Insect Populations in Heavy Metal Polluted Environment in Ibadan, Oyo State, Nigeria

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Abstract
Insects form a major part of the ecosystem and serve as tools for ecosystem management and conservation. Insect populations and fitness is however disturbed by environmental factors like heavy metal Pollution. Thus, the purpose of this research was to examine the populations of insects found in Ori-Ile village and its environs in Egbeda Local Government Area of Ibadan, Oyo State, Nigeria. Ori-Ile village which was formally a battery waste dumpsite, has been ascertained from previous studies, to contained heavy metals in its soil. Insects were collected using sweep net and handpicking methods forth nightly every month from the study area (Oril-Ile, Majue 1, Majue 2 and Ogunbade-Egberi) for 18 months, between April 2016 to September 2017. Insect specimens collected were identified using comparative morphology with preserved insect specimens at the Departmental Museum, Zoology Department, University of Ibadan and at the insect museum in the Department of crop protection and Environmental Biology, University of Ibadan. In all, 8,917 insects from 22 species and 6 orders were gathered from the study sites. The most prevalent category of insects, according to the results of the descriptive statistics used to analyse the data, were Hymenoptera (98.74%) > Lepidoptera (0.93%) > Orthoptera (0.18) > Odonata (0.07%) > Coleoptra (0.07) > Heteroptra (0.01). Majue 1 has the highest diversity index (Shanon's index (H) = 0.54) and richness index (Margalef's index (D) = 1.88). With an Evenness value (E = 0.13), Ogunbade-Egberi (the control site) had the highest evenness. According to the study, lepidopterans were the most varied and hymenopterans the most prevalent. In conclusion, this initial survey demonstrated that the research area has a high diversity and number of insects. Thus, this finding provides a basis for future investigation.

Keywords: Insect, Populations, Heavy Metal, Polluted Environment, Ibadan.

Introduction

With an astounding 75% to 80% of all known animal species, insects are the most varied group of animals on Earth [1]. There is continuous discussion over the number of insect species in the globe; estimates range from 10 to 30 million, of which 1.11–1.7 million have been briefly documented [2]. They are an important component of the ecosystem and are used as instruments for species conservation and ecosystem management. In the fields of biomechanics, climate change, developmental biology, ecology, evolution, genetics, paleolimnology, and physiology, insects have been employed in seminal research [3]. Insects support the stability and functionality of the ecosystem and can be found in a variety of settings [3]. According to reports, plants are home to around 30 million animal species, of which 14 million have been described, with 750,000 of those being insects. More than 75% of the known species diversity in the world is made up of insects and other invertebrates [4].

The life history, strategy, movement, seasonality, size, trophic level, and ecological requirements of insects vary greatly from one another [5]. Additionally, they are said to have made significant contributions to pollination, soil aeration, organic matter decomposition, and nutrient cycling in ecosystems [6]. According to reports, Insect sampling and monitoring are two crucial components of an Insects and Pest Management (IPM) program that increases knowledge of insect activity in a field or study site [7]. Despite being present almost everywhere; it is still unknown how common insects are in various terrestrial habitats. Despite the fact that insects play important economic roles in the ecosystem, many of them are falling and going extinct worldwide due to habitat fragmentation, degradation, bush burning, and overgrazing, according to [8]. Heavy metal pollution is one of the threats to insect biodiversity and fitness, especially in Ori-Ile village.

Heavy metals pollute the environment, bioaccumulate and adversely affect organisms including insects. High levels of toxic heavy metals occur in battery production industry wastes such as the non-operational dumpsite located at Ori-Ile Village, Olodo Community in Ibadan, Oyo State, South Western Nigeria. Interest in evaluating insect richness and variety in various habitats and ecosystems has grown as the significance of comprehending and protecting biodiversity has come to light. The bulk of research on insect composition and abundance, however, focusses mostly on one or two insect orders and/or families, as previously reported [9].

Heavy metal pollution in the soil can be harmful to living organisms by changing physiological activities and causing many genotoxic effects, disruption of reproductive potential and endocrine system [10], initiation of stress proteins and oxidative stress [11]. Ecosystem disruption is another major consequence of heavy metal contamination. Heavy metals affect the abundance and distribution of organisms, most especially insects [12]. Membrane damage, protein synthesis and photosynthesis have been affected by heavy metals in plants [13]. Similarly, heavy metals are known to have a deleterious effect on the fitness of insects [14]. Reduction in weight of insects has been associated with exposure to heavy metals [15]. This was evident as most of the insects (ants in particular) collected from the study area, showed obvious reduction in size.

The insect populations at the non-operational dumpsite in Ori-Ile Village, Olodo Community, Ibadan, Oyo State, South Western Nigeria, have not yet been documented in any literature. In order to give a preliminary inventory of the insect composition and abundance at Ori-Ile Village and its surroundings, this study was conducted. This will give future research on the ecology of insects in the region a baseline of data.

Materials and Methods

Description of Study Area

The research area is situated at latitudes 7°24'28.1"N, longitudes 4°00'52.2"E, and elevations of 176 meters. It is a semi-urban residential and agricultural area. It included a garbage disposal site northwest of Egbeda Local Government Area in Ibadan, Oyo State, near Ori-Ile village in Ikumapaiyi Area of Olodo community. Ori-Ile Waste Dumpsite is the common name for it. The study site is a sizable, barren area of roughly two hectares of land with no vegetation. The grasses, which included *Echinopogon ovatus* (hedgehog grass), *Muhlenbergia emersleyi* (bull grass) and *Panicum clandestinum* (corn grass), were the most prevalent type of vegetation on and near the trash dumpsite. Areas close to the study site had the highest concentration of *Panicum clandestinum*. June and September saw the highest levels of the region's bimodal rainfall pattern [8]. The location served as an unauthorised battery disposal site for the now-defunct West African Battery Industry, which manufactured the "Exide Battery" battery. Additionally, local and informal operators of Used Lead Acid Batteries used it as a site for informal lead recovery. The majority of the residents in the vicinity of the garbage dumpsite are peasant farmers and traders [16]. The study was conducted in four areas: Site A - Ori-Ile village (the main polluted site), Site B (Majue 1), Site C (Majue 2) and Site D (Ogungbade-Egberi village) - the control site, as shown in Figure 1.

