most efforts to address this issue have been directed to almost all production inputs for improving crop yields, other than pollination. The conservation of biodiversity and, most significantly, the provision of food depend on pollination, an essential ecological service. Due to habitat degradation, invasive species invasions, pollution, overharvesting, and changes in land use, pollination is declining (Mandela *et al.,* 2018). The plight of pollinators is so important that the first report of the new Intergovernmental Platform on Biodiversity and Ecosystem Security (IPBES, 2016) was devoted to pollinators. Flowering plants and insect pollinators are symbiotic. Pollinators receive food rewards from nectar and pollen (Arena and Farina, 2012). Bees, butterflies, moths, beetles, wasps, and flies are just a few of the many insect species recognized as pollinators of different plant species.

In comparison to other groups of insects, bees are the most significant and efficient pollinators (Siregar *et al.,* 2016). Bees are a complex collection of insects divided into social and solitary bees based on how they build their nest (Rehan, 2010). Maintaining protected areas in their desirable state requires monitoring. A lack of sturdy designs, nonetheless, hampers effective monitoring. Much less effort must be put into monitoring to assess changes in diversity and abundance than in richness. Crop loss impacts rural farmers' ability to support themselves, especially in developing nations, ultimately making them vulnerable to poverty. Understanding which aspects of damaging events determine crop loss is essential for developing and assessing deterrents, since it is the most common cause of conflict between humans and primates (Jaleta & Tekalign, 2023).

Yobe State was ranked as one of the poorest states compared to other states in Nigeria, with a poverty rate of 71.9 % in 1999 (Musa, 2020). Currently, the poverty level of Yobe State stands at 71.8 % in 2020, 63% in 2021, and no research has been carried out to find out why (Akinlolu & Maina, 2020). However, the degree of vulnerability to poverty stands at 58.7 %; the factors that are responsible for vulnerability to poverty in the state include Age, educational status, and household size of the respondents. Poverty is a global phenomenon whose impact is multi-dimensional; it touches the economic, social, political, psychological and physical aspects of human endeavors. Moreover, it is found in almost all communities; if poverty were to be seen as a visible object, it would appear horrific, devastating, and unpleasant in all ramifications (Sani *et al.,* 2021).

The state's economy is largely driven by agriculture, with more than 80 % of the citizens engaged in small-scale subsistence farming, food crops such as millet, sorghum, beans, maize, and rice (Musa, 2020). This study, therefore, reveals the diversity and abundance of insect species (Pollinators) in Yobe State, Nigeria, and the need for sustainable strategies or actions to conserve beneficial species.

MATERIALS AND METHODS

Site Selection:

The site selection was carried out with the help of land use/ land cover of Yobe State, using data collected by the GIS and Remote Sensing Laboratory of the Centre for Dry Land Agriculture, Bayero University Kano (CDA), (Fig. 1).

