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Density and Diversity of Insects That Visit Cashew (*Anacardium occidentale* L.) Plants in the Flowering and Fruiting Periods in Northern Ghana

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Abstract: Field survey was conducted in ten farms in Northern Region from December 2014 to April 2015 to collect, identify and access the insects distribution on the cashew farms close to natural forest and agricultural farm land, during the flowering and the fruiting periods of cashew. The sample farms were divided into four plots measuring 20 m x 25 m. Insects found on the cashew plants during the flowering and fruiting periods were identified, counted and unidentified insects were killed in killing jars and preserved in 70% alcohol for further identification. The following were the insects encountered in both farms during the flowering period: Total insects 6161, mean 1232.2 (SD = 250.7, N = 40). Density was 6161/ha and diversity was 3.34. Total insect 2745, mean 549 (SD = 103.2, N = 40). Density was 2745/ha and diversity was 3.56. During the fruiting period, the following insects were also enumerated in both farms: Total 4665, mean 933 (SD = 143.5, N = 40). Density was 4665/ha and diversity of 3.13. Total 2056, mean 411.2 (SD = 52.1, N = 40). Density was 2056/ha and diversity was also 3.14. Density in both farms during the flowering period were more than the fruiting period in both farms, however insect diversity was more during the fruiting period than the flowering period. Further studies should be conducted on an all year round survey to identify residence insects from insects that visit cashew during flowering and fruiting period, integrated pest management strategies and integration of insect conservation into the national biodiversity conservation policy were also recommended.

Keywords: Insects, Cashew, Flowering Period, Fruiting Period, Insect Behaviour and Insect Diversity

1. Introduction

The development of plants has changed the global environment into an extremely useful resource for the herbivore community. In the natural ecosystems, plants and insects are constantly interacting with each other in a complex way. These two organisms are closely connected such that, insects provide several beneficial services including defence, dispersal and pollination to plants while plants provide shelter, oviposition sites and food, which are the three main factors necessary for insect production [1].

On the other hand, depending on the amount of insect attack, herbivores might be enormously detrimental to plants leading to death. Plant-insect interaction is a dynamic system, subjected to a repeated disparity and change. Numerous plants devote resources in protecting their flowers against insects because some insects are usually unproductive pollinators [2]; [1].

Though, direct insect–plant conflicts have seldom been documented in mutualitic insect–plant systems [3], many plants have evolved chemical or physical devices against insects on their flowers who are pollinator's or fruit eaters [4].

Cashew (*Anacardium occidentale* L.) was introduced into Ghana by the Government in the 1960s for a forestation in the savannah, coastal savannah and forest-savannah transition zones in Greater Accra, Eastern, Volta and Brong-Ahafo regions. Its cultivation was also measured necessary for tree cover in tattered areas where land recovery programmers' were under way to put off more erosion [5]. Large scale farming of the crop started in 1991 and by 1997, the section under cashew cultivation nation-wide was

covering 12,500 ha. Between 2000 and 2004, incentives were provided to farmers in the form of loans and improved planting materials to establish new and rehabilitate old plantations. The product of commercial significance is the nut, which contains 47% fat, 21% protein and 22% carbohydrate, vitamins, especially thiamine [6]. A liquid obtained from the cashew, known as cashew nut shell liquid (CNSL), is used broadly in brake linings of motor vehicles, paints, varnishes and laminated products [7]. However, several insects are found on the cashew plant, both beneficial and non beneficial insects at the various stages of its development [8].

There has not been much information on insect species associated with cashew in Ghana, regarding to either the flowers or the fruits. Likewise, literature on cashew insects is lacking in Ghana during the flowers and fruits seasons [9]. Though [5] conducted a survey on insects that associate with cashew plants in Ghana, they did not categorise them into seasons.

There have been several debates whether insects that visit cashew during the flowering and fruiting seasons are the same [10] ; [11] More recently, the concept of the pollination syndrome has been questioned by [12], whether the insects that visit flowers pollinate them in order to consume the fruits in future or they do so purposely for the mutualism existing between them (i.e. in search of their resources).

