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Monitoring Insect Populations in Cocoa Agro-Ecosystems within the Catchment of the Bobiri Forest Reserve in Ghana

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ABSTRACT

Population diversity of insects in an ecosystem at any given time is a good indication of their role in ecosystem function, and it helps to facilitate their management. A two-year monitoring survey was conducted in cocoa farms within the catchment of the Bobiri Forest Reserve in Ghana. Pan traps consisting of fluorescent white, blue and yellow plastic bowls were set in 10 cocoa farms spread out in the study area. On each farm, 30 traps consisting of 10 white, 10 yellow and 10 blue were each mounted on a 1m high 5 cm wide PVC pipe stand. Sampling was carried out during the major and minor cocoa flowering seasons in 2011 and 2012, with each sampling session lasting approximately 48 hours. A total of 496 insects were collected at the end of the survey period with yellow and white traps being more attractive to pollinators in the study area. The dominant taxa recorded were Dipterans 177 (35.69%), of which midges constituted 79 (15.9%). There were 175 (35.3%) Hymenopterans, which included 100 (20.2%) ants, 57 (11.5%) stingless bees, 15 (3.0%) wasps, and 3(0.6%) honey bees. There were 77 (15.5%) coleopterans (beetles) and lepidopteran groups recorded and 52 (10.5%) lepidopterans. The primary cocoa pollinator *Forcipomyia* midge was recorded both in the minor (October-January) and major (April-July) cocoa flowering seasons. Midges' population in the cocoa ecosystem proved to be generally high in the wet season. The results suggest differences in the adaptation of resident insects in the cocoa agroecosystem.

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Keywords: *Insect diversity, Cocoa ecosystem, Pollinators, Forcipomyia spp, Honeybees, insect populations*

INTRODUCTION

Insects play diverse roles in various ecosystem processes (Janzen, 1987), which include pollination, natural regulation and nutrient cycling (Kevan, 1999). At any particular point in time, the diversity of insects in any ecosystem is a good indication of their role in the functioning of the ecosystem (Adjaloo and Oduro, 2013) Being generally small in size and cold-blooded, insects are readily affected by variations in prevailing climatic and environmental conditions (Ayres and Schneider, 2009), especially temperature and rainfall. Other ecological factors such as food, predation and disease also readily influence the temporal and spatial variations of insect populations (Young, 1982), and in effect, the carrying capacity of the environment (Schowalter, 2006).

Pedigo and Rice (2006) have noted that insect populations are dynamic as the number of individuals in a population may change by the day, through the seasons and years due to interactions with the environment. The environment itself is subject to change though it provides diverse resources needed by insects for survival, and this affect the size of insect population (Khaliq *et. al*., 2014). Within an agro-ecosystem, environmental variations are attributable to anthropogenic activities such as tillage, planting, and the application of fertilizers and pesticides (Altieri *et. al*., 2005; Harrison *et. al*., 2006). These practices, however, constitute disturbance which provide conditions for fluctuations in populations of insects.

To our knowledge there are not much published studies on the status, trends and functional roles of insects in cocoa agro-ecosystems in Ghana and tropical Africa, especially their role as pollinators. Earlier studies by Room (1975), Majer *et. al*. (1994), Frimpong *et. al*. (2011) and Adjaloo and Oduro (2013), have focused on the mosaic of insect species in the cocoa ecosystem rather than the population dynamics. But a good knowledge and understanding of insect population trends helps to facilitate their management (Waser *et al*., 1996).