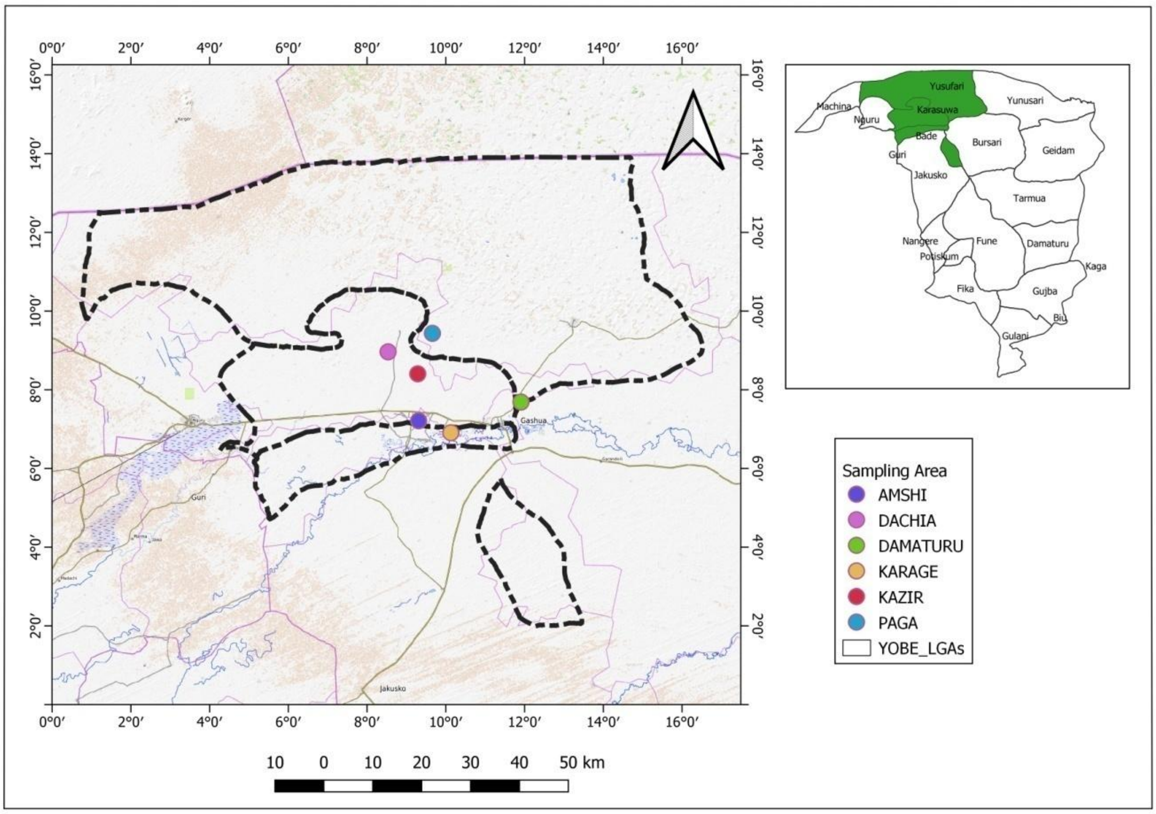

Fig 1: Land use/ Land cover of Yobe State, Showing Sampling Sites.

Survey and Sampling Procedure:

Systematic sampling design (Systematic line transect) was employed to lay out plots for two straight line transects, each 1000 m long and separated by 500 m, in the sampling sites. This was done to map out and collect insect pollinators in stations on two separate points on each site at every study visit. Four Temporary Sample Plots (TSP) of 50×50 m were laid along each transect at a 250 m interval (Fig 2). A field survey was conducted fortnightly in the selected study areas for one year. Each station was chosen according to the distribution of plants based on the proximity of river Yobe, geographical location, Irrigational farming system by farmers, foraging activities of insects, especially Honey bees in their natural habitat in the area, according to the method described by Salami & Akinyele (2018), Salami *et al.* (2019), Abdullahi *et al.* (2011), Wafubwa & Ndong'a, 2019; Alarape *et al*. (2015); Fayyaz *et al.* (2016). The start and end of each transect were marked with flags made from white or red cloths to enhance visibility.

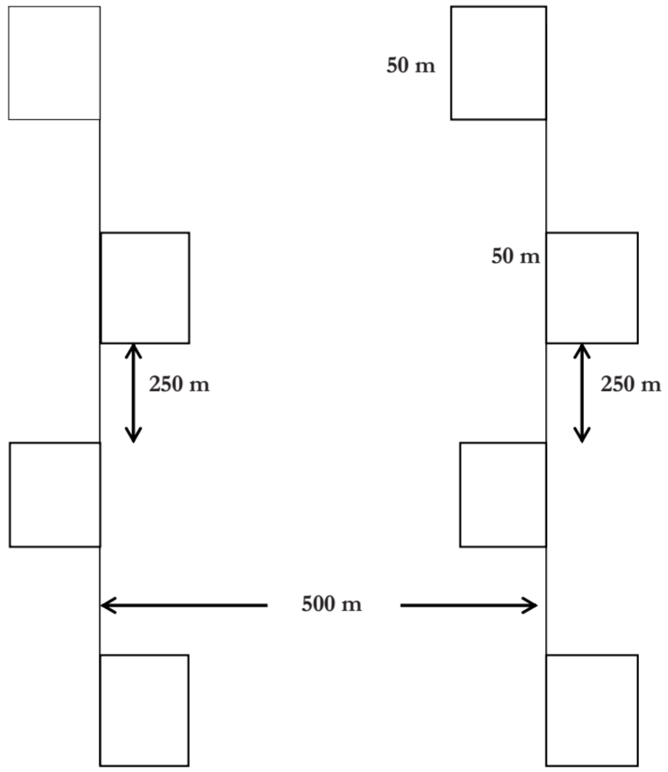

Fig 2: Plot Layout with Systematic Line Transects Sampling Technique **(**Salami & Akinyele, 2018**).**