Activities of insects generally affect the tree, depending on where it is found will either affect the whole plant or part of the plant. Meanwhile, these activities of insects have not clearly been defined on seasonal bases (flowering and fruiting). The only comprehensive study on insects that visit cashew plant in Ghana was by [5] who reported that insect order associated with cashew plant comprises of Hemiptera, Coleoptera, Hymenoptera, Dictyoptera, Orthoptera, Lepidoptera, Homoptera, Diptera and Thysanoptera.

It is therefore, necessary to investigate into the insects that visit cashew plant during the flowering and the fruiting seasons, the insect density, diversity and species composition of insects that visits cashew plant during the flowering and fruiting seasons in different locations (natural forest and agricultural land).

2. Methods and Materials

The study was carried out in two stratified areas; farms closer to forest (<1km) and farms away from forest (>5km) in the Northern Region specifically Sawla and Bole. The study areas are located in the western part of the Northern Region, between latitudes 8° 40' and 9° 40' North, longitudes 1° 50' and 2° 45' West (Fig. 1: map of the study area)

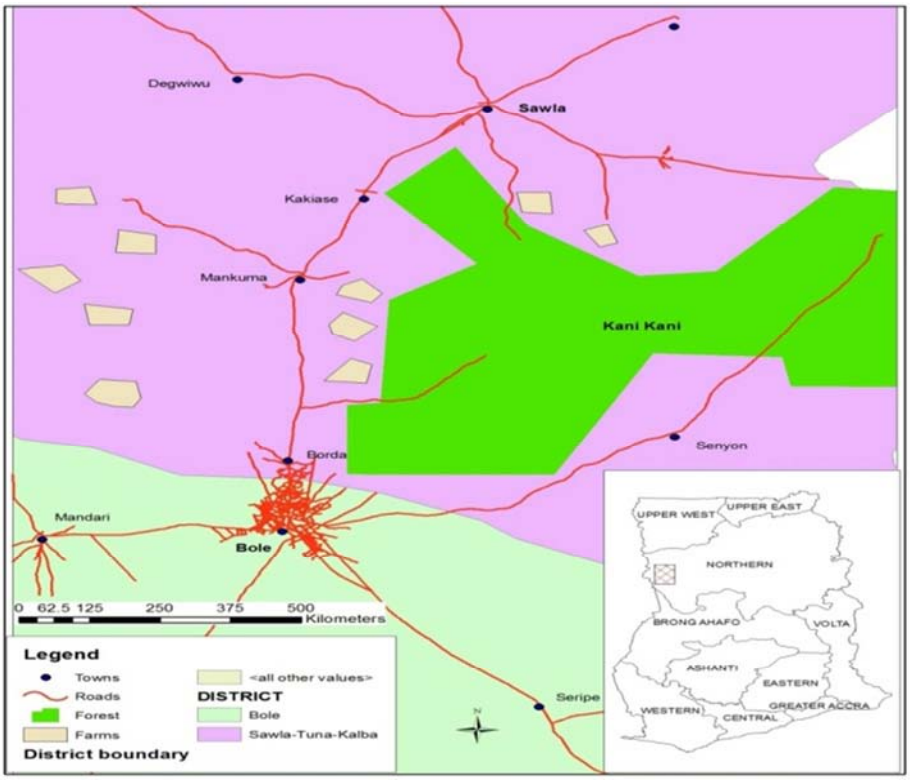

Figure 1. *Map of the study area indicating the farms distributions (farms positions not up to scale).*

Cashew farms are cultivated with dwarf cashew variety CCP76. Trees are 10 years to 20 years, spaced 7.5 x 7.5 m, with a total maximum number of 178 trees per ha. All farms are submitted to the main standard agricultural practices for cashew crops such as pruning, soil clearing, and weed control prior to blooming season by the farmers.

Equipment used for the execution of the research are: G.P.S, Lap top computer, Sweep net with a long handle,

Forceps, Field note book and pencil, Tubes for specimen, Paper envelopes and Vials with alcohol. The study follows the methodology proposed by [13].

In each farm four plots of an area measuring 25 m x 50 m (1,250 $m^{2)}$ were established in all the ten cashew farms with approximately 30 trees per plot. The enumeration team was made up of three members: one person served as a recorder and the two others scanned through the cashew trees, identified insects, count and inform the recorder. This procedure was carried out on all the trees in the plots.