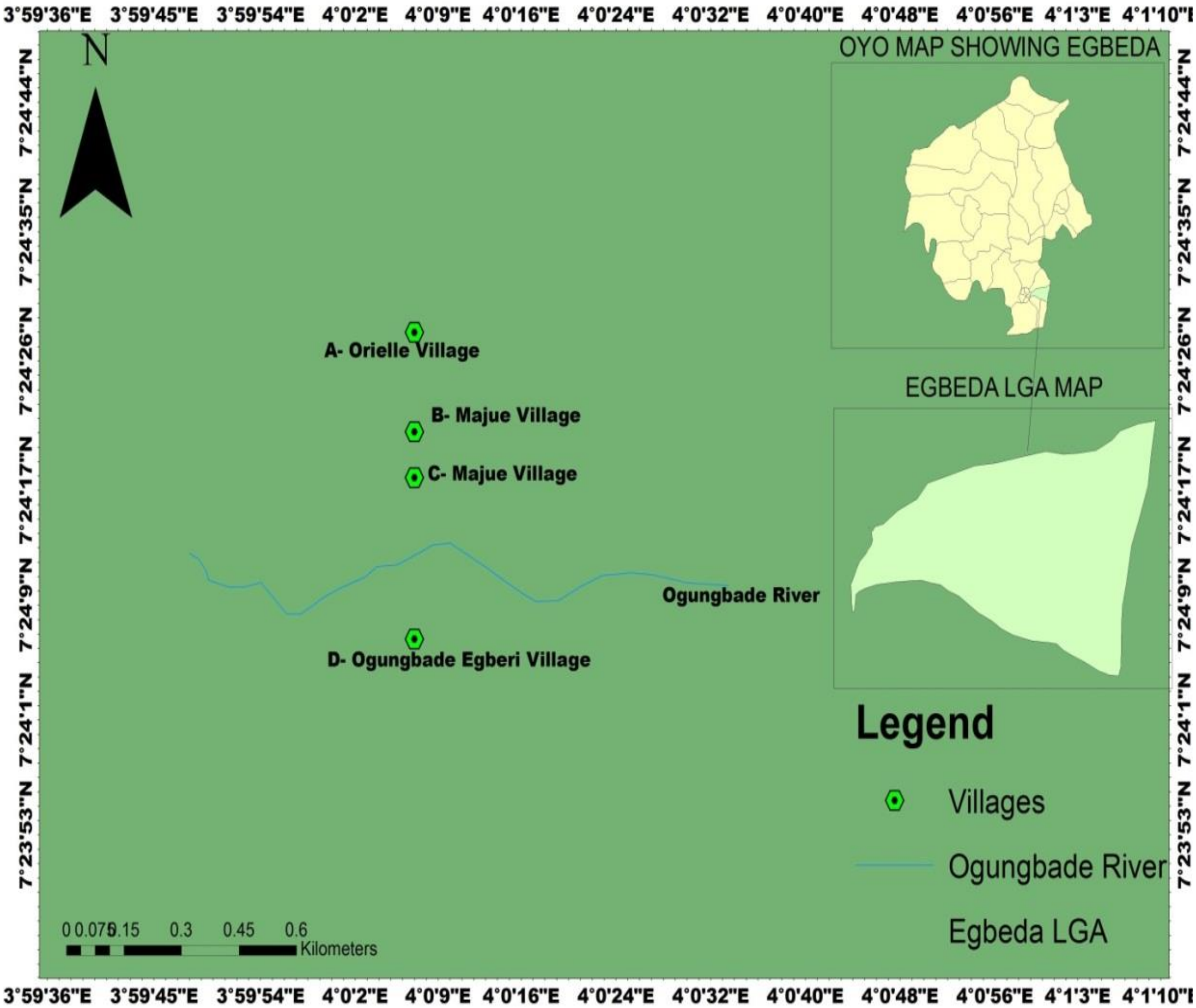

Fig. 1: Map of Oyo State and extracted Egbeda Local Government Area showing the sampling sites.

Insect Sampling

Insects were collected twice a month from the study areas for 18 months, between April 2016 to September 2017. The insects were collected using sweep net and handpicking, according to the methods described by Upton and Mantle [17].

Sweep net consists of a bag made of net. The bag is attached to a long wooden handle. The mouth of the net is about 40cm in diameter and its length is about 30cm. The mouth opening is supported by a metal ring which is then connected to the wooden handle (Plate 1). The sweep net is moved back and forth gently through the vegetation. The net is suitable for catching Butterflies, Moths, Beetles, Dragonflies and other flying insects.

The handpicking method involves capturing insects with the use of bare hands or with the aid of forceps. Some Grasshoppers and Beetles were caught using this method. The ants used for this research were caught using the hand picking method.

Plate 1: Locally fabricated sweep net

Processing of Insects Collected

Before conserving the insects gathered for the biodiversity study, a killing jar was created to kill them. Chloroform was added to a glass container filled with cotton wool to create the killing jar. After that, the cotton wool inside the glass container containing the trapped insects was covered tightly with a plain white sheet of paper. Because certain insects, like bees, might readily sting the collector, it was crucial to kill them before preserving them. Additionally, some insects, like butterflies, are simply able to fly away and escape, if not killed first. Pinning maintained the insect specimens after they were killed.

The insect specimens were placed on a stage and pins were then strapped perpendicularly via the thorax of the insect specimens, they were then left to dry.

Environmental Factors

Environmental factors measured in this study included temperature, Relative Humidity and rainfall. The monthly temperature and Relative Humidity at the point of insect collection were determined using Relative Humidity meter *in situ* (Plate 2), while rainfall data from April 2016 to September 2017 were obtained from the meteorological unit of the International Institute of Tropical Agriculture (IITA), Ibadan.

Data Analysis

Margalef's index was utilized to assess species richness of each of the study sites. Other indices of diversity were used to assess the distribution of insect species found in the study area. Shannon and Simpson diversity indices were used to estimate relative abundance within the study sites. Correlation coefficient by Pearson was used to determine the association of insect abundance and each of the environmental factors measured. Statistical analysis was performed using Graph pad software, with a significance level determined at $\alpha < 0.05$.

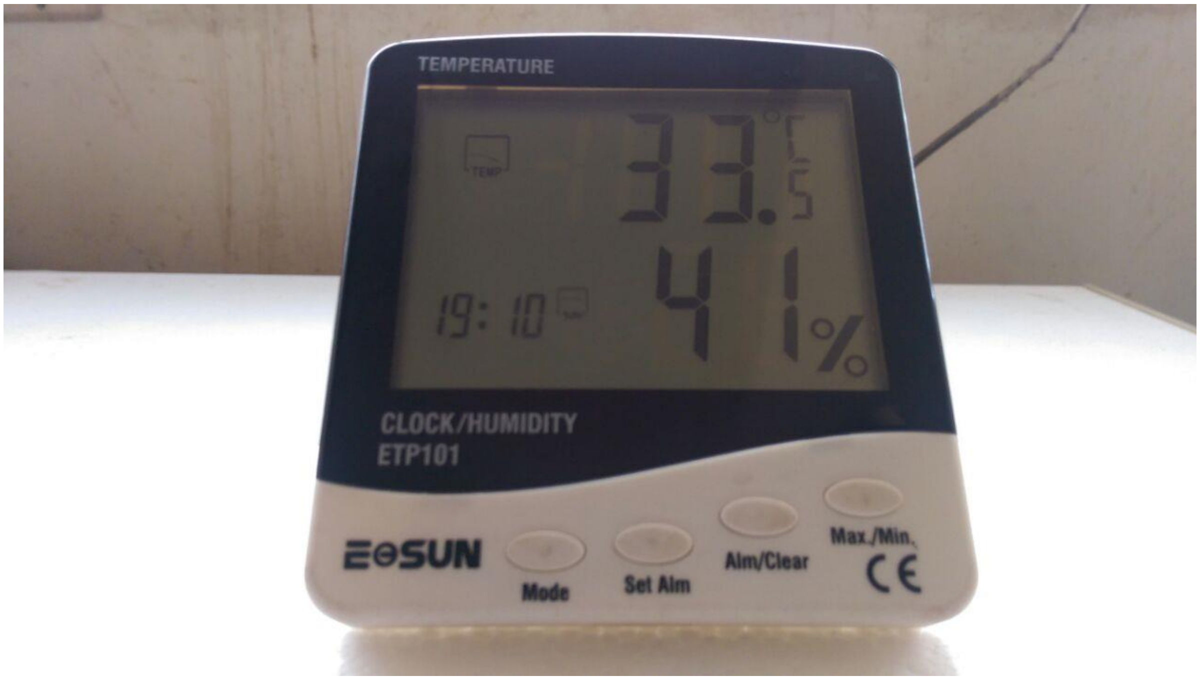

Plate 2: Relative humidity metre for temperature and humidity measurement

Results

Insect Populations Encountered in the Study

The populations of insects obtained in the course of the study are summarized in Table 1. Seven recognised orders were found from a sum of 8,917 insects. Site B, had fifteen (15) taxa, comprising of 1,694 individuals; site C, had twelve (12) taxa, made up of 1,850 individuals; site A, had ten (10) taxa, consisting of 3,303 individuals and site D, had eight (8) taxa, comprising of 2,070 individuals. In terms of species diversity, Majue site 1 is more diverse having 15 taxa, followed by Majue site 2, Ori-Ile and Ogunbade Egberi site having the least (8 taxa). In terms of species abundance, site A took the lead with a total of 3,303 individuals, followed by site D (2,070 individuals), site C (1,850 individuals) and site B having the least (1,694 individuals).