Observation, Collection, and Preservation of Insect Pollinators:

All Flowering plants found within a 50 m radius on each transect were visited and observed for pollinators' presence and foraging activities within a predetermined period of 30 minutes. Every two transects crossed at the center (500 m) perpendicularly. Pollinators were collected when they landed on the plants (flowers) during foraging periods (Abdullahi *et al.,* 2011; Yager *et al.,* 2016; Jimmy, 2015). The insect collection was carried out in the early hours, as they are active. On each sampling date, samples were obtained from the field at 07:00 am - 12:00 pm. A sweep net was used to sample ground vegetation and selectively target aerial insects, like wasps, bees, and butterflies, at different locations within the study sites. Pollinators caught were transferred into the prepared bottle containing Chloroform soaked with cotton wool for preservation and later taken to the laboratory for pinning (mounting) on an insect collection box using entomological pins for further identification using morphological features. Some online sources and pictorial keys were also used for identification. The collected insects were preserved in 70 % ethanol (Mattu & Nairala, 2013; Kausar, 2016; Naman *et al.,* 2019).

Identification and Classification of Insect Pollinators:

The insect pollinators collected were transported to the CDA Laboratory, Bayero University Kano, for Identification and classification in accordance with standard procedures (Usman, 2013).

Statistical Analysis:

Data obtained were analyzed using GenStat version 2020 and subjected to one-way analysis of variance (ANOVA) to compare sampling sites with seasons. P-values < 0.05 were considered significant.

RESULTS

The Abundance of Each Particular Species at The Specified Study Site Was Obtained During the Rainy Season:

The insect pollinators obtained during the rainy season are presented in **Table 1.** Thirteen species were recorded, including: *Lucuster migratoria*, *Polistes exclamans*, *Anax imperator*, *Libellula quadrimaculata, Apis mellifera, Apis anthophila, Anoplocnemis curvipes, Hycleus lugens, Colias hyale, Pieris virgiensis, Pieris rapae, Pyronia Cecilia,* and *Danaus plexippus,* belonging to 7 orders (Orthoptera, Hemiptera, Odonata, Hymenoptera, Heteroptera, Coleoptera, and Lepidoptera), which were from 9 families (Acrididae, Vespidae, Aeshnidae, Libelluidae, Apidea, Coreidae, Meloidae, Pieridae, and Nymphalidae). *Apis mellifera* had the highest abundance of 92 (45.55%) while *Polistes exclamans* had the least in abundance of 3 (1.48%) individuals. From the sampling sites, Amshi has the highest number with 41 insect pollinator species, while Karage had the least with 27 individuals of insect pollinator species (Fig. 3).

Table 1: Abundance of each particular species at the specified study site obtained during the rainy season.

Order	Family	Species	No. of Species in Study Area						
			DCH	AMS	KZR	KRG	PAG	DTR	TOTAL (%)
Orthoptera	Acrididae	*Lucuster migratoria*	2	1	2	2	1	2	**10**(4.95)
Hemiptera	Vespidae	*Polistes exclamans*	0	1	2	0	0	0	**03**(**1.48**)
Odonata	Aeshnidae	*Anax imperator*	3	1	2	1	2	2	**11**(5.44)
	Libelluidae	*Libellula quadrimaculata*	1	1	2	1	2	0	**07**(3.47)
Hymenoptera	Apidea	*Apis mellifera*	19	17	18	12	14	12	**92**(**45.55**)
	Apidea	*Apis anthophila*	2	1	2	1	1	0	**07**(3.47)
Heteroptera	Coreidae	*Anoplocnemis curvipes*	3	3	0	1	2	0	**09**(4.46)
Coleoptera	Meloidae	*Hycleus lugens*	2	5	1	1	2	7	**18**(8.91
Lepidoptera	Pieridae	*Colias hyale*	2	3	1	2	0	1	**09**(4.46
	Pieridae	*Pieris virgiensis*	1	2	1	2	2	0	**08**(3.96)
	Pieridae	*Pieris rapae*	0	2	0	2	1	1	**06**(2.97)
	Nymphalidae	*Pyronia cecilia*	2	0	1	0	1	1	**05**(2.47)
	Nymphalidae	Danaus plexippus	3	4	2	2	4	2	**17**(8.41)
TOTAL			40	41	34	27	32	28	**202**(100)

