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Article

An Assessment of Insect Fauna on Staminate and Pistillate Flowers of *Cocos nucifera*: A Case of Asebu in the Central Region of Ghana

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Abstract: Quantitatively, this study aimed to determine the abundance and diversity of the insect fauna that visits the staminate and pistillate flowers of *Cocos nucifera.* The study was conducted at an experimental plantation belonging to the Coconut Research Programme (CRP) of the Oil Palm Research Institute (OPRI) of the Council for Scientific and Industrial Research (CSIR), to provide diagnostic support for the Cape St. Paul Wilt Disease (CSPWD) at Asebu in the Central Region of Ghana. The populations of coconut palms represented the dwarf type with few tall ecotypes. Five Insects were randomly chosen with newly opened inflorescences. Observations and collections of insect visitors to coconut flowers were made once a week on 30 newly opened inflorescences, five from each batch within the plantation. Specimens of the data were deposited in the official insect collection and processed at the laboratory of the Entomology Museum of the Department of Conservation Biology and Entomology, University of Cape Coast, Ghana. The study indicated that 9 different species of insects were identified to be the true fauna that visited the staminate and pistillate flowers of *C. nucifera Ethiosciapus sp., Sarcophaga sp., Scolia dubia, Lucilia sp., Ornidia sp., Apis melifera, Dactylurina standingeri,* Red Ant and Black Ant. These insects were observed in all the six batches considered and were available at all times of the day. Most of the insects were observed in the early morning from 6 am - 9 am followed by the evening 4 pm –7 pm. The abundance of insect visitors was low during the mid-day (11 a.m. to 3 p.m.) in all six batches during high temperatures. The results of this study revealed that there were abundances of *Ethioscipus sp.* was the least abundant in all the batches followed by *Scolia dubia* then *Sarcophaga sp.* Red Ants had the highest abundance in most of the Batches thus becoming the most abundant insect that forage the coconut inflorescence at the Asebu plantation. The bees, *Apis melifera* and *Dactylurina standingeri* were the most abundant species after the Red Ants. All these groups of insects were not considered in the study and it is recommended that further studies consider such visitors to observe which insects are doing what on the inflorescence. The range for the 'time of day for' of the study was mostly diurnal (morning 6 am-9 am, afternoon 11 am-2 pm and evening 4 pm7 pm). There was no observation made of the pollination system or activities of these insect visitors nocturnally. There may be high pollination activities of these insects during the late evenings. It is recommended that future work should incorporate the late evening period to observe an abundance of diurnal insect visitors of the coconut inflorescences.

Keywords: Insect, Fauna, Staminate, Pistillate Flowers, *Cocos nucifera*

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1. Introduction

One of the most important crops throughout the tropics is coconut palm (*Cocus nucifera* L. (*Arecaceae*) [1]. Domestication of *C. nucifera* probably started from Southeast Asia and then to Malaysia and Melanesia [2]. *C. nucifera,* being a tropical tree species was once the first major estate crop in Southeast Asia, which extended over large uniform areas and is now mainly grown and harvested by small farmers. Originally from the shoreline of uninhabited oceanic islands to the mountain ranges foothills and inland locations on the desert fringes, it can provide local markets and international trade, every necessity for the survival of castaways and subsistence consumption [3]. *C. nucifera* is used in the production of vegetable oil for industrial uses, from cosmetics and explosives to bio-fuels and health and wellness products. It is also a fibre crop, a food and beverage crop, and a visual amenity palm for tourist hotels, golf courses city parks and village gardens throughout the tropics [3]. *Cocos nucifera* is the only species recognized in the genus *Cocos* and also the most well-known member of the palm family Arecaceae [4]. It is in the subfamily Cocoideae, genus *Cocos*, and species *nucifera* (Chan and [5]. The description of the shape of the coconut fruit by early Spanish explorers coined the name coconut palm (*Cocos nucifera*). The coconut is usually classified into the 'Tall' and the 'Dwarf' varieties with the 'Tall' variety being the most common. As the name suggests the 'Dwarf" variety is generally shorter in stature, has a thinner stem and fruit earlier with smaller fruits than the 'Tall' varieties [6].