Order Hymenoptera, conspicuously represented by the group Formicidae. They were the predominant order of insects encountered in this study. Site A had a total relative abundance of 99.46%, followed by site D with 99.18%, site C with 98.70% and site B with 96.87%. The species *Camponotus herculeanus* and *Dorylus Rhogmus* were predominant. *Camponotus herculeanus* was found in all the sampled sites. *Dorylus Rhogmus* was present only in site B and site C. The species *Synagris calida* was found only in site C, *Belonogaster junceus* was found only in sites B and D.

Member of the order Lepidoptera were represented in the study areas as well, with 2.13% relative abundance in site B, followed by site C (1.01% relative abundance), site D with 0.68% and lastly site A with 0.51% relative abundance. The species *Catopsilia sp* and *Acraea Terpsichore*, were found in all the sampling sites. *Papilio demodecus* was present in site A and site C; *Acraea lycia* was found in site A and site B; *Belonis calypso* was present in sites A, B, and site C, but absent in site D, while *Colotis ione* was only found in site A.

Order Odonata were rarely abundant in the study, with 0.21% relative abundance in site C, followed by 0.05% in site D; 0.03% in site A and 0.00% in site B. Only three species were recorded in the sampling period. The species *Orthetrum brachiale* were found in site A and site C; *Palpopleura sp* was found only in site C, and *Parazyxama flavicans* were found only in site D.

Table 1: Comparative Richness and Distribution of Insects Encountered in the Study

ORDER **Species**	**Site A**		**Site B**		**Site C**		**Site D**	
	Number of Individuals	% RA	Number of Individuals	% RA	Number of Individuals	% RA	Number of Individuals	% RA
HYMENOPTERA								
Camponotus herculeanus	3,285	99.46	1,465	86.48	1,815	98.11	2,052	99.13
Dorylus Rhogmus	0	0.00	175	10.33	10	0.54	0	0.00
Synagris calida	0	0.00	0	0.00	1	0.05	0	0.00
Belonogaster junceus	0	0.00	1	0.06	0	0.00	1	0.05
LEPIDOPTERA								
Papilio demodecus	1	0.03	0	0.00	1	0.05	0	0.00
Catopsilia sp	5	0.15	19	1.12	13	0.70	6	0.29
Panlymnas alcippus	0	0.00	2	0.12	1	0.05	1	0.05
Precis oenone	0	0.00	2	0.12	2	0.11	1	0.05
Acraea Terpsichore	2	0.06	10	0.59	1	0.05	6	0.29
Belonis calypso	3	0.09	2	0.12	1	0.05	0	0.00
Colotis ione	2	0.06	0	0.00	0	0.00	0	0.00
Acraea lycia	1	0.03	1	0.06	0	0.00	0	0.00
ODONATA								
Orthetrum brachiale	1	0.03	0	0.00	1	0.05	0	0.00
Parazyxama flavicans	0	0.00	0	0.00	0	0.00	1	0.05
Palpopleura sp	0	0.00	0	0.00	3	0.16	0	0.00
ORTHOPTERA								
Acrida turrita	2	0.06	3	0.18	0	0.00	0	0.00
Atractomorpha sp	0	0.00	3	0.18	0	0.00	0	0.00
Trilophida conturbata	0	0.00	3	0.18	1	0.05	0	0.00
Chrysomiya sp	1	0.03	1	0.06	0	0.00	2	0.10
COLEOPTERA								
Aulacophora transversa	0	0.00	6	0.35	0	0.00	0	0.00
HETEROPTERA								
Cletomorpha lanciger	0	0.00	1	0.06	0	0.00	0	0.00
Total number of species collected	**3,303**		**1,694**		**1,850**		**2,070**	

***% RA implied Percentage Relative Abundance**

Order Orthoptera were also represented in the study, with 0.54% relative abundance in site B; 0.06% relative abundance in site A; 0.05% relative abundance in site C and 0.00% relative abundance in site D. Three different species were recorded; *Acrida turrita* were found in sites A and B; *Trilophida conturbata* were found in sites B and C; while *Atractomorpha sp* was found only in site B.

Order Diptera, Coleoptera and Heteroptera were all represented by one species each. Order Diptera was represented by the species *Chrysomiya sp*, present in sites A, B, and C, but absent in site D. Order Coleoptera was represented by the species *Aulacophora transversa*, found only in site B. Order Heteroptera was represented by the species *Cletomorpha lanciger*, present only in site B.

Figure 2 showed the chart representing the total number of insects recorded monthly from the sites, while figure 3 showed the total number of insects collected from each study sites. The largest number of insects was collected in September 2016 (741 individuals) while the least was obtained in April 2016 (122 individuals). The result also showed that the number of insects increases as we progress into the rainy season and begin to decrease as the dry season approaches.

Insect Richness and Diversity in the Study Locations

The abundance and diversity of insect species obtained in the study locations are illustrated in Table 2. Site B had the highest species richness with Margalef's index value of 1.88, followed by site C (1.46), site A (1.11) and lastly site D (0.92). Shannon's index (H) value was also highest in site B with the value 0.54, followed by site C (0.13), site D (0.06) and lastly site A, with Shannon's index (H) value of 0.04. Evenness's index value was highest in site D (0.13), followed by site B (0.11), and 0.10 and 0.09 for site A and site C respectively. The biodiversity indices value implied that site B had the highest species richness and diversity among the sampled sites. Species are relatively well distributed in site B and site D, compared to site A and site C.

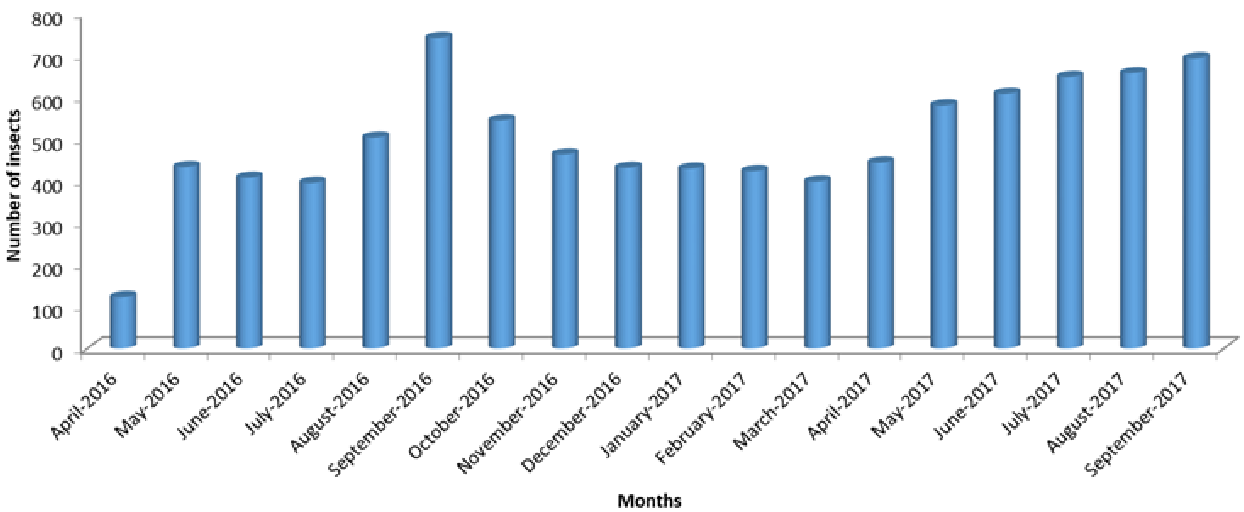

Fig. 2: Sites cumulative distribution of insects within study area.