Keys: DCH=Dachia;AMS=Amshi;KZR=Kazir;KRG=Karage;PAG=Paga;DTR=Damaturu

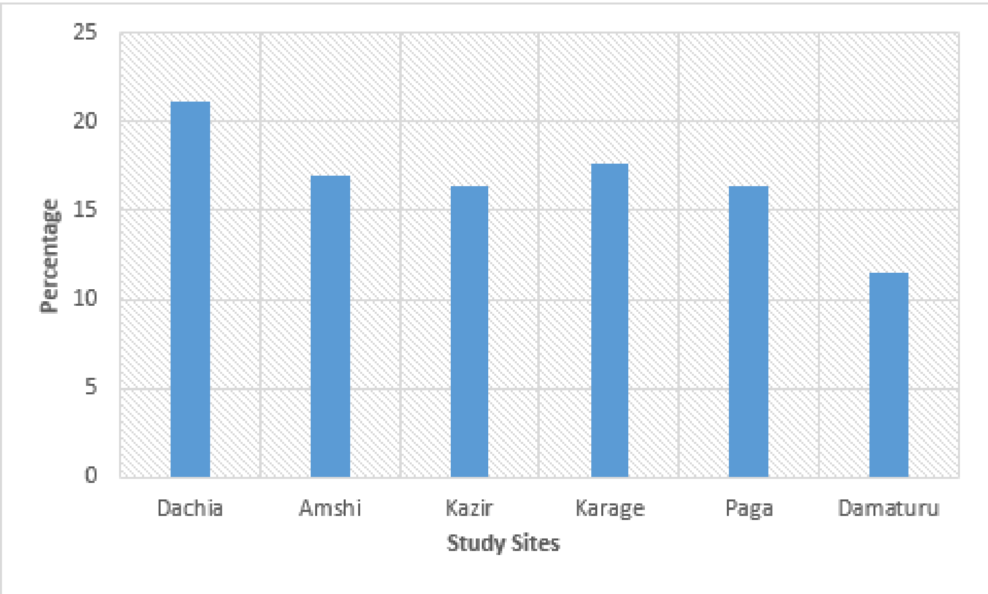

Fig 3: Percentage Distribution of insect pollinators in the study sites obtained during the rainy season

The abundance of each particular species at the specified study site was obtained during the dry Season. The insect pollinators obtained during the dry season are presented in table 2. Six species were recorded, comprising: *Lucuster migratoria, Polistes exclamans, Apis mellifera, Apis anthophila, Anoplocnemis curvipes, and Hycleus lugens.* They belong to 5 orders: Orthoptera, Hemiptera, Hemiptera, Heteroptera and Coleoptera, which were from 5 families namely: Acrididae, Vespidae, Apidea, Coreidae, and Meloidae, the species *Apis mellifera* has the highest abundance of 110 (74.83%) while *Polistes exclamans* has the least in abundance of 4(2.73%) individuals species. Results from sampling sites Dachia have a total number of 31 species, Amshi has 25, Kazir has 24, Karage has 26, Paga has 24, and Damaturu has 17 total species and 147 species (Table 2 and Fig. 4).

Table 2: Abundance of each particular species at the specified study site obtained during the dry Season.

Order	Family	Species	No. of Species in Study Area						
			DCH	AMS	KZR	KRG	PAG	DTR	TOTAL (%)
Orthoptera	Acrididae	*Lucuster migratoria*	1	1	0	2	0	2	06(4.08)
Hemiptera	Vespidae	*Polistes exclamans*	0	1	0	3	0	0	04(2.73)
Hymenoptera	Apidea	*Apis mellifera*	23	19	21	14	18	15	110(74.83)
	Apidea	*Apis anthophila*	2	0	2	4	3	0	11 (7.48)
Heteroptera	Coreidae	*Anoplocnemis curvipes*	3	2	0	1	1	0	07(4.76)
Coleoptera	Meloidae	*Hycleus lugens*	2	2	1	2	2	0	09(6.12)
|TOTAL			**31**	**25**	**24**	**26**	**24**	**17**	**147(100)**