Interest in the study of the diversity and population dynamics of insects in cocoa agrosystems in Ghana was kindled recently with the implementation of the global study on pollination (Gemmill-Herren, 2016) during which Ghana and six other countries across the globe participated in the monitoring of honeybees and other pollinators in selected cropping systems. With funding from Global Environment Facility (GEF) and the United Nations Environment Programme (UNEP), and Food and Agriculture Organization (FAO) implementing agency, the “Conservation and Management of Pollinators for Sustainable Agriculture through an Ecosystem

Approach" project gave a good overview of the status of honeybee and other key pollinators through monitoring surveys conducted during 2010 to 2014 in Brazil, Ghana, India, Kenya, Nepal, Pakistan and South Africa (Gemmill-Herren, 2016). Ghana's monitoring surveys were conducted in three cropping systems namely, cocoa, mango and vegetables (Annoh, *et. al.,* 2017). The objective of the study was to determine the diversity, abundance and seasonal trends of insects in the cocoa ecosystems within the catchment of the Bobiri Forest Reserve, and in particular determine the dynamics of *Forcipomyia* midges which are recognized as primary cocoa pollinators in Ghana, and the occurrence and diversity of honeybees in the cocoa agroecosystem

MATERIALS AND METHODS

Study Location

The survey was conducted in cocoa farms located near the Bobiri Forest Reserve (BFR) and close to the village of Kubease in the Ejisu-Juaben District of the Ashanti Region, Ghana. The reserve is approximately 35 km northwest of Kumasi. The area was one of the three locations designated under the Global Pollination Project in Ghana as a Study, Training, Evaluation and Promotion (STEP) site. STEP sites were areas designated under the Global Pollinators Project for testing pollinator-friendly best practices. The area is a tropical moist deciduous forest and is approximately 224 m above sea level and situated at latitude of 6^0 38' north and longitude 1^0 17' west. The total area of the reserve is 54.6 km^2. The Bobiri Forest Reserve creates optimum environmental conditions for the cultivation of cocoa and other food crops, for which many farming communities have settled.

The nearest community to the reserve however is the village of Wuraponso which consists of about 25 families along the fringes of the forest. Most of the farmers here are migrants who have settled from different parts of Ghana to engage primarily in cocoa cultivation. The cocoa farms are typically small, ranging from as small as 1.0 acre (0.4 ha) to several acres in size. Most of the farm work is done manually and quite traditional, depending heavily on the use of cutlasses, hoes and some other simple farm tools. Considerable use of agrochemicals such as fertilizers, herbicides and pesticides however occurs.