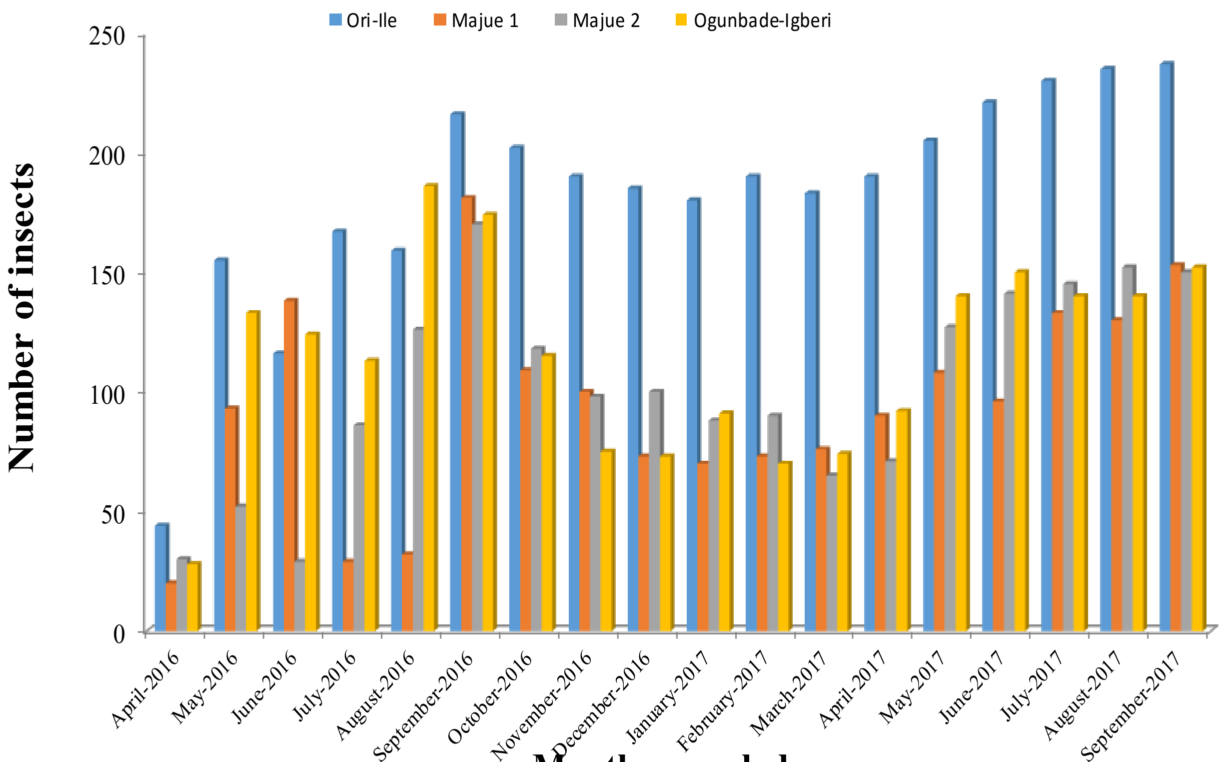

Fig. 3: Monthly distribution of insects observed from the four sampling sites.

Table 2: Insects' Richness and Diversity Indices in the Study Locations

Ecological Indices	Site A	Site B	Site C	Site D
Taxa_S	10	15	12	8
Individuals	3,303	1,694	1,850	2,070
Dominance	0.98	0.76	0.96	0.98
Simpson	0.01	0.24	0.04	0.02
Shannon	0.04	0.54	0.13	0.06
Evenness	0.10	0.11	0.09	0.13
Menhinick	0.17	0.36	0.28	0.18
Margalef	1.11	1.88	1.5	0.91
Equitability	0.02	0.19	0.05	0.03

Association between Insect Richness and Environmental Factors

The Pearson correlation coefficient between the monthly insect abundance and the average monthly temperature in the four sampling sites summarized in Figure 4a, 4b, 4c and 4d. A negative relationship (r = -0.16) between temperature and the number of insects collected was observed in site A. However, the relationship was not significant at $p<0.05$. Pearson correlation coefficient showed an inverse relationship (r = -0.34) between insect abundance and temperature in site B, but the relationship was not significant at $p<0.05$. There was negative relationship (r = -0.46) between temperature and the number of insects collected was observed in site C, but it was not significant at $p<0.05$. A negative relationship (r = -0.43) between temperature and the number of insects obtained was observed in site D. However, the correlation was not significant at $p<0.05$.

Pearson correlation coefficient between the monthly insect abundance and the average monthly relative humidity in the four study locations are illustrated in Figure 5a, 5b, 5c and 5d. A positive relationship (r = 0.12) between relative humidity and the number of insects collected was observed in site A. However, at $p<0.05$, the relationship was not significant. Pearson correlation coefficient showed a positive relationship (r = 0.42) between insect abundance and relative humidity in site B, however the relationship was not significant at $p<0.05$. A positive correlation (r = 0.35) between relative humidity and the number of insects collected was observed in site C, but was not significant at $p<0.05$. A positive relationship (r = 0.46) between relative humidity and the number of insects collected was also observed in site D. However, the correlation was not significant at $p<0.05$.

Pearson correlation coefficient between the monthly insect abundance and the average monthly rainfall across the four sampling sites is summarized in Figure 6a, 6b, 6c and 6d. A positive relationship (r = 0.06) between rainfall and the number of insects collected was observed in site A. However, the correlation was not significant at $p<0.05$. A positive correlation (r = 0.55) between rainfall and the number of insects collected was also observed in site B, and the relationship was significant at $p<0.05$. Pearson correlation coefficient also showed a positive relationship (r = 0.22) between insect abundance and rainfall in site C, but the relationship was not significant at $p<0.05$. A positive relationship (r = 0.53) between rainfall and the number of insects collected was equally observed in site D, and the correlation was significant at $p<0.05$.