Keys: DCH=Dachia, AMS= Amshi, KZR= Kazir, KRG = Karage, PAG = Paga, DTR=Damaturu

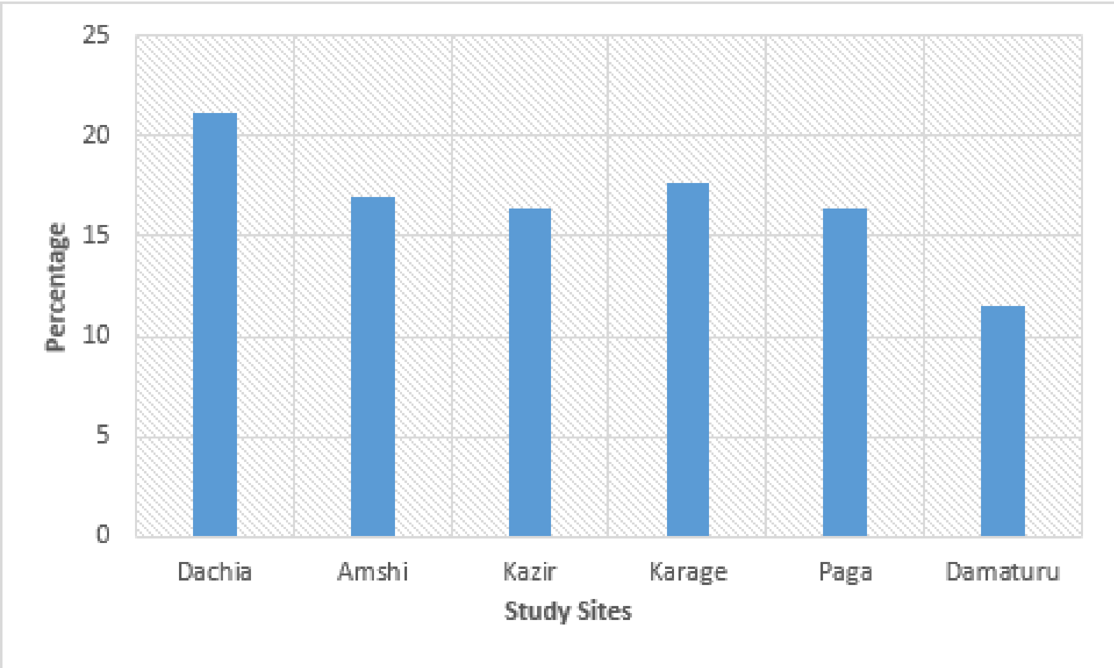

Fig 4: Percentage Distribution of insect pollinators in the study sites obtained during the dry season

Distribution and Abundance of Insect Pollinators Obtained During the Rainy and Dry Seasons:

The Insect Pollinators obtained during the rainy and dry seasons are presented in Table 3. During the rainy season, the Sampling sites Amshi had the highest mean value with 3.15, and the least 2.08 was obtained in Karage. The species of *Apis mellifera* had 15.33 as the highest, and the least had 0.50 from *Polistes exclamans*. During the rain, the sampling

sites had an LSD of 1.78, species 0.84, and a P-value of 0.77 for sampling sites, P<0.001 for the species, and P>0.05 for sampling sites/ species. There was no significant difference in insect distribution and diversity between sampling sites and species, P> 0.05 (Table 3).
During the dry season, the sampling site Dachia had the highest mean value of 5.17, and the lowest was in Damaturu, 2.83 (Fig 2). The species of *Apis mellifera* had 18.33, while the least was in *Polistes exclamans,* 0.67. Also, during the dry seasons, the LSD obtained was 4.5 for the sampling sites and 1.11 for the species. P-value, the sampling sites had 0.954, species <0.01, and sampling site/ species P>0.05. Therefore, there was no significant difference between sampling site and species, P> 0.05(Table 3).

Table 3: Distribution and Abundance of Insect Pollinators Obtained During the Rainy and Dry Season