Representatives of all insects were captured and sacrificed in to killing jars with 70% alcohol. These species were sent to the University of Cape Cost and Cocoa Research Institute (CRIG) Tafo Entomology museums for further confirmation and identification of unidentified species. The nomenclature of the insects was after [14].

This procedure was carried out in two separate seasons: (1) the flowering season (mid December 2014 to mid January 2015) and (2) the fruiting season (March to April 2015).

The data collected were analyzed as follows:

- *Density* was calculated using the formula:

$$density = \frac{total\ number\ of\ all\ insects}{total\ sampled\ area}$$

- *Diversity* was calculated using Shannon (H):

$$H = -\sum_{t=1}^{s} p_i lnp_i$$

- *Abundance* was calculated by adding the number of individuals per species encountered in both seasons.
- *Relative abundance* (%) was calculated as follows:

$$relative\ abundance = \frac{number\ of\ individual\ species}{total\ number\ of\ all\ species} X100$$

- *Frequency of occurrence* was determined from the raw data by dividing the number of farms where a particular species was collected by the total number of farms occupied by each species in question and multiply by 100.

3. Results

The total number of insects enumerated during the flowering season in the five farms closer to the forest was 6161 and the mean number of insects per plot was 1232.2 (SD=250.7, N=40). The insect density was found to be 6161/ha in farms closer to the forest. This comprises of 6 orders 20 families and 56 different species. Higher number of insects was counted among the following species; *Apis mellifera, Oecophylla longinola, Cataulacus guineesis, Dactylurina staudingeni* and *Euchrysops malathana* in farms closer to the forest. On the insect status of species enumerated in farms closer to the forest, 77% of insects were classified abundant, 13% of insects were common and 10% of insects were rare.

On the other hand, the total number of insects enumerated in the remaining five farms away from the forest during the flowering season was 4665 and the mean number of species per plot was 933 (SD=143.5, N=40). The density was found to be 4665/ha. This comprises of 41 species belonging to 22 families and 7 orders. On the farms that were away from the forest, the following species were found to be relatively in higher number of individual insect, with respect to all other insects encountered: *Apis mellifera, Oecophylla longinola, Atelocera* sp. *Atractomorpha aberrans* and *Chilomenes lunata*.

Furthermore, still in the flowering season 94% of insects encountered were classified as abundant and 6% of insects were common there was no species classified as rare away from the forest. (Figure: 3) present the means of insects enumerated per plot in both farms closer and away from the forest.

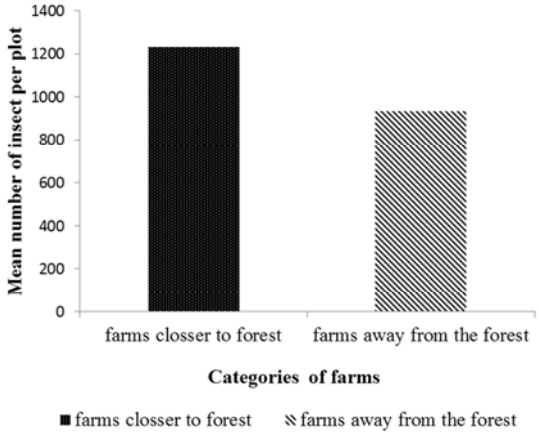

Figure 2. *Mean of insect per plot in both farms close and away from the forest during the flowering period.*

In addition, (Figure: 4) presents the frequency of occurrence on insects enumerated for both farms closer to the forest and away from the forest reserve (flowering season).