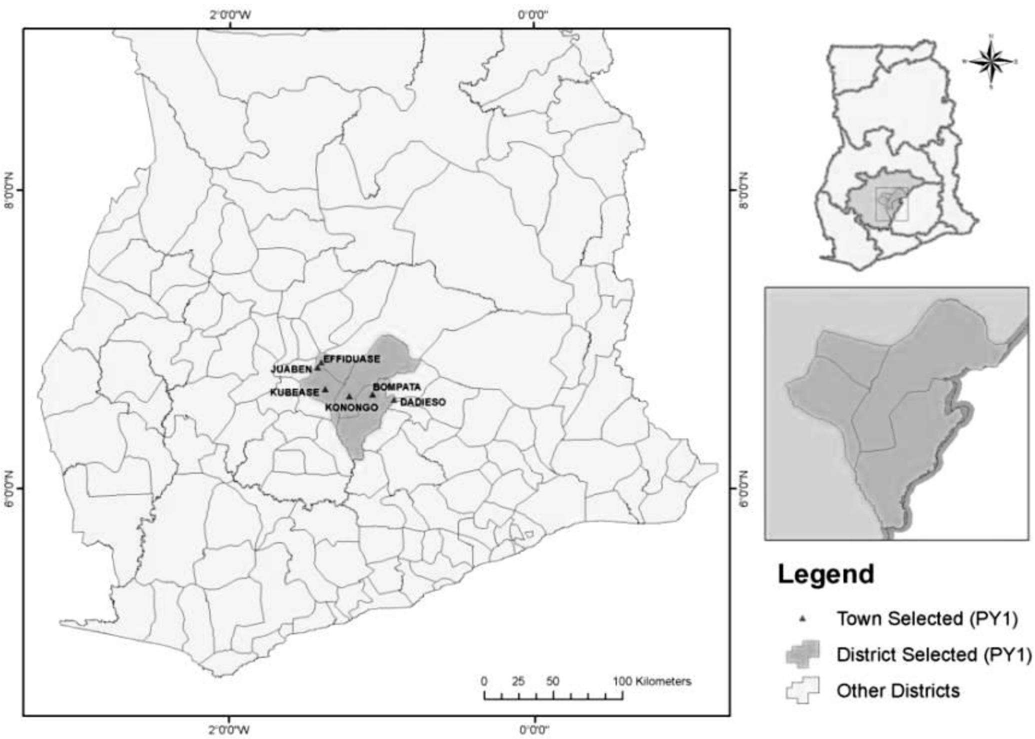

Figure 1: Map of Ghana showing the Study Area

Sampling Method

The sampling protocol was based on the use of pan traps. Pan traps used were made of fluorescent white, blue and yellow plastic bowls following Potts (2005). The use of different coloured pan traps were to increase the probability of insects trapped. The cups were filled to two-thirds full of water mixed with a small amount of detergent. Normally an insect landing on water floats as a result of surface tension, but in this case the soap diminishes the surface tension enough that they sink. Traps were set in 10 cocoa farms spread out in the STEP area. At each of the 10 farms, 30 traps consisting of 10 white, 10 yellow and 10 blue were set up. Each trap was mounted on a 1m high 5 cm wide polyvinyl chloride (PVC) pipe stand, enabling the cup to be conveniently fitted into the P VC pipe. The open end of the PVC pipe was deliberately widened to allow the cup to sit without falling off. Pan traps were arranged in a web-like format with the different coloured pans alternating on each line. Each of the pan traps was placed on the transect such that the same colour was at the ends of each transect (LeBuhn, *et al*., 2013).

Sampling was carried out at approximately once every month beginning in October 2011 and was planned to coincide with the flowering seasons of cocoa trees. On each sampling session, the traps were set between 9:30 -11:00 am and collected at about the same time period on the third day (approximately 48 hours). The PVC pipe stands were left in the farms, whiles the plastic bowls were collected, cleaned and stored until the next sampling.

Identification of Insects

Samples were collected from the plastic bowls and transferred into plastic bags or vials containing 70% ethanol, labeled and transported to the Entomology laboratory of the Forest Research Institute of Ghana for sorting and identification. The label included date on which traps were mounted, date of collection, the farm, identification and colour of pan. Contents of traps of the same colour on each plot were put together. Trap content were sorted out in the laboratory and grouped accordingly using a field datasheet developed for the purpose. Although the monitoring was targeted first and foremost at honey bees, stingless bees, carpenter bees, and *Forcipomyia* midges which are considered as the most important visitors of cocoa were also targeted. In addition, other arthropods in the traps were recorded. Due to taxonomic difficulties, the identification of the midges was mostly limited to the genus. Total number of individual insects and species for each of the 10 farm plots were then recorded.

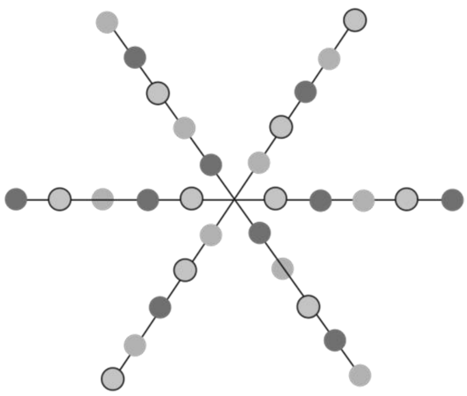

Figure 2: Arrangement of coloured plastic pan traps for sampling (*Courtesy:* LeBuhn, *et. al*., 2013).

Data Analysis

We used one-way analysis of variance (ANOVA) to test for differences in species richness and abundance between plots and trap colours. For this purpose, we first calculated the total species richness and abundance of each plot based on observed species richness and abundance of the six surveys. Species richness is the number of all species captured on the plot or trap colour whiles abundance is the number of all individuals captured on the plot.