Rainy season		**Dry season**	
Sampling sites	**Species**	**Sampling sites**	**Species**
AMS 3.15^{a}	*Lucuster migratoria* 1.67^{bcd}	AMS 4.17^{a}	*Apis anthophila* 1.83^{b}
DCH 3.08^{a}	*Polistes exclamans* 0.50^{d}	DCH 5.17^{a}	*Anoplocnemis curvipes* 1.17^{b}
DTR 3.15^{a}	*Anax imperator* 1.83^{bcd}	DTR 2.83^{a}	*Lucuster migratoria* 1.00^{b}
KRG 2.08^{a}	*Libellula quadrimaculata* 1.17^{d}	KRG 4.33^{a}	*Apis mellifera* 18.33^{a}
KZR 2.62^{a}	*Apis mellifera* 15.33^{a}	KZR 4.00^{a}	*Hycleus lugens* 1.50^{b}
PAG 2.46^{a}	*Apis anthophila* 1.17^{d}	PAG 4.00^{a}	*Polistes exclamans* 0.67^{b}
	Anoplocnemis curvipes 1.50^{cd}		
	Hycleus lugens 3.00^{b}		
	Colias hyale 1.50^{cd}		
	Pieris virgiensis 1.33^{d}		
	Pieris rapae 1.00^{d}		
	Pyronia cecilia 0.83^{d}		
	Danus plexippus 2.83^{abc}		
LSD 1.78	0.84	4.50	1.11
P-VALUE			
Sampling sites	0.77		0.954
Species sites/species	>0.05		>0.05

Keys: DCH=Dachia;AMS=Amshi;KZR=Kazir;KRG=Karage;PAG=Paga; DTR=Damaturu

DISCUSSION

The results indicate that the abundance and diversity of pollinators were higher in the rainy (wet) season than in the dry season. The high diversity could be due to the rain exhibiting different kinds of flowers of varying phenologies, attracting different or diverse insect pollinator visitors. The insect pollinators obtained during raining(wet) and dry season were from 7 orders of Orthoptera, Hemiptera, Odonata, Hymenoptera, Heteroptera, Coleoptera and Lepidoptera which belongs to 09 families; Acrididae, Vespidae, Aeshnidae, Libelluidae, Coreidae, Meloidae, Apidea, Nymphalidae and Pieridae*, and* 13 number of species *Lucuster migratoria, Polistes exclamans, Anax imperator, Libellula quadrimaculata, Apis mellifera, Apis anthophila, Anoplocnemis curvipes, Hycleus lugens, Colias hyale, Pieris virgiensis, Pieris rapae, Pyronia cecilia and Danaus plexippus.* Among the species, *Apis mellifera* was the most abundant (92 and 110) in the two seasons. *Polistes exclamans* is the least abundant, with 3 and 4 species abundance for rainy and dry seasons, respectively. There was no significant difference in insect distribution and diversity between sampling sites and species (P> 0.05) in both seasons. This may be as a result of *Apis mellifera* being highly attracted by the color of the flower and the pleasant smell, which has a significant impact on the attraction of pollinators. This is in line with the work of Muhammad *et al.* (2019), who reported that color significantly impacts the attraction of insect pollinators.

However, the study environments are characterized by trees such as *Ziziphus mauritiana, Piliostigma reticulatum, Piliostigma thonningi, Diospyros mespiliformis, Acacia sieberana, Tamarindus indica, and Guiera senegalensis,* among others, which are abundant in Amshi and Dachia; these trees are an essential habitat for *Apis mellifera* in the sampling sites. Also, the closeness of the two sampling sites (Amshi and Dachia) and the agricultural activities occurring there. During the dry season, the result shows Dachia (31) and Karage (26) have the highest abundance, while Damaturu (17) has the lowest. The abundance of insect pollinators in Dachia and Karage during the dry season shows that the large-scale irrigation farming system in the study sites provides foraging habitat and good environmental conditions for the insects to survive. This study is consistent with the findings of Adeduntan and Olusola (2013), who reported pollinators of Orthoptera, Lepidoptera, and Hymenoptera, but never found Hemiptera, Odonata, and Heteroptera in the study area. The species reported in this study is consistent with that of Adeduntan and Olusola (2013). Adelusi *et al.,* (2018) reported *Blattodea, Coleoptera, Dermaptera, Diptera, Hemiptera, Hymenoptera, Isoptera, Lepidoptera, Mantodea, Odonata, and Orthoptera* orders of the diversity and abundance of insects in Makurdi L.G.A of Benue State. These findings conform with the distribution of orders in the present study, and also additional orders, such as *Isoptera* and *Mantodea,* which are not pollinators, were reported in addition to the observed orders from the current study sites. These findings were also similar to the work of Wafubwa and Ndong'a (2019), who stated that the high abundance of pollinators witnessed during the wet season was most likely influenced by the high reproductive capacity and short developmental periods of most members of the Order Hymenoptera, which includes bees and ants. Besides, the butterflies swarmed during this period to feed, mate, and reproduce.