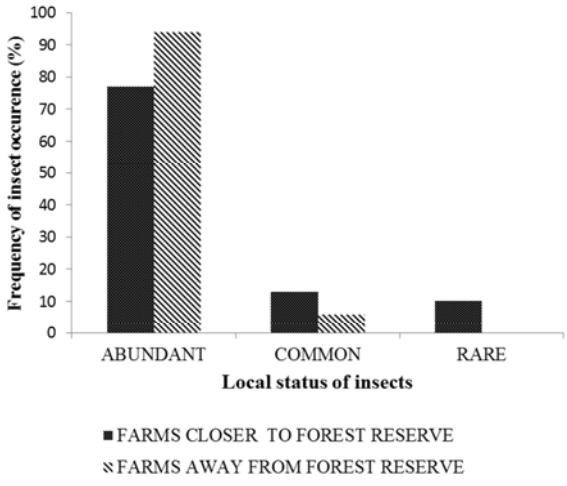

Figure 3. *Frequency of occurrence of insects enumerated for both farms closer to the forest and away from the forest during the flowering period.*

The total number of insects enumerated during the fruiting season in the five farms closer to the forest was 2745 and the

mean number of insects per plot was 549 (SD=103.2, N=40). The density was found to be 2745/ha insects in farms closer to the forest. This comprises of 48 different species belonging to 21 families and 6 orders. Higher number of insects was counted among the following species; *Apis mellifera, Oecophylla longinola, Mylabri bifasciata, Crematogaster striatula* and *Crematogaster africana* in farms closer to the forest (Table 1). On the status of the species enumerated in the farms closer to the forest, 82.7% were classified abundant, 17.3% common.

On the other hand, the total number of insects enumerated in five farms away from the forest during the fruiting season was 2056 and the mean number of species per plot was 411.2 (SD=52.1, N=40). This comprises 55 species belonging to 22 families and 7 orders. The density was found to be 2056/ha insects in farms far away from the forest (Table 1).

Table 1. *Insects enumerated during flowering phase closer and away from the forest reserve.*

	FARM CLOSER TO FOREST			FARMS AWAY FROM FOREST		
Species	**Abundance**	**Relative Abundance**	**Frequency of Occurrence**	**Abundance**	**Relative Abundance**	**Frequency of Occurrence**
Acrida turrita	109	2.3	100	109	1.8	100
Acrocerops sp.	37	0.8	100	60	1.0	100
Amorphoscelis	53	1.1	100	70	1.1	100
Anacridium sp.	173	3.7	100	182	3.0	100
Analeptes trifasciata	0	0.0	0	68	1.1	100
Anoplocnemis curvipes	103	2.2	100	121	2.0	100
Apate telebrans	58	1.2	80	103	1.7	80
Apate terebrans	70	1.5	100	82	1.3	100
Aphis sp.	96	2.1	80	110	1.8	80
Apis mellifera	734	15.7	100	733	11.9	100
Asbecesta cyanipennis	0	0.0	0	60	1.0	100
Atelocera sp.	155	3.3	100	267	4.3	100
Atractomorpha aberrans	142	3.0	100	195	3.2	100
Camponotus olivieri	114	2.4	80	165	2.7	80
Cataulacus guineensis	193	4.1	100	196	3.2	100
Chilomenes lunata	146	3.1	80	200	3.2	100
Clavigralla shadabi	31	0.7	100	28	0.5	80
Clavigralla tomentosicollis	24	0.5	40	27	0.4	80
Conocephalus longipennis	39	0.8	80	62	1.0	80
Crematogaster africana	174	3.7	100	222	3.6	100
Crematogaster striatula	70	1.5	40	94	1.5	40
Dactylurina staudingeri	186	4.0	100	231	3.7	100
Euchrysops malathana	201	4.3	80	204	3.3	80
Homoeocerus pallens	82	1.8	80	137	2.2	100
Hypotrigona sp	165	3.5	100	207	3.4	100
Meliponula ferruginea	189	4.1	100	188	3.1	100
Mylabris bifasciata	0	0.0	0	35	0.6	80
Nezara viridula	41	0.9	100	81	1.3	80
Oecophylla longinoda	380	8.1	100	387	6.3	100
Pantelia horrenda	20	0.4	100	43	0.7	100
Phaneroptera sparsa	169	3.6	100	179	2.9	100
Pheidole megacephala	108	2.3	80	133	2.2	80
Philematium festivum	75	1.6	100	162	2.6	100
Piezodorus rubrofasciatus	78	1.7	60	113	1.8	60
Polyrachis laboriosa	10	0.2	80	21	0.3	100
Polyspilota variegata	72	1.5	100	118	1.9	100
Prosopocera lactators	78	1.7	60	143	2.3	80
Pseudotheraptus devastans	45	1.0	80	66	1.1	100
Sphex pensylvanicus	65	1.4	80	129	2.1	80
Sphodromantis lineola	32	0.7	100	51	0.8	100
Tarachodes afzelii	35	0.8	80	59	1.0	80
Unidentified(a1)	15	0.3	60	28	0.5	60
Unidentified(a2)	45	1.0	80	74	1.2	80
X. varipuncta	20	0.4	60	35	0.6	80
Zographus regalis	0	0.0	0	105	1.7	100
Zonocerus variegatus	33	0.7	80	49	0.8	100
Total	4665	100		6161	100	