RESULTS

A total of 496 insects were collected at the end of the monitoring period (Table 1). The most abundant of these were the Diptera recording 177 (35.7%). Hymenoptera followed closely recording 175 (35.3%). Notable hymenopterans recorded were wasps, honey bees, stingless bees and ants. Ants were most abundant recording 100 (20.2%), with honey bees recording the least of 3 (0.6%). Wasps and stingless bees were 57 (11.5%) and 15 (3.0%), respectively. The coleopterans (beetle) and lepidopteran groups recorded 77 (15.5%) and 52 (10.5%) respectively. Cocoa pollinator midges represented 79 (15.9%) in the cocoa growing area.

Table 1: Insect pollinator groups collected at the end of the monitoring period

Insect Taxa	Common Name	Order	Total No. sampled	% of Total No. of Insects
Polistes spp	Wasps	Hymenoptera	57	11.49
Hypotrigona spp	Stingless bess	Hymenoptera	15	3.02
Cremastogaster spp	Ants	Hymenoptera	100	20.16
Apis m. adansonii	Honeybees	Hymenoptera	3	0.6
Pterocarpus spp	Butterflies	Lepidoptera	52	10.48
Carabid spp	Beetles	Coleoptera	77	15.52
Forcipomyia spp	Midges	Diptera	79	15.9
Drosophila spp	Other flies	Diptera	98	19.75
	Unknown		15	3.02
	Total		496	100

Ants were most attracted to the white and yellow pan traps (4.5/month) (Table 2). The yellow pan trap attracted the highest number of midges (4.3/month) followed by blue (2.9) and white pan traps (2.8). The 3.8 beetles recorded for yellow pan traps makes it the most attractive colour to this group of insects, followed by the white (3.1) and blue pan trap (2.8), respectively. White pan trap caught merely 0.4 honey bees, but none were caught by blue and yellow pan traps.

Table 2: Mean trap catches of insect pollinator groups by pan traps of different colors

Group	No. of insects/trap/month		
	Blue	Yellow	White
Midges	2.87	4.25	2.75
Stingless bees	0.37	1.00	0.50
Ants	3.50	4.50	4.50
Honey bees	0.00	0.00	0.37
Wasps	2.50	2.25	2.37
Beetle	2.75	3.75	3.12
Lepidoptera	1.87	2.75	1.87
Other flies	3.62	4.25	4.37
Unknown	0.62	0.62	0.62

In all the yellow pan traps attracted the most number of insect followed by white and blue coloured traps (Fig. 3). Midges were recorded throughout the minor flowering season (October-January) and the major cocoa flowering season (April-July). The lowest number of midges was recorded towards the end of the minor flowering period (January). In the major flowering period a significant number of midges was recorded at the early stage (April) characterized by a decline and with the height number of midges recording.