The introduction of the coconut palm to Ghana occurred about 500 years ago when the Portuguese brought the coconut to the Atlantic coast of Africa [4]. After World War I, stimulation for the coconut markets came from both African and European interests. Thus, large communal coconut plantations were established along the coast, in Ghana [7]. By 1936, there were at least 5,693.4 hectares (14,076 acres) of coconut plantations in southern Volta as well as the Eastern, Central, and Western regions, totalling over 1.3 million individual coconut palms [8]. The coconut palm was important along the coastal region due to its contribution to trade routes but was not immediately commercialized [8]. *Cocos nucifera* can be found along the entire coast of Ghana though they are less common in the driest parts of the coastal savannah. If the coconuts had been left to disperse on their own, the coast would be the only place they would be found [8]. Environmental conditions in Ghana are highly conducive to the growth and development of coconut palms. But humans have aided the dispersal so much that coconuts can be found at any location that meets the silvicultural requirements in Ghana [9]. This has effectually extended the range of coconuts north to approximately 8° N latitude, with a thinning amount of the density of the coconuts as you move north in the distribution [9]. There is therefore a density decrease of coconut as one moves from east and north with only solitary coconut palms perhaps one per village, at the extremes of the range. The climatic condition in the Western Region is best suited to coconut production [9]. In many coconut plantations, some coconut palms can produce more fruits while others produce fewer fruits, implying a deficit in coconut yield. Some factors account for this yield deficit as much is not known about the coconut fruiting and pollination ecology of insect visitors of coconut flowers. This study aimed to determine the abundance and diversity of the insect fauna that visits the staminate and pistillate flowers of *C. nucifera.*

1.1. The Inflorescence and Flower

Coconut inflorescences are formed in the axils of every leaf of a bearing tree and a very prolific tress will produce twelve or more inflorescences per annum or approximately one per month [10]. As the flower appears in the axils of leaves, it is noteworthy that the leaves are arranged on the stem in the form of a spiral so that every sixth leaf opens, nearly above the first one ([10]. The inflorescences first appear enclosed in a thick, fibrous sheath called the spathe which is again protected during its early life by

one more yellow sheath of a somewhat flat nature and of softer fibres ([10]. In the course of time when the spathe is fully grown, the development and distension of the inflorescence within causes great pressure on the walls of the spathe with the result that ruptures longitudinally along a groove usually on its ventral side and the flowering branch eventually emerges [11]. The rupturing of the spathe sometimes takes place on its dorsal side but then the spadix turns round till the inflorescence within falls out [11]. It is at first yellowish-white in colour within the spadix but later turns greenish and also more inclined downwards from its vertical position [12].

The coconut inflorescence consists of many flower-bearing ramification or spikelets situated on a fleshy peduncle; hence the inflorescence is termed a spadix. The size of the inflorescence varies from 2.5-6.0 feet in length from the tip to the base, depending on the variety of the palm [13]. A coconut palm mostly takes between 3-7 years to flower, but some varieties, usually 'Dwarfs', fruit as fast as 3 years [6, 14]. In ideal conditions, a healthy palm produces a new inflorescence, or spadix, with each new frond. With healthy palms, 40-60 coconuts per spadix are produced per year with an average of 50-80 coconuts [4, 6-15]. As the spadix matures, a woody sheath that splits open and peals back is produced. There are 0-3 female flowers at the base and several hundred male flowers above the female flowers for every 40-60 spikelets on the spadix. A single female flower develops into a mature fruit [6]. The male and female flowers mature at different times, to facilitate cross-pollination; however, self-pollination is possible with little or no complications [4, 6]. Conditions necessary for spadix maturity occur years before it emerges, and in mature spadix, after 1-2.5 years, adverse growth conditions will manifest [4, 6].

2. Materials and Methods

The study was done in an experimental plantation belonging to the Coconut Research Programme (CRP) of the Oil Palm Research Institute (OPRI) of the Council for Scientific and Industrial Research (CSIR), to provide diagnostic support for the Cape St. Paul Wilt Disease (CSPWD) at Asebu in the Central Region of Ghana. The populations of coconut palms represented the dwarf type with few tall ecotypes.

2.1. Preliminary Visit to the Field

An initial visit was paid to the field in June 2014 (Figures 1& 2) to see the plot layout and to be informed on how the work should be designed. The field had the dwarf coconut type planted in rows of eighteen (18) and each row consisted of twenty-five (25) palms. It was established that the field is made up of 450 coconut palms (Figures 1, 2 &3) mainly of different varieties of the Dwarf ecotypes with few Tall ecotypes. During this preliminary visit, observation and collection of insect visitors of *C. nucifera's* inflorescences were made. This was necessary because once the insects were collected they were sent to the laboratory for identification and pinning in order to make subsequent identification for abundances on the inflorescences easier.

Figure 1. Rainy season in June, 2014 when preliminary visit was made to the Asebu plantation many insects were observed collecting pollen.

Figure 2. With the Coordinator and the Entomologist of the Coconut Research Programme (CRP) part of Oil Palm Research Institute (OPRI) of CSIR explaining the varieties of the Dwarf and the layout of the field.

Figure 3. Showing some of the *Lucilia sp* observed on the inflorescence on the day of the preliminary visit.