On the farms that were away from the forest the following species; *Apis mellifera, Oecophylla longinola, Anancridim* sp. *Mylabri bifasciata* and *Crematogaster striatula* recorded higher number of individual insects, with respect to all other insects encountered. The statuses of farms away from the forest 89.2% of insects were classified as abundant and 10.8% of insects were also classified as common. There was no species encountered rear away from or closer to the forest.

Refer to (Figure 4) for the mean of insects enumerated per plot.

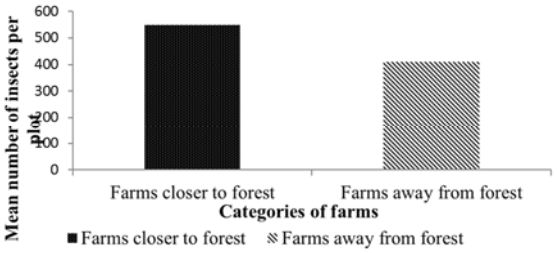

Figure 4. *Mean number of insects per plot of both farms close and far away from forest during the fruiting period.*

(Figure: 5) presents the frequency of occurrence on insects enumerated for both farms closer to the forest and away from the forest (during the flowering and fruiting seasons).

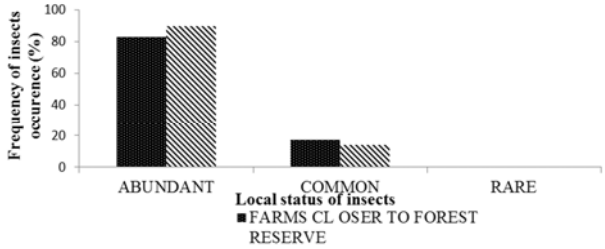

Figure 5. *Frequency of occurrence of insects enumerated in both farms closer and far away from forest during the fruiting period.*

Diversity of insects that were found during the flowering season in farms closer to the forest was 3.34 and insects that were encountered in the fruiting season close to the forest were 3.56. The difference between the diversity of insects in the two seasons was highly significant ($t= 11.148$, $p < 0.001$). However, diversity of insects for farms away from the forest during the flowering season was 3.13 while during the fruiting season insects diversity was 3.14. A significance difference was found between the two seasons ($t= 28.097$, $p< 0.005$). Table 2 and Table 3 present the diversity index and student's diversity of insects calculated.

Table 2. *Diversity index of insects in farms closer and farms away from forest in both seasons.*

Farms	Period	Diversity (H)	Evenness	Confidence intervals	
				Upper	Lower
Farms close to forest	Flowering	3.34	0.67	3.59	3.55
	Fruiting	3.56	0.75	3.59	3.55
Farms away from forest	Flowering	3.13	0.79	3.59	3.53
	Fruiting	3.14	0.79	3.59	3.54

Table 3. *Diversity't' test between insects in farms close and away from forest.*

Farms close to forest	Farms away from forest	T value	P value
Flowering close to forest	Flowering away from forest	-0.3818	0.70263
Flowering close to forest	Fruiting close to forest	11.148	1.4749E-28**
Fruiting close to forest	Fruiting away from forest	-0.3818	0.70263
Flowering away from forest	Fruiting close to forest	25.48	1.8868E-133**
Flowering close to forest	Fruiting away from forest	-11.773	1.0368E-31**
Flowering away from forest	Fruiting away from forest	28.097	3.5278E-164**

** Significance at 0.001

4. Discussions

The study identified a number of different insect species on the cashew plant during the flowering and fruiting seasons in both farms closer and away from the forest. The phenology of the plant can be said to determine the type of insects that can be attracted to the plant. Though the variation of species that visit the cashew during the flowering and fruiting seasons were not wide, their density differed significantly.