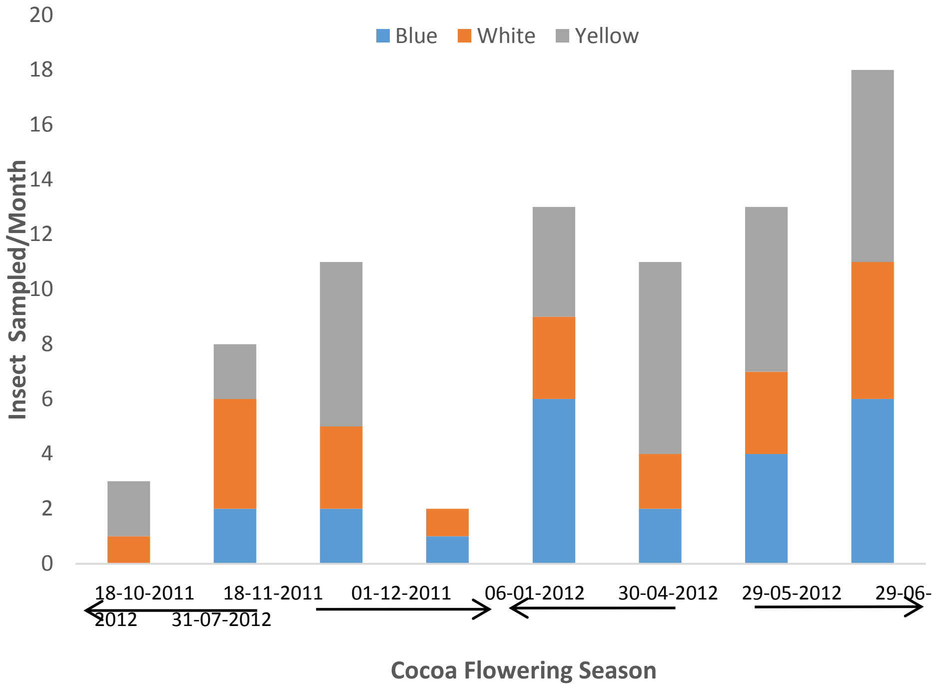

Figure 3. Number of *Forcipomyia* midges in sampled from cocoa farms near Bobiri Forest Reserve using different coloured (blue, white, yellow) pan traps at different cocoa flowering periods.

Stingless bees were only recorded in the minor cocoa flowering season (October-January) with the highest occurring in the latter period (December) (Fig 4). Few number of honey bees was recorded in the major flowering period (April-July). There was no recording of honey bees in the major season (October-January) (Fig. 5). For wasps there was a steady rise from the minor flowering period to the major flowering. The highest number of wasps was recorded in the major flowering season, characterized by a sharp fall in later period in the season (Fig. 6). The highest recording of ants occurred in the major flowering season. Ants were recorded throughout the period and did not appear to have preference for any particular season (Fig. 7). In general it was characterized by irregular rise and fall in numbers throughout the seasons.

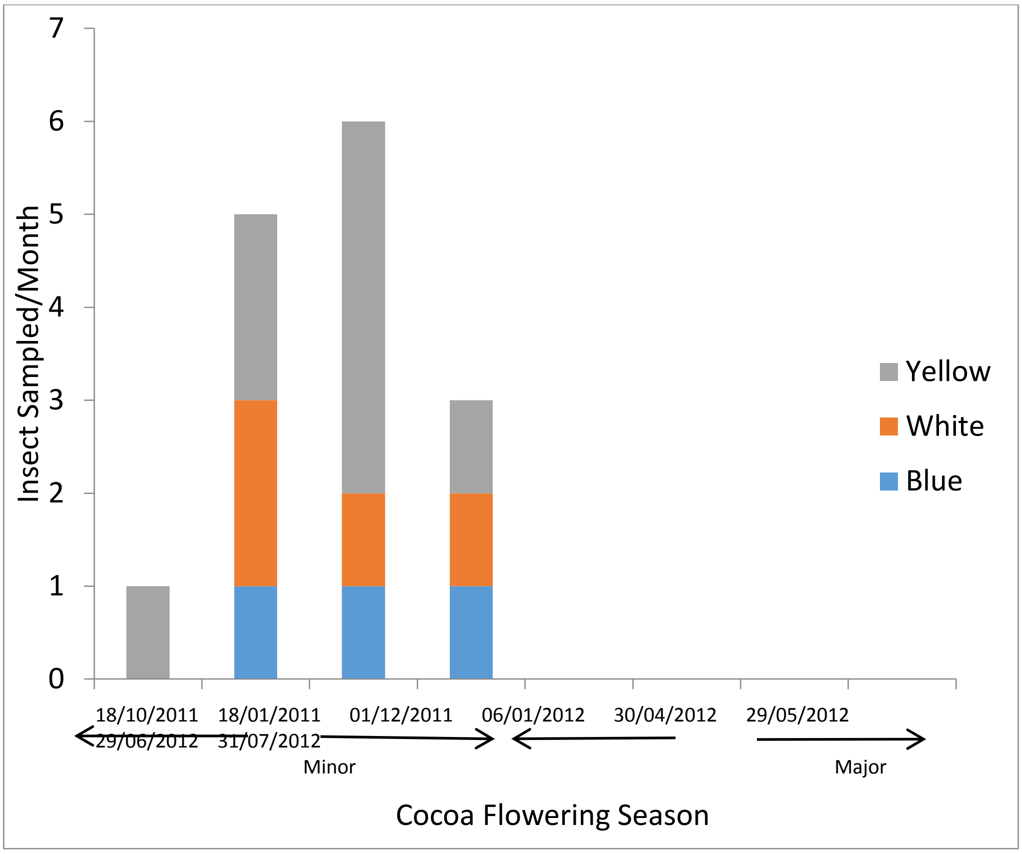

Figure 4. Number of stingless bees sampled from cocoa farms near Bobiri Forest Reserve using different coloured (blue, white, yellow) pan traps at different cocoa flowering periods.