2.2. Plot design

The 450 palms on the field in 18 rows each containing 25 palms was divided into 6 batches with each batch containing 25 palms. These palms are planted in 8.5 m apart and are basically the dwarf types. Three rows of the palms at the four sides of the field making a total of 246 palms were used as boundary or boarders and as such were not included in the 6 batches. Three rows each of eight or nine palms were selected as a batch and another three rows each of eight or nine palms by the side of the other batch. The batches were separated by a row of palms were sounded by three rows boarders or boundaries. This arrangement resulted in three plot arranged in a line with another line of three batches behind them as seen in Figure 4.

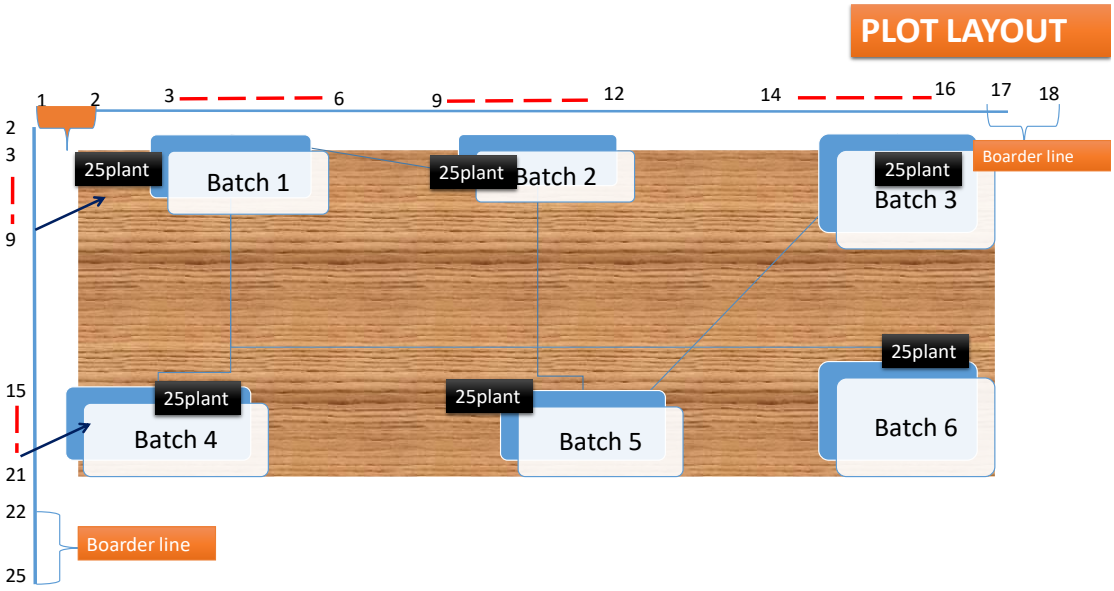

Figure 4. Showing the plot design of the six bathes of 25 palms each and boundaries etc.

2.3. Insect collection

Between July and December 2014, observations and collections of insect visitors to coconut flowers were made once a week on 30 newly opened inflorescences, five from each batch within the plantation. Insects on five randomly chosen newly opened inflorescences from each batch were observed from morning (6.00hours to 9.00hours), afternoon (11.00hours to 13.00 hours) and evening (15.00 hours to 18.00 hours) which includes the period of maximum insect activity at coconut flowers at most 4min on an inflorescence each for insects activities on the palm [16]. The numbers of different species of insects that have been identified already in the preliminary visit moving from an inflorescence of a palm to another were recorded. Insects were collected with nets, and glass tubes, killed and kept in plastic vials in 70% ethanol for identification and pollen analyses (Figures 5 and 6). Specimens were deposited in the official insect collection (Entomology Museum of Department of Entomology and Wildlife, University of Cape Coast, Ghana). The glass tubes were used for those insects that were difficult to capture using the sweep net. In this case, the glass tube is steadily brought near to the insect and suddenly covers the insect as the hand is used to seal off the opening as the content is gradually lowered into the killing bottle.

These insects collected were classified as morphospecies for further quantitative analyses [17]. Climatological data (temperature and relative humidity) were collected every time the number of insect visitors on inflorescence was taken together with wind speed in Kestrel 2000 anemometer, Figure 7 and time of day from Forestry Suppliers, Inc., Jackson, MS, Catalogue 2001.

Figure 5. Showing the glass tubes as used in collecting insects that were difficult to capture using the sweeping net.

Figure 6. Using the Sweep net in collecting insects from the coconut inflorescence

Figure 7. Using the Kestrel 2000 Anemometer to take readings of temperature, relative humidity and wind speed at the plantation.

2.4. Lab work

All the insects collected in the work, both from the preliminary work and the main work were brought to the lab contained in 70% ethanol after killing them in soapy water. This usually happened when the insects' collected and killed in soapy water was not sent to the lab the day of collection. These insects were first washed to get rid of any debris and the legs, antennae, wings and head is then stretched out to dry with all parts visible before they are finally pinned as demonstrated by Figures 8,9, and 10 below.