The species that visit the cashew plant during the flowing stage were found to belong to six insect orders namely: Hemiptera, Coleoptera, Lepidoptera, Dictyoptera, Hymenoptera, and Diptera. The order Hemiptera contributed two families namely: Coreidae and Pentatomidae, order Coleoptera contributed seven families namely; Cetoniidae, Bostrychidae, Cerambycidae, Buprestidae, Meloidae, Galerucidae and Coccinellidae. Order Lepidoptera contributed three families namely; Lycaenidae Gracilariidae Lycaenidae. Order Dictyoptera contributed one family namely; Mantidae. Order Diptera contributed two families namely; Mucidae and Drosophilidae. Order Hymenoptera contributed six families namely; Formicidae, Apidae, Halictidae, Megachilidae, Sphecidae and Braconidae.

The families Formacidae and Apidae dominated in terms of species and some of them are as follows: Crematogaster striatula, Camponotus olivieri, Pheidole megacephala, Cataulacus guineensis, Polyrachis laboriosa, Oecophylla longinoda, Crematogaster striatula and Camponotus olivieri, Apis mellifera, Dactylurina staudingeni and Euchrysops malathana (Table 1)

On the other hand, during the fruiting season the species that visit the cashew plant were found to belong to seven insect orders namely: Hemiptera, Coleoptera, Lepidoptera, Dictyoptera, Hymenoptera, Homoptera and Diptera. Hemiptera composes of two families Coreidae and Pentatomidae, order Coleoptera composes of seven families Cetoniidae Bostrychidae Cerambycidae Buprestidae Meloidae Galerucidae and Coccinellidae, order Lepidoptera composed of three families Lycaenidae, Gracilariidae and

Lycaenidae, the order Diptera contributed two families Drosophilidae and Mucidae, Dictyoptera contributed one family Mantidae, order Homoptera composes of four families Cocidae Pseudococidae Aphididae and Miridae, order Hymenoptera contributed six families Formicidae, Apidae, Halictidae, Megachilidae, Sphecidae and Braconidae, then order Orthoptera also composed of Tettigoniidae, Acrididae, Pyrgomorphidae, and Tetrigidae.

Comparing the insect composition in both flowering and the fruiting seasons, it was found out that though the same family may occur in both seasons species occurrence may differ. For example, during the flowering season the family Pentatomidae was present with these species *Piezodorus rubrofasciatus* and *Atelocera sp.* but during the fruiting season with the same family *Nezara viridula* Linn. was found. The family Pentatomidae has been known to be predators but the differences might have occurred because of their different prey requirements.

Some species were found to be visiting cashew in both seasons not because they were interested in the flowers or the fruits but because of different resources that they required. It could be deduced that a thin gap occurred between the flowering and the fruiting seasons. This is because flowers and fruits develop concurrently so there were some overlaps of species during the flowering and the fruiting seasons. For instance, *Oecophylla longinoda* were found throughout both seasons not because there were after the flowers nor the fruits but probably because (1) they were interested in making their nest on the plant, (2) scanvageing and (3) praying because they are carnivorous insects and can be served as biological controllers [9]; [15].

In terms of frequency at which insect species occurred in the sample area, 77% of insect species were classified as abundant, this means they occurred in almost all the sample areas. 13% were found between 30% and 70% of the sample areas while 10% were classified rare because they were found only at few places i.e., between 1% and 30% of the study area. In farms away from the forest reserve 94% of insects encountered were classified as abundant and 6% were common there was no species classified as rare during the flowering season in farms away from the forest reserve this supports the hypothesis that insect status of occurrence are not the same in farms close and farms close to the forest. During the fruiting season in farms closer to the forest, 82.7% of insect were classified as abundant, 17.2% common none of the species were classified rare. In farms away from the forest, 89.7% were classified as abundant 13.8% common and there was none classified as rare. In this instance, it can be deduce that, the forest has no influence on the frequency of occurrence in insects species in farms closer and away from the forest reserve during both seasons (flowering and fruiting) and this also supports the hypothesis that natural forest has no influence on insect status.