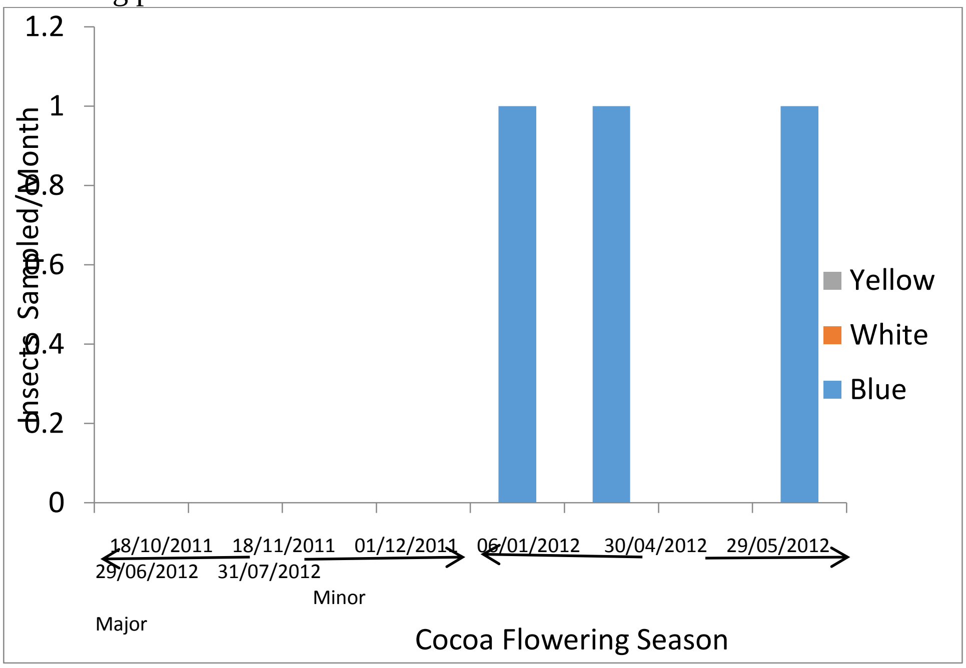

Figure 5. Number of honey bees sampled from cocoa farms near Bobiri Forest Reserve using different coloured (blue, white, yellow) pan traps at different cocoa flowering periods.