Figure 8. Preparing insects collected for pinning at the Entomology Museum, Dept. Of Conservation Biology and Entomology UCC.

Figure 9. Washing insects with tap water to get rid of the ethanol and some debris at the Dept. Of Conservation Biology and Entomology UCC.

Figure 10. Showing the processes involved in pinning a specimen at the Entomology Museum, Dept. Of Conservation Biology and Entomology UCC.

3. Results

This section presents results on the abundance and diversity of the insect fauna that visits the staminate and pistillate flowers of *C. nucifera.* There are different species of insect visitors of the inflorescence of coconut palm, *Cocos nucifera* at the Asebu plantation of the central region. Species that were found in almost all the Batches during the experimental period were *Apis mellifera, Ethioscipus sp., Sarcophaga sp., Dactylurina standingeri, Lucilia sp.,* Red ants and Black ants. The abundances of the insect visitors of the palm were observed under low and high temperatures, time of the day (morning, afternoon and evening), wind speed and different relative humidity on their foraging behaviours. The effects of their pollination system on the fruit set of the *C. nucifera* at the plantation were also observed and recorded. The results obtained from the various treatments are reported in Figures 1-10.

3.1. Species Richness

The species Richness (S) of insects that foraged on *C. nucifera* was found to be 9. In other words, 9 different species of insects were identified to be the true fauna that visited the staminate and pistillate flowers of *C. nucifera.* These were *Apis mellifera, Ethioscipus sp., Spheridae* digger wasp, *Musca sp., Sarcophaga sp., Ornidia sp., Dactylurina standingeri, Lucilia sp.,* Red ants and Black ants.

3.2. Species Diversity

Shannon-Weiner diversity index was computed with the aid of Microsoft Excel for each of the 6 batches of the plantation (Table 1). The relative abundances were then computed and presented in Pie charts.

Table 1. Diversity indices of insect fauna on Six Batches of *C. nucifera* farms

Diversity Indices	Batches of Farm					
	1	2	3	4	5	6
Richness $S = {}^{0}D$:	9.00	9.00	9.00	9.00	9.00	9.00
Shannon Entropy $H' = \ln({}^{1}D)$:	1.908	1.987	1.967	1.988	1.926	1.908
Shannon'sequitability.$H'/H_{max(\%)}$	86.8	90.4	89.5	90.5	87.7	86.8

3.3. Proportional Abundances

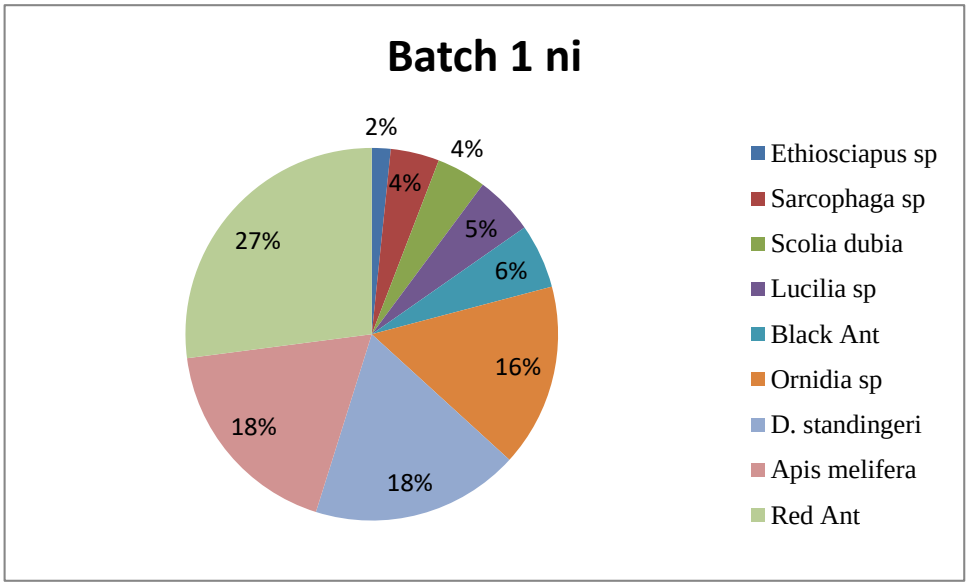

Figure 11. Proportional abundances and distribution of insect fauna on *C. nucifera* from Batch 1

Red Ant was highly distributed in Batch 1 with 27% abundance as compared to *Ethiosciapus sp*. with the lowest distribution or abundance of 2%.