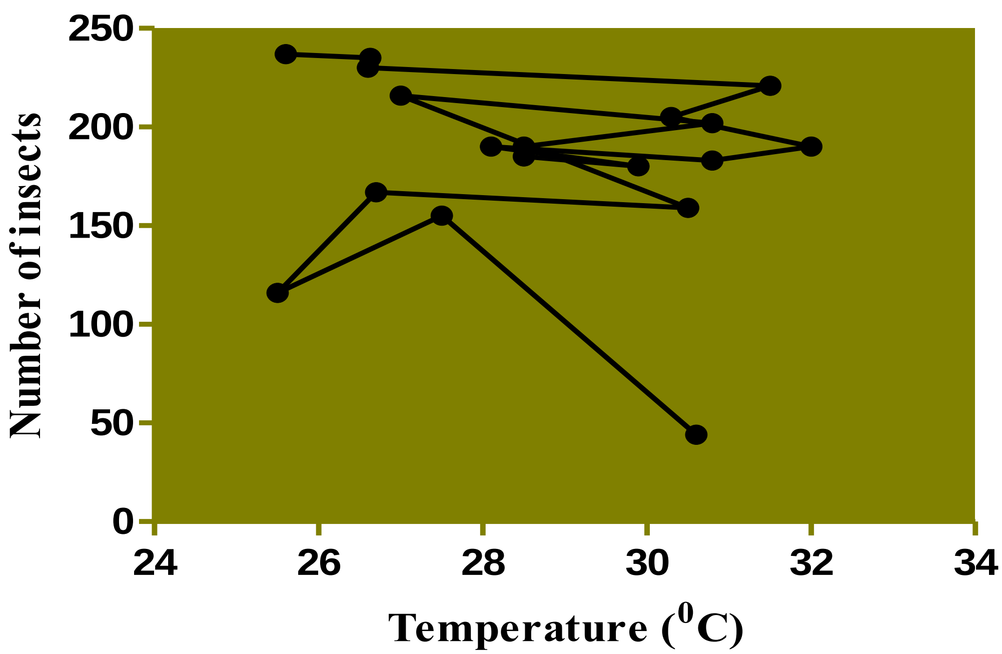

Fig. 4a: Association between insect abundance and temperature in site A.

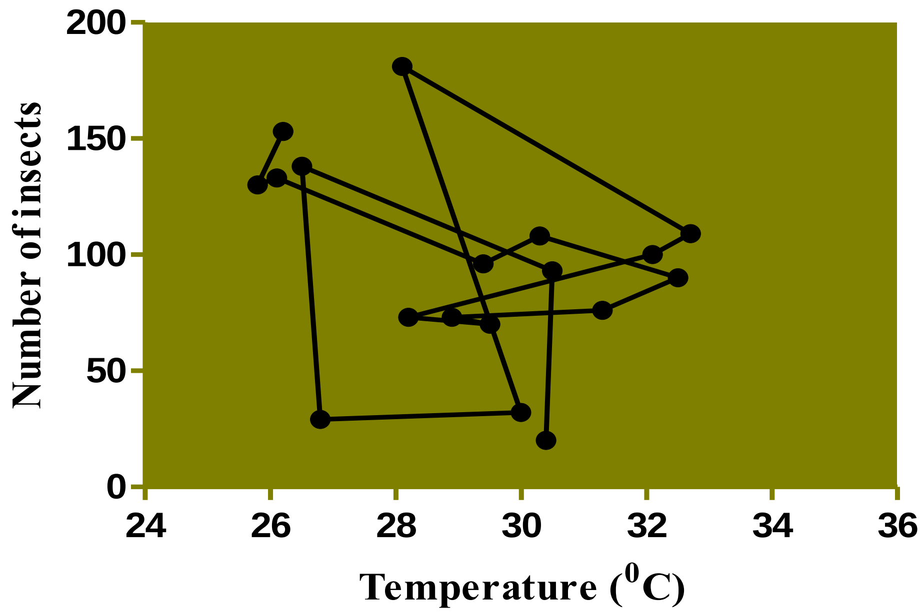

Fig. 4b: Association between insect abundance and temperature in site B.

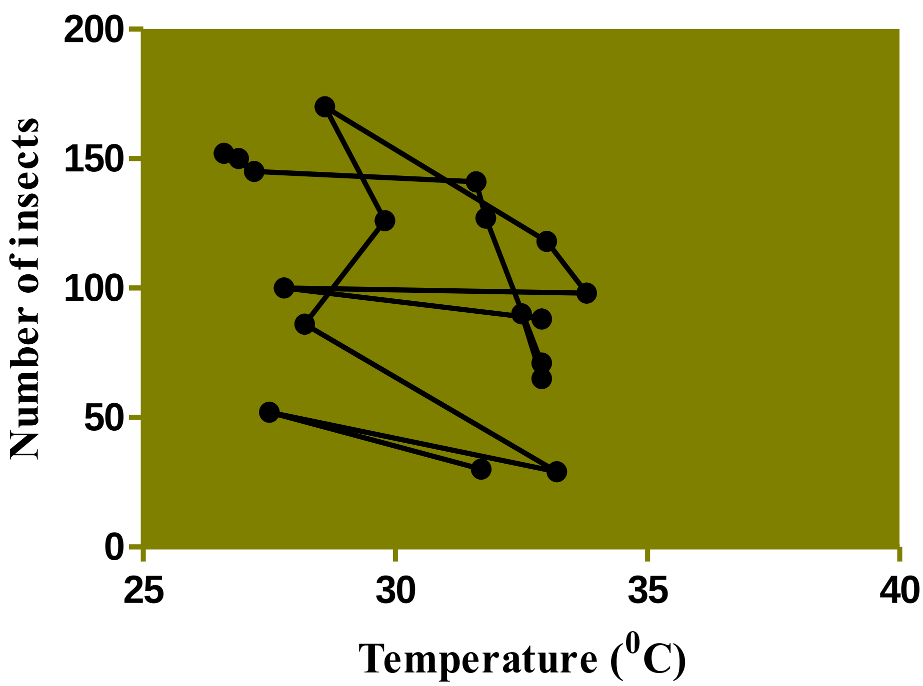

Fig. 4c: Association between insect abundance and temperature in site C.

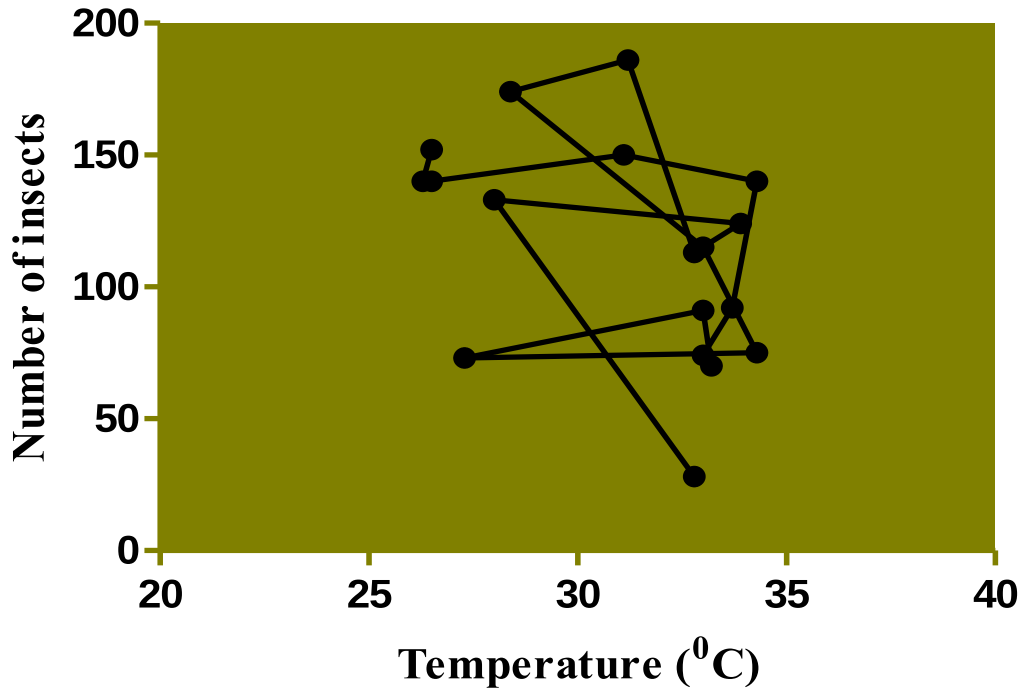

Fig. 4d: Association among insect abundance and temperature in site D.