Moreover, insects density recorded in farms closer to the forest reserve during the flowering season was higher than the fruiting season 6161/ha as compared to 2745/ha. A similar observation was also made in farms away from the forest reserve during both seasons 4665/ha as compared to 2056/ha. This indicates that the resources that attract the number of insects to the plant during flowering (nectar, pollen, colour of petals, scent) differ from during fruiting (Colour of fruit, scent, fermentation, yeast). This was similar to [16] who reported that flowers of plant normally serve as attractant to several categories of insects. For example, weaver ants (*Oecophylla smaragdina*), are attracted to the plant not to pollinate the flower directly but to deter insects that attack pollinator. On the other hand, during the fruiting some volatile compounds have been reported to attract insects to the plant. For example, volatile compounds have been reported to serve as insects attractant to rips fruits of coffee [17].

Diversity of insects recorded in farms closer to the forest reserve during the flowering season differed from that of fruiting season ($t = 11.148$, $P<0.001$); a similar observation was also made in farms away from the forest reserve during both seasons ($t = 28.097$, $P<0.001$). This supports the hypotheses that insects diversity in both seasons of the cashew plant are not the same. It shows that the forest has less influence on insect that attracts the cashew plant during both seasons. There are differences of conditions that attract insects to visit cashew during the flowering and fruiting seasons. In addition, insects that visit the cashew plant during the fruiting season were more diverse than those that visit the flowering season. This supports the hypotheses that insect's diversity on cashew flowers and fruits are not the same. This is because, individual species have specific requirement of resources from the cashew plant. Some insects visit the plant purposely for any of the following; food, shelter, oviposotion, chemical for pheromone or for all. Colour differences between the flowers and the fruits of cashew might influence the type and number of insects that visit the plant. This can bring about the differences in insect diversity during both seasons as the colour of cashew fruit is more conspicuous than the colour of flowers.

It has been shown that, flowers are more conspicuous to pollinators and fruits are also more conspicuous to fruits dispersers, yet despite the differences in visual systems of the insect, flower and fruit colours have evolved to attract multiple and distinct mutualists [18]. In addition, another study has reported that yeast production also attract insects to the flower [19].

During the fruiting seasons, apart from colour, fermentation can also be a major attractant of insects to the plant in the fruiting season. This has also been supported by [20] that many insects have been attracted to fermenting fruit and also micro-organisms like Saccharomyces yeasts growing on fruit occupy a trophic level between fruit and insects. [20] continued to support that Drosophila flies also used immature fruits for their oviposition place due to the presence of yeast in the fruits for the growth of their larvae.

5. Conclusions

Based on the results of the study, the following conclusions were made:

The study revealed a number of insects that visit cashew during the flowering season from the orders Hemiptera, Lepidoptera, Coleoptera, Dictyoptera, Hymenoptera, and Diptera. During the flowering season, insects encountered were 6161 comprising 56 different species belonging to 20 families and 6 orders in farms closer to the forest. In farms away from the forest reserve, 4665 individual insects were identified also comprising 41 species belonging to 22 families and 7 orders during the flowering season. During the fruiting season the same orders occurred except the order Homoptera. Insects encountered were 2745which comprises 48 different species belonging to 21 families and 6 orders in farms closer to the forest reserve, whiles in farms away from the forest insect recorded were 2056 comprising 55 species belonging to 22 families and 7 orders. The density of insects on cashew farms during the flowering season in farms closer and away from the forest was higher than that of the fruiting season. In terms of diversity, insects were lower in the flowering season than the fruiting season in both farms. On the status of insect enumerated, most of the insects were ranked either as abundant or common in both seasons just a few were classified rare only in the flowering season.

Inferring from the study, the following recommendations were made: Further studies should be conducted throughout the year in order to differentiate resident insects from insects that were attracted to the plant because of the flowers and fruits seasons. Laboratory test should be done to determine the common nutrients on insects that visit cashew during both seasons. Integrated pest management strategy should be adopted by farmers to manage insects, because not all insects seen during the flowering and fruiting seasons might be harmful to the cashew plant.

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