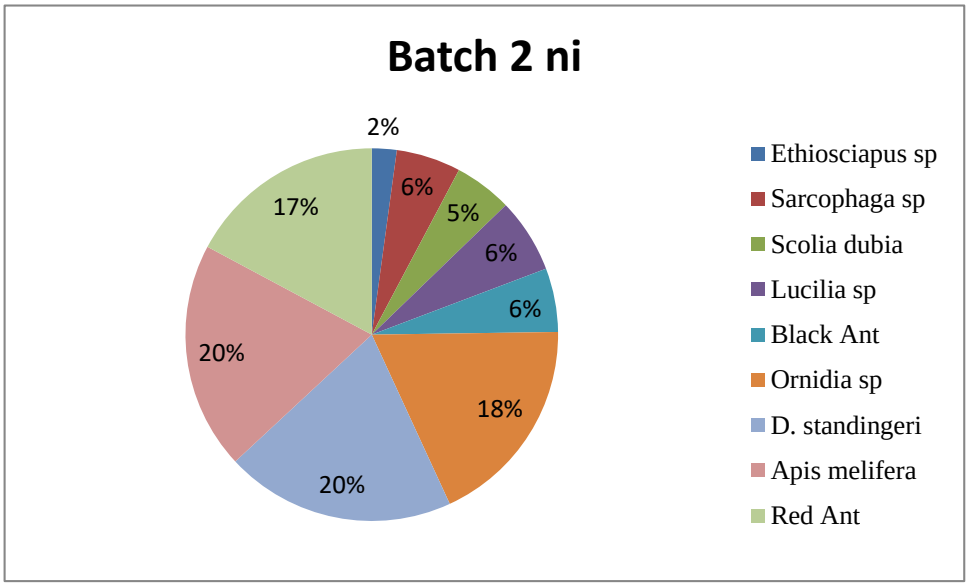

Figure 12. Proportional abundances and distribution of insect fauna from Batch 2

In Batch 2, *Dactylurina standingeri* and *Apis melifera* are with higher abundances of 20% each whilst *Ethiosciapus sp.* with the least abundance of 2%.

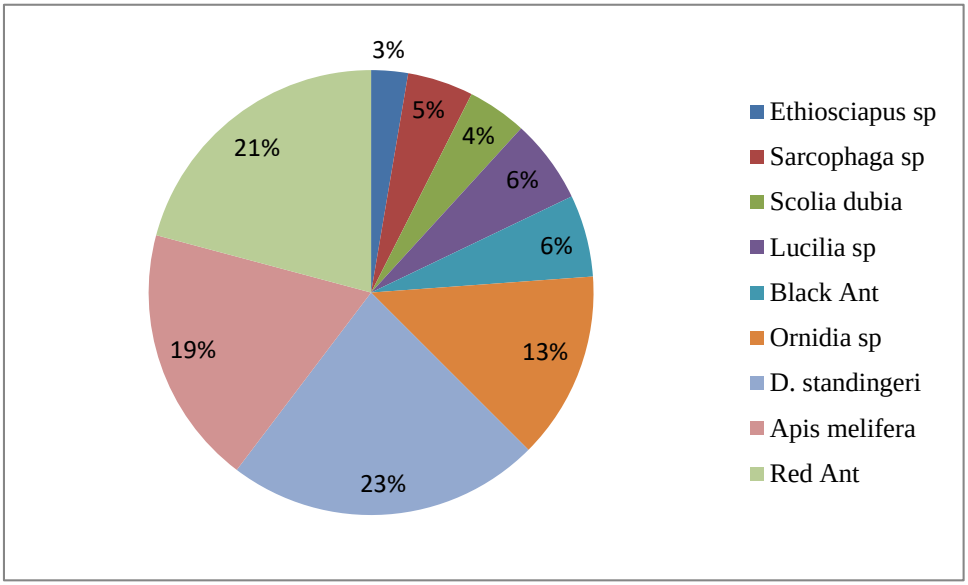

Figure 13. Proportional abundances and distribution of insect fauna from Batch 3

Dactylurina standingeri with highest abundance of 23%, followed by Red Ants with 21% in Batch 3 compared to 3% of *Ethiosciapus sp*., being the least distributed insect species.