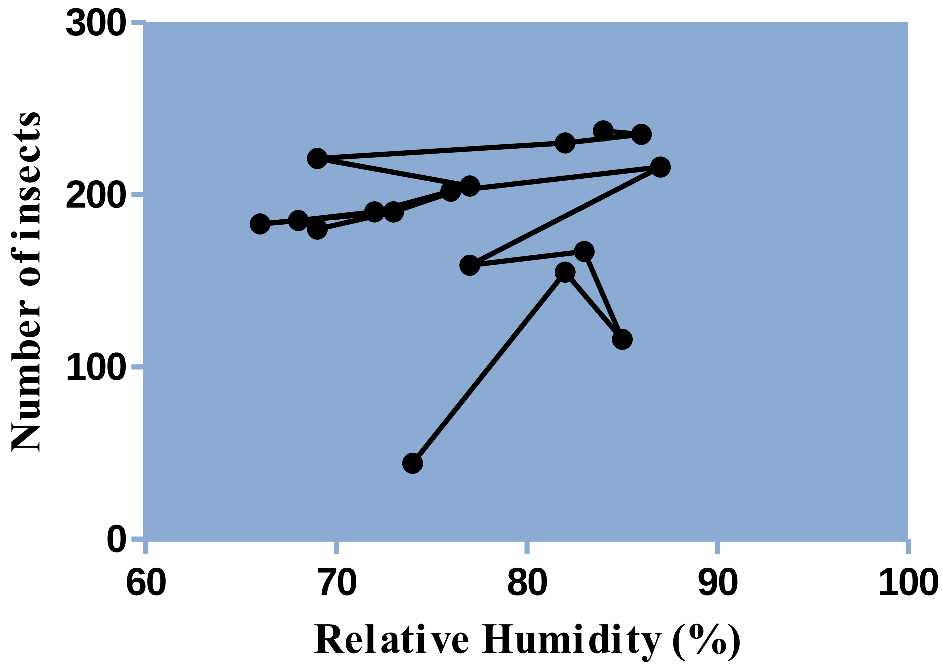

Fig. 5a: Relationship between insect richness and relative humidity in site A.

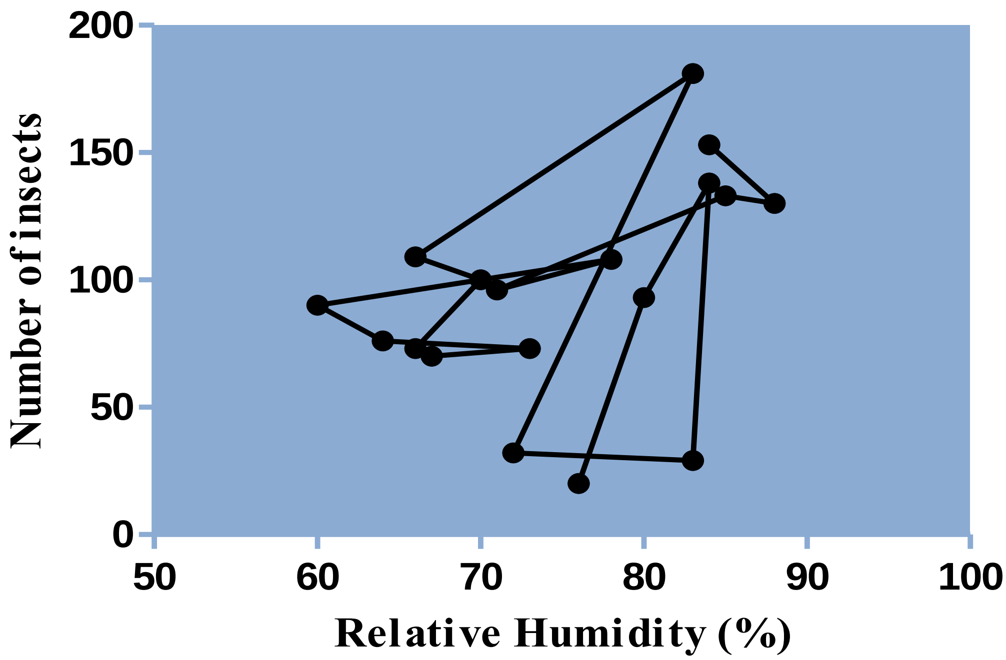

Fig. 5b: Association between insect richness and relative humidity in site B.

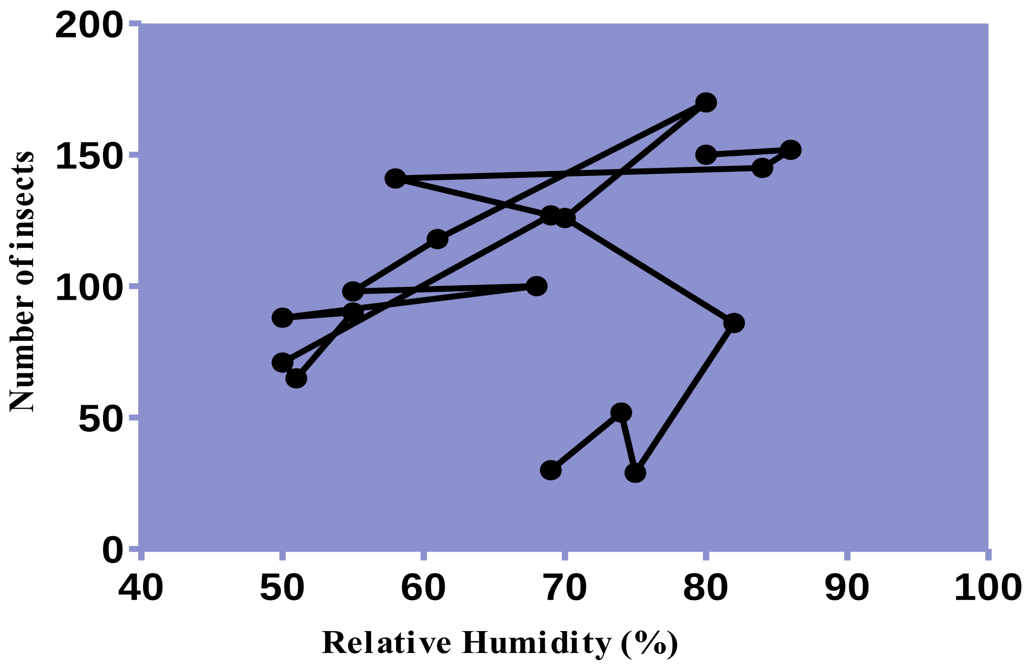

Fig. 5c: Association between insect abundance and relative humidity in site C.