In the terrestrial environment, the honeybee is a particularly pertinent model for developing biomarkers to assess environmental contamination (Leita *et al.*, 2004). A field experiment was conducted on diversity of insect pollinators on Pigeon pea (*Cajanus cajan* L.), in Odisha" during Autumn, 2017-2018 at the Entomology block in Central Research Station of Orissa University of Agriculture and Technology, Bhubaneswar, Odisha by Padhy *et al.* 2018 the studies reveal that order Hymenoptera (Family Apidae with 45.5 %), was most dominant order. This study is also similar to research conducted by Naman *et al.*

(2019), who reported that Hymenoptera (20.83 %) was dominant, and the least ordered was Hemiptera, with 2.08 %. Siregar *et al.* (2016) found that Hymenoptera have the highest abundance (388 individuals, 31 species, nine genera, and three families). Fayyaz *et al.* (2016) in their study, Diversity and Relative Abundance of Insects (Arthropoda) in Pumpkin Plantations in District Haripur, Khyber Pakhtunkhwa, Pakistan, reported similar results in that order; Hymenoptera was the most diverse in terms of the highest number of families. Genus Apis represented family *Apidae, Bombus* represented Bombidae*,* while *Vespidae* was represented by *Polistes*. Alarape *et al.* (2015) researched Butterfly species diversity and abundance in the University of Ibadan Botanical Garden, finding that the family Pieridae has the highest percent of species and individuals (38 % and 57.9 % respectively). Insects are susceptible to changes in climatic factors such as rainfall, temperature, wind, humidity, and altitude (Khaliq *et al.,* 2014; Alarape *et al.,* 2015), as these affect their population dynamics, distribution, abundance, intensity, and feeding behavior (Naman *et al.,* 2019). Nwosu and Iwu (2011) reported that Hymenoptera (Apidae) was the dominant Order regarding individual species. This could result from several plant, ornamental, and seedling species, as well as because the Botanical Garden (BG) and Behind Females' Hostel (BFH) are protected areas with forest canopy. The present study is in contrast with the work of Yager *et al.* (2016); who reported Lepidoptera family of Nymphalidae as the dominant insect Order in Federal University of Agriculture, Makurdi Forestry Nursery, Benue State, Nigeria while Adeduntan and Olusola, (2013) recorded Orthoptera as the most dominated insect Order in different forest vegetation types in Ondo State. These differences can be attributed to the variation in environmental conditions, season of insect collection, and the presence of susceptible hosts within the study area. This is confirmed by the views of Khaliq *et al.* (2014), who reported that both abiotic (temperature, humidity, light) and biotic (host, vegetative biodiversity, crowding, and diets) factors significantly influence the insects and their population dynamics. The study also disagrees with the findings of Okrikata and Yusuf, (2017) in Wukari, Taraba State and Yager *et al.* (2016), in Federal University of Agriculture, Makurdi Forestry Nursery; Naman *et al.* (2019), in Kaduna State University Main Campus, Kaduna, Nigeria which reported that the Order Coleoptera, Lepidoptera and Odonata Order were the most dominant individual species respectively. This disparity might be attributed to differences in study location and other environmental factors. The abundance of particular species at any given point on a temporal scale depended again on abiotic and biotic environmental factors.

Conclusion

The present survey shows that seven orders, nine families, and thirteen species of insect pollinators were recorded. This indicates that the study sites are rich in insect Biodiversity. The studies also provide baseline information on the diversity of Insect Pollinators. However, the result showed that physical factors had a significant relationship with Butterfly families and species richness. Therefore, further research should be conducted using other Sampling techniques and expanding the study areas' geographical scope. The findings of our research are convincing. Thus, the information will assist all stakeholders to optimize the beneficial insects to make an informed decision, potentially leading to economic benefits.

Declarations:

Ethics Approval: This study has been granted approval by the Science, Technology and Environment Research Ethics Committee of Bayero University, Kano.
Authors Contributions: KMU did the conceptualization. YA and KMU contributed to the formal analysis. YA and KMU took part in the investigation. YA wrote the original draft. KMU did the writing review and approved the final manuscript. All authors have read and

approved the final manuscript.
Competing Interests: The authors have no competing interests to declare that are relevant to the content of this article.
Availability of Data and Materials: The entomological box containing samples of collected insects is available at the Department of Biological Sciences, Yobe State University, Damaturu.
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