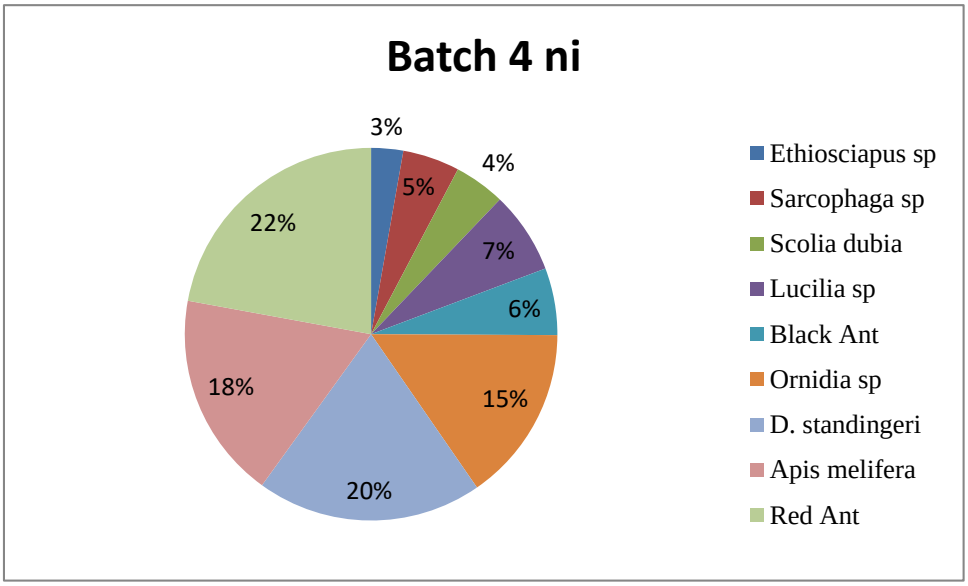

Figure 14. Proportional abundances and distribution of insect fauna on *C. nucifera* from Batch 4

In Batch 4, Red Ant has the highest abundance of 22% , followed by *Dactylurina standingeri* with 20% and *Ethiosciapus sp*., with the lowest abundance of 3% and as such the least distributed in the Batch.

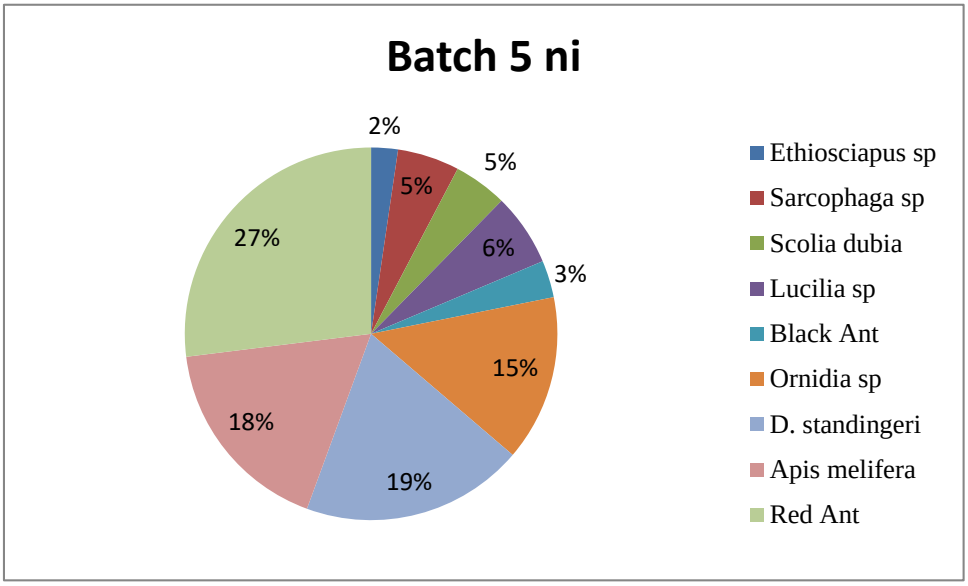

Figure 15. Proportional abundances and distribution of insect fauna on *C. nucifera* from Batch 5.

In Batch 5, Red Ants was highly distributed with abundance of 27%, followed by *Dactylurina standingeri of* 19% as against *Ethiosciapus sp*. with the least abundance of 2%.

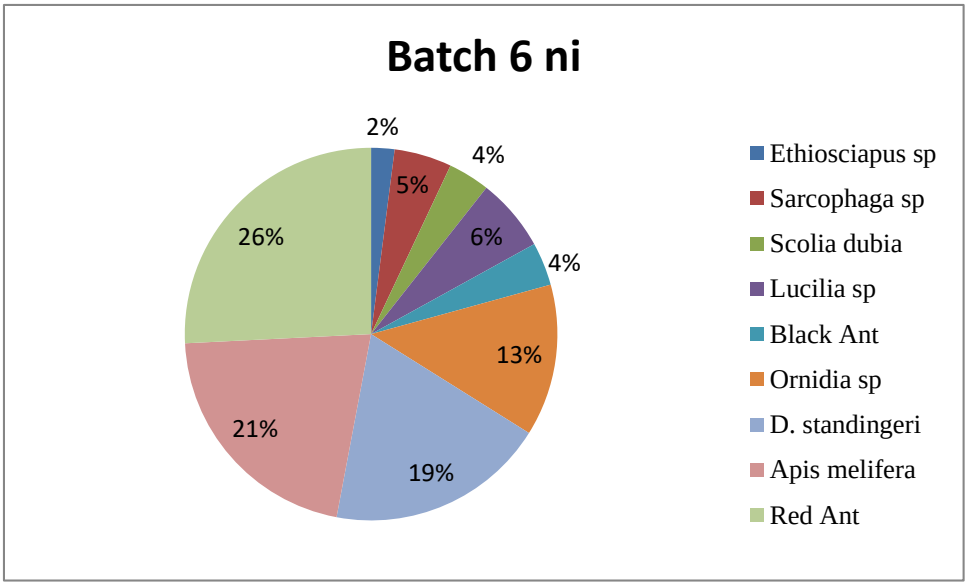

Figure 16. Proportional abundances and distribution of insect fauna on *C. nucifera* from Batch 6