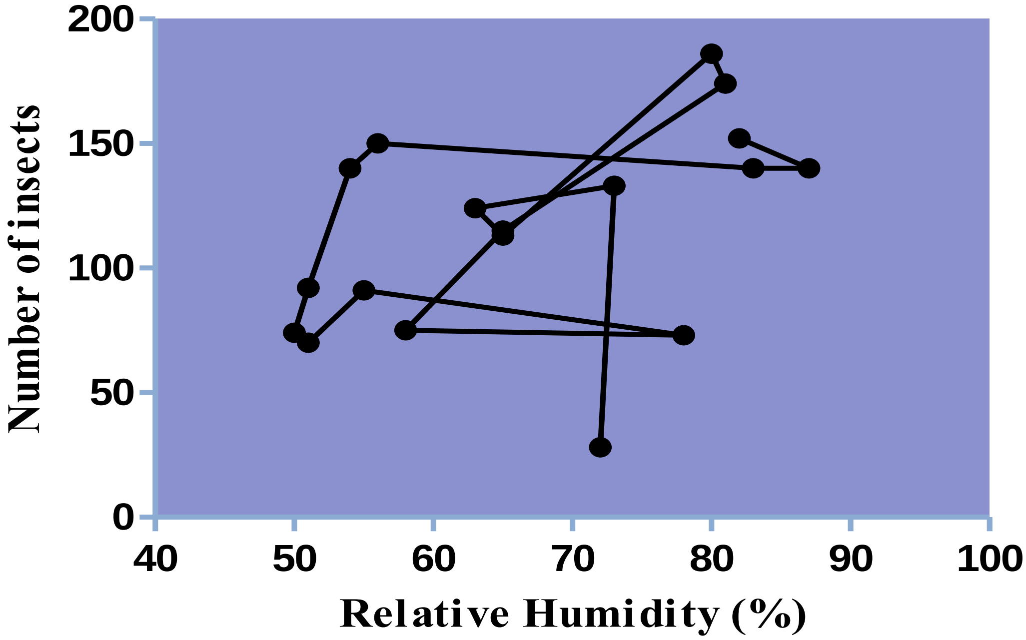

Fig. 5d: Association between insect abundance and relative humidity in site D.

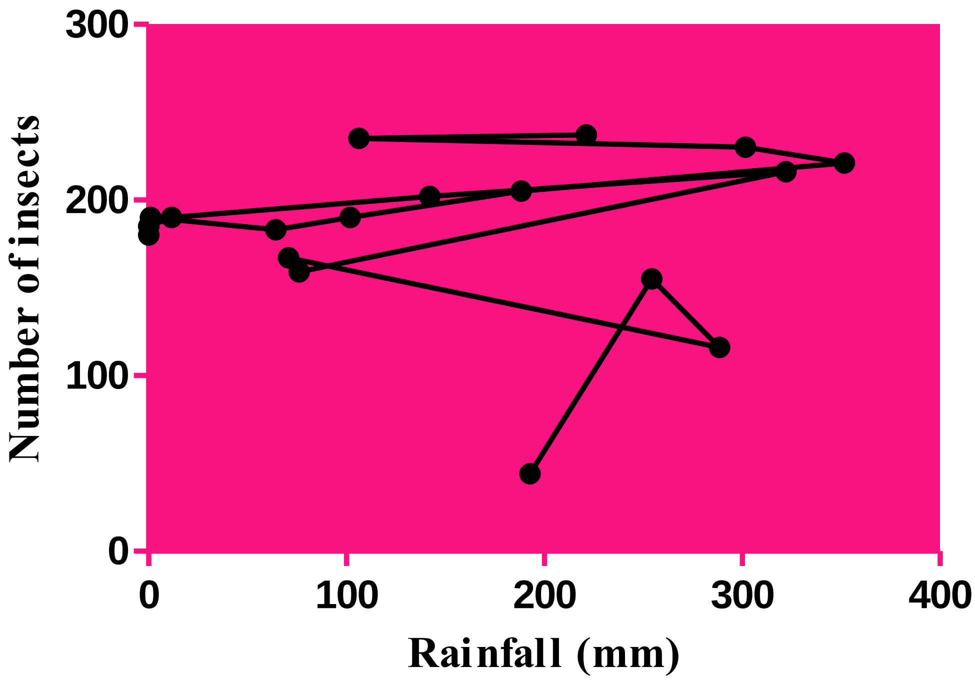

Fig. 6a: Correlation between insect abundance and rainfall in site A.

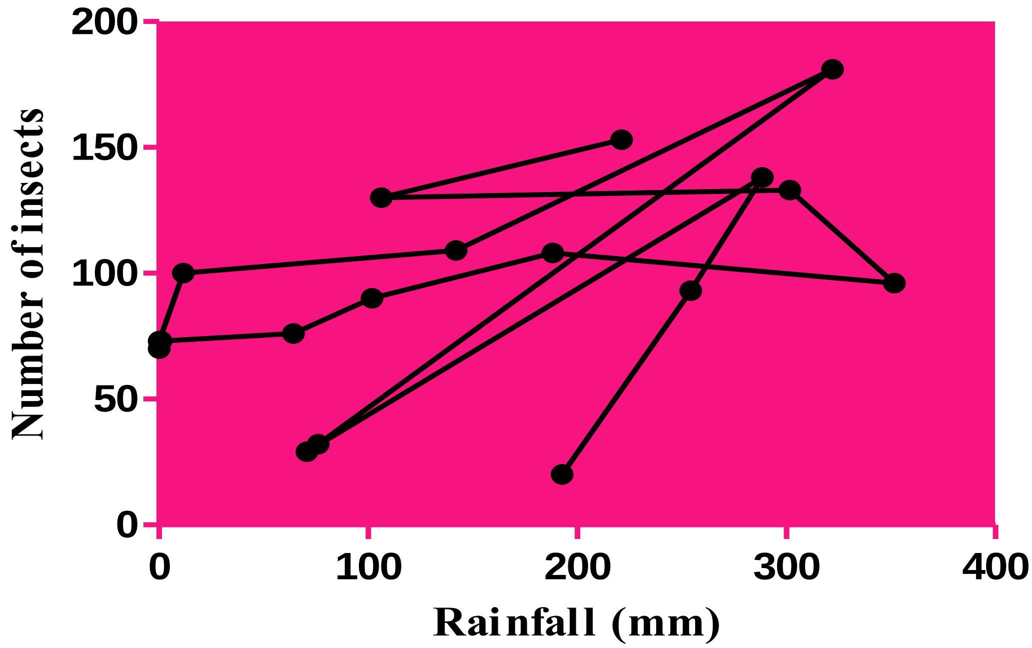

Fig. 6b: Correlation between insect abundance and rainfall in site B.

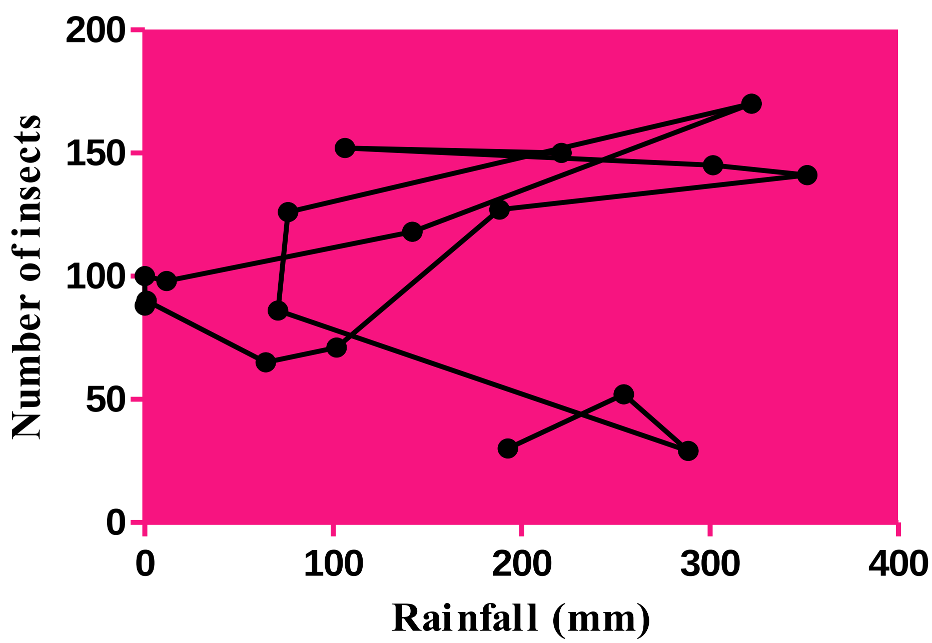

Fig. 6c: Correlation between insect abundance and rainfall in site C.