In Batch 6, Red Ants was highly distributed with abundance of 26% followed by *Apis melifera* with 21% as against *Ethiosciapus sp*. with the least abundance of 2%.

4. Discussion

This section also presents discussion on the results of the study, abundance and diversity of the insect fauna that visits the staminate and pistillate flowers of *C. nucifera.* Species richness is the simplest measure of species diversity and is either a count of the number of or the list of, species inhabiting a given area or habitat [18]. Measures of species diversity are formed from species richness by further classifying the species by attributes,

such as abundance, size, or ecological role [18]. In this study, species richness in addition to classifying the species by relative abundance (evenness or dominance) is used to evaluate the insect fauna that visits the staminate and pistillate flowers of *C. nucifera.* One of the most commonly recommended diversity indices is the Shannon-Weiner index. Hence, the Shannon-Weinner index of diversity is used in this study. Yet, it should be noted that Diversity indices represent other phenomena, such as entropy and probability and will thus be treated as such in this study [19]. Another important fact to note is that contrary to common belief, diversity index such as the Shannon entropy ("Shannon-Wiener index") is not diversity but would have to be converted to effective numbers of species (ENS) before they can be treated as true diversity [20]. This declaration is necessary due to the overwhelming variety of literature on how to measure diversity which has often led to heated debates and confusion. The solution seems to be to first adopt a certain index, understand how it is used and stick to it.

Table 2. The effective number of Species (ENS) of insect fauna on six Batches of *C. nucifera* farms.

Batch No.	1	2	3	4	5	6
Shannon Entropy	1.908	1.987	1.967	1.988	1.926	1.908
ENS = exp(x)	6	7	7	7	6	6

Table 3. Proportional Abundances of Insect Fauna on Six Batches of *C. nucifera* Farms

Species	Batch 1		Batch 2		Batch 3		Batch 4		Batch 5		Batch 6	
	N*i*	P*i*(%)	n*i*	P*i*(%)	N*i*	P*i*(%)	n*i*	P*i*(%)	n*i*	P*i*(%)	n*i*	P*i*(%)
Ethiosciapus sp	215	1.6	216	2.2	274	2.7	266	2.8	241	2.3	181	2.0
Sarcophaga sp	556	4.2	562	5.6	491	4.8	473	4.9	558	5.4	446	5.0
Scolia dubia	567	4.3	504	5.0	443	4.3	424	4.4	483	4.7	323	3.6
Lucilia sp	675	5.1	649	6.5	626	6.1	682	7.1	653	6.3	568	6.4
Black Ant	737	5.6	555	5.5	611	6.0	557	5.8	334	3.2	335	3.7
Ornidia sp	2091	15.9	1842	18.4	1399	13.6	1465	15.3	1497	14.4	1179	13.2
D. standingeri	2380	18.1	2003	20.0	2340	22.8	1875	19.6	2008	19.3	1705	19.1
Apis melifera	2383	18.1	1980	19.7	1931	18.8	1716	17.9	1811	17.4	1900	21.2
Red Ant	3562	27.1	1725	17.2	2137	20.8	2119	22.1	2801	27.0	2306	25.8

In Batch 1, Shannon Entropy (H'), was found to be 1.908 (Table 1) reported as percentage. Commenting on the Shannon entropy, if all the species (9 of them) were equally present (dominant), the value would have been 2.197 (calculated as the Natural Logarithm of S). Hence, Shannon entropy of 1.908 suggest that the community of insect fauna that forage on *C. nucifera* are quite fairly distributed. To make more sense out of the Shannon index, the value of the index is converted to effective numbers of species (ENS). This is done by finding the anti-natural log of 1.908. Hence, the ENS was found to be 6. This means that a community of insect fauna that forages *C. nucifera* on Batch 1 (farm 1) has an equivalent diversity as a community with 6 equally common species (see Table 2).

From Table 1, Batch 2 (Farm 2) recorded a Shannon Entropy of 1.987 and converting this value to ENS, Shannon entropy results in an ENS of 7 (Table 2). Hence, with reference to Shannon's index, the insect fauna of *C. nucifera* at Batch 2 had diversity equivalent to a community with 7 equally common species. All remaining Batches of *C. nucifera* produced ENS varying between 6 and 7 (see Table 2). Hence, it could be safely concluded that insect

fauna on the six (6) Batches of farms under study had diversities equivalent to communities' having 7 equally common species.