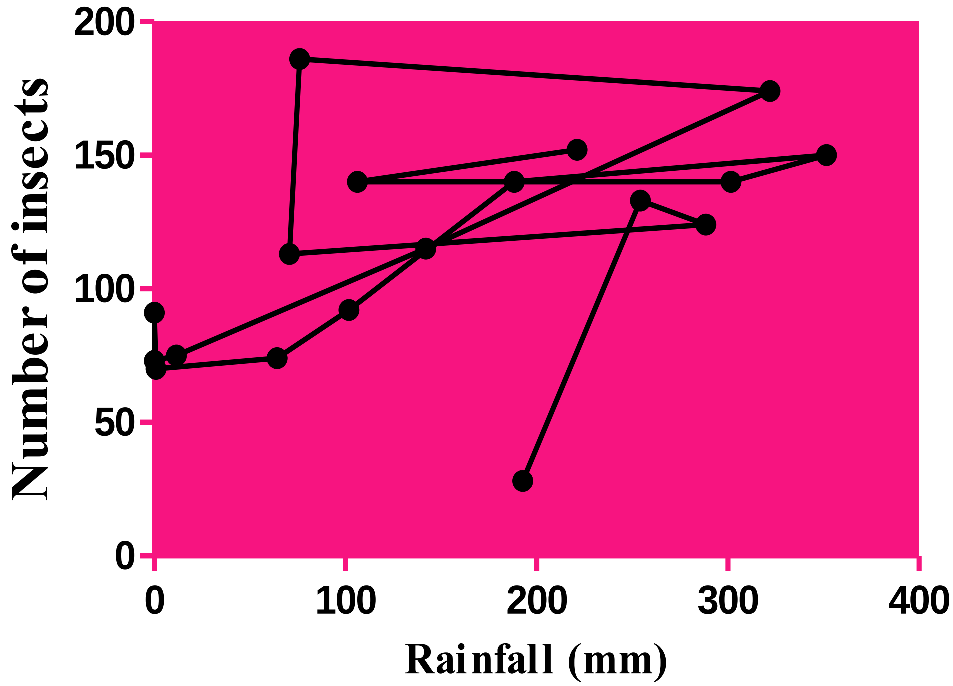

Fig. 6d: Correlation between insect abundance and rainfall in site D.

Discussion

Insects are the most dominant and abundant of all groups of arthropods. [18] stated that insects are more in number than all other terrestrial animals, and they occur virtually in all habitats. The extensive distribution and success of insects are due to their ability to fly, enabling them to escape from danger; their small size, which enables them to escape from enemies undetected. Their ability to eat a wide variety of food items, thus minimizing interspecific competition for food; their adaptability to virtually all habitats; their resistance to desiccation, due to the possession of chitinous exoskeleton; their possession of efficient nervous system with numerous sensory organs such as antennae, eyes and setae for detecting changes in their immediate environment and their production of resistant eggs which can be carried by air, water current and animals.

The diversity of insects in a given habitat is influenced by the flora cover of the area [18]. Agwe also stated that the diversity of plant forms provides a variety of food sources and diversity of microhabitats, which various animals may exploit. Order Hymenoptera was revealed by this research as the most abundant (Table 4.6). Within the Hymenopterans, the family Formicidae, (dominated by the species *Camponotus herculeanus* and *Oecophylus sp*) outnumbered all other insects collected in this research. It is possible that the high concentration of Hymenopterans obtained in this study might be due to food availability and habitat suitability. Hymenopterans, or ants, can survive in contaminated habitats despite the harmful effects of heavy metals for a number of reasons. Through a variety of strategies, including the synthesis of metallothionein, antioxidant defences, and genetic adaptation, ants can become resistant to heavy metals [19]. Furthermore, they can communicate, collaborate, and share resources thanks to their social organization, which can help them deal with environmental stressors like heavy metals. Ants' ability to adapt their nests can assist them lessen the consequences of heavy metal pollution, and their nesting practices can shield them from environmental stressors [20]. Ants can modify their food to prevent or reduce exposure to heavy metals because they are omnivores, according to [21]. [22] claimed that because ants have evolved in a variety of settings, including ones with high concentrations of heavy metals, they may have been selected for characteristics that allow them to withstand or withstand the toxicity of heavy metals. The ant species *Lasius niger*, according to a study by [23], may accumulate significant levels of heavy metals in their bodies while still sustaining the growth and reproduction of their colony. Ants can adjust to heavy metal pollution by altering their physiology and behaviour, according to a different study on the *Pheidole megacephala* ant species [24].

The results of this research showed that all the sampling sites in the study have the ability to support insect biomass. Climatic and weather changes affect insect status, population dynamics, distribution, abundance, intensity and feeding behavior [25]. Environmental disturbances particularly temperature, affects insect multiplication, diapauses, emergence, flight and the dispersal rate [26]. Both high and low temperature plays a key role in insects growth, development and distribution [27]. Insects are cold-blooded animals, meaning that the temperature of their bodies is relatively the same as that of the environment. Therefore, temperature is probably the single most important environmental factor influencing insect behavior, distribution, development, survival, and reproduction.

High and low temperatures have a resultant consequence on the physiology and behaviour of many insects [28]. It can alter the internal system and cause dehydration of the cells. In scientific literature, considerable research has been made to check the physiological behavioural response of insects against abiotic factors [29].

The findings of this research showed that a negative relationship exists between insect abundance and temperature in all the sampling sites (although not significant at $p<0.05$). The implication is that as temperature increases, insect population tends to decrease and vice versa. [30], stated that at higher temperatures, aphids have been shown to be less responsive to the aphid alarm pheromone they release when under attack by insect predators and parasitoids – resulting in the potential for greater predation. Rise in temperature is usually observed during the dry season when farmers don't normally grow crops.

The findings of this research highlighted a positive correlation between insect abundance and rainfall; and also a positive relationship between insect abundance and relative humidity. This result is similar to the observation of [31] who also discovered a progressive association between insect species richness and precipitation. The reproduction, growth and development of insects can be enhanced through the availability of water.

Conclusion

Insects form a major part of the ecosystem and serve as tools for ecosystem management and species conservation. They also form important link in food chains and can serve as bioindicators of heavy metals. Insect populations and fitness is however disturbed by environmental factors like heavy metal Pollution. The current investigation has demonstrated that the insect populations in the studied area are abundant and varied. The checklist of insects found in Ori-Ile hamlet, which was formerly a battery waste dumpsite, has also been made available for the first time. This will help all stakeholders maximise the utilisation of beneficial insects while regulating noxious species and provide baseline data for future research at the study location. This preliminary study has revealed that the dominant group of insect populations found are the Hymenopterans (ants). It is therefore recommended that further studies on this area should focus on heavy metal bioaccumulation in ants and their mechanism of survival in the polluted environment.

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