4.1. Species Richness

The species Richness (S) of insects that foraged on *C. nucifera* was found to be 9. In other words, 9 different species of insects were identified to be the true fauna that visited the staminate and pistillate flowers of *C. nucifera.* These were *Apismellifera, Ethioscipus sp.,Spheridae*digger wasp, *Sarcophaga sp., Ornidia sp.,Dactylurinastandingeri, Luciliasp.*, Red ants and Black ants.

4.2. The relative abundances of insect fauna

Nearly all diversity and evenness indices are based on the relative abundance of species, i.e. on estimates of Pi in which Pi =Ni/N (see Help, Herman, & Soetaert, 1998) with N, the abundance of the *i*th species in the sample, and

$$N = \sum_{i=1}^{s} Ni$$

where S is the total number of species in the sample (Help *et al*., 1998).

Accordingly, the relative abundances of insect fauna on *C. nucifera* in all the 6 batches of farms were computed.

From Table 3, the relative abundance of *Apismelifera* was consistently low across the farms of *C. nucifera*except in Batches 1, 2 and 6 where it emerged as the second highest abundant species (18.1%, 19.7% and 21.2 respectively). The most abundant species of insect on *C. nucifera* was the Red Ant. It emerged as the most dominant species in 3 out of 6 Batches of *C. nucifera* farms. The second most abundant species of insect was *Dactylurina standingeri*. The proportional abundances and distribution are presented in pie charts (figs 9A-F). However, the species Richness (S) of insects that foraged on *C. nucifera* was found to be 9. In addition, the diversity of insect fauna of *C. nucifera* on Batches (Farms) 1, 5, and 6 were all equivalent to a community of insect fauna with 6 equally-common species, on the Shannon-Weiner index. The other three (3) Batches (2, 3 and 4) similarly showed a diversity of insect fauna of *C. nucifera* equivalent to 7 equally common species. Hence, *C. nucifera* at Batches 2, 3, and 4 had a more diversified insect fauna than those of Batches 1, 5, and 6. Finally, the most abundant species of insect on *C. nucifera* was found to be the Red Ant, while *Apis melifera* consistently recorded low relative abundance across farms 3, 4, and 5.

5. Conclusions

The species Richness (S) of insects that foraged on *C. nucifera* was found to be 9. In other words, 9 different species of insects were identified to be the true fauna that visited the staminate and pistillate flowers of *C. Nucifera Ethiosciapus sp., Sarcophaga sp., Scolia dubia, Lucilia sp., Ornidia sp., Apis melifera, Dactylurina standingeri,* Red Ant and Black Ant. These insects were observed in all six batches considered and were available at all times of the day. Most of the insects were observed in the early morning from 6 am-9 am followed by the evening 4 pm –7 pm. The abundance of the insect visitors was low during the mid-day (11 am -3 pm) in all the six batches during high temperatures. Summation of all the abundances reveals that *Ethioscipus sp.* was the least abundant in all the batches followed by *Scolia dubia* then *Sarcophaga sp.*. Red Ants had the highest abundance in most of the Batches thus becoming the most abundant insect that forage the coconut inflorescence at the Asebu plantation. The bees, *Apis melifera* and *Dactylurina standingeri* were the most abundant species after the Red Ants. They were seen moving from inflorescence to inflorescence collecting pollen and thus aiding in pollination of the palm.

Ornidia sp., *Lucilia sp*. and Black Ants were intermediary and as such were seen in fewer numbers.

6. Recommendations

Some of the insect visitors to had very fewer abundances or no spotting at all in several of the inflorescences and as such were not considered. Some of the insect visitors were so difficult and swift to collect or even photograph for identification and as such were not considered. All these groups of insects were not considered in the study and it is recommended that further studies consider such visitors to observe which insects is doing what on the inflorescence. The range for the 'time of day for' of the study was mostly diurnal (morning 6am-9am, afternoon 11am-2pm and evening 4pm-7pm). There was no observation made of the pollination system or activities of these insect visitors nocturnally. There may be high pollination activities of these insects during the late evenings. It is recommended that future work should incorporate the late evening period to observe abundances of nocturnal insect visitors of the coconut inflorescences.

Author Contributions: Conceptualization ESA and MG; methodology, ESA and MG; validation, ESA and MG; formal analysis, ESA and MG.; investigation, ESA and MG.; resources, ESA and MG.; data curation, ESA; writing—original draft preparation, ESA; writing—review and editing, ESA and MG; visualization, ESA and MG; supervision, ESA and MG.; project administration, ESA and MG; All authors have read and agreed to the published version of the manuscript.

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