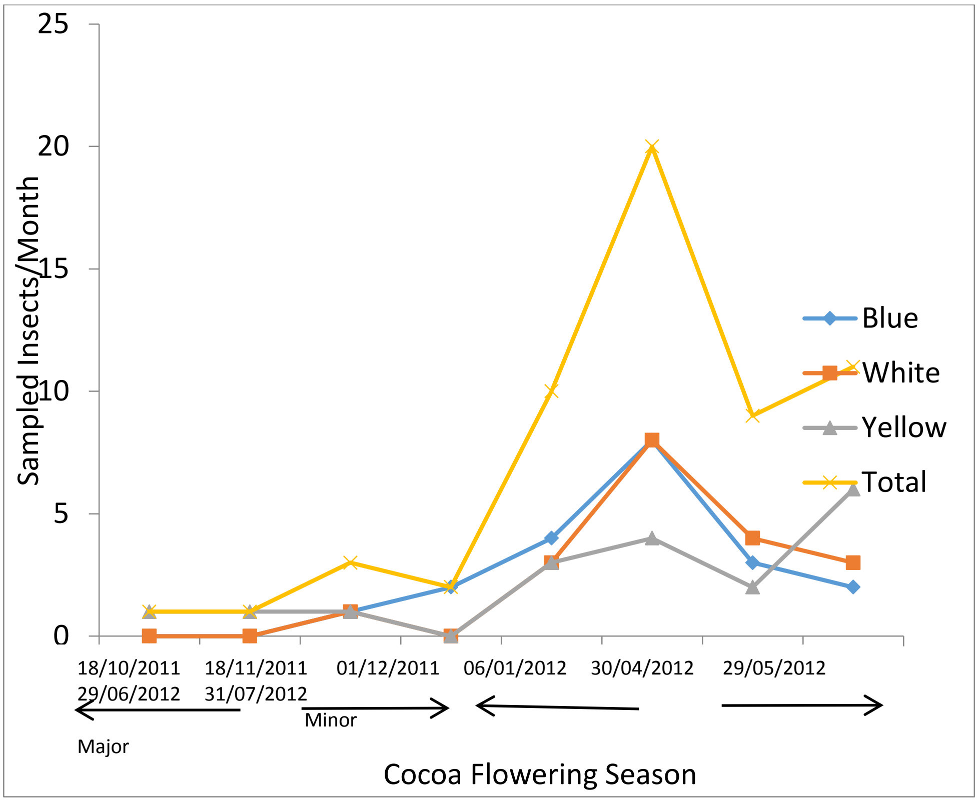

Fig 6: Population trends of wasps in the major and minor cocoa seasons

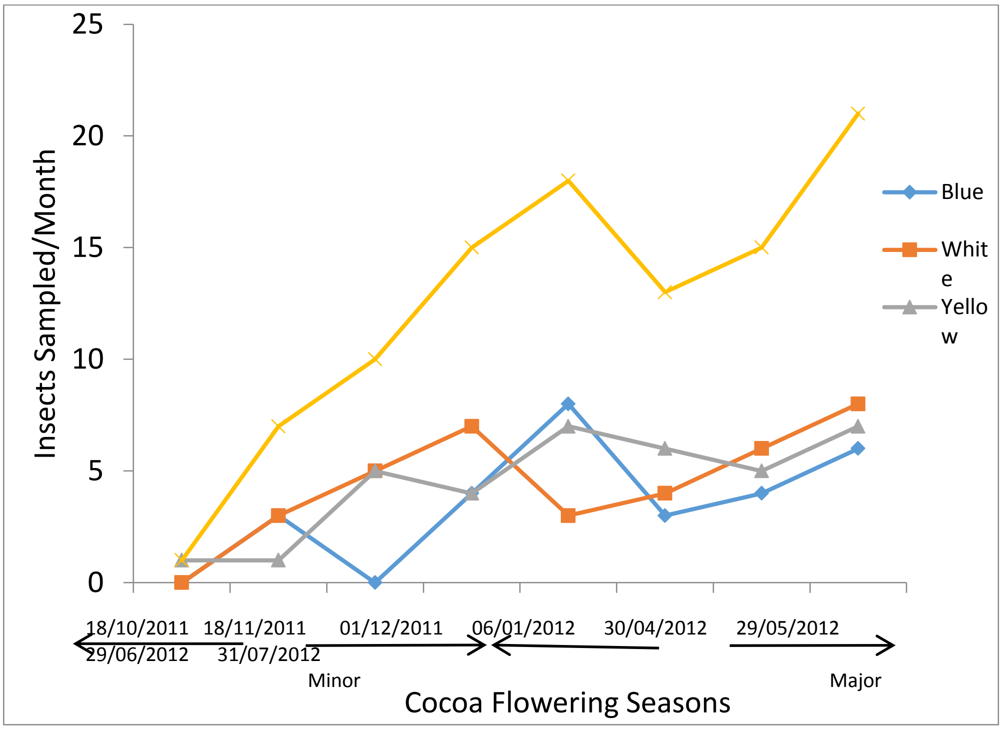

Fig 7: Population trends of ants in the major and minor cocoa seasons

There was a significant decline in the number of midges captured in the dry season, most especially during the peak period of the dry season. Midges' population in the cocoa ecosystem proved to be generally high in the wet season. Their population in the cocoa ecosystem started increasing at the beginning of the wet season and most intense at the later periods of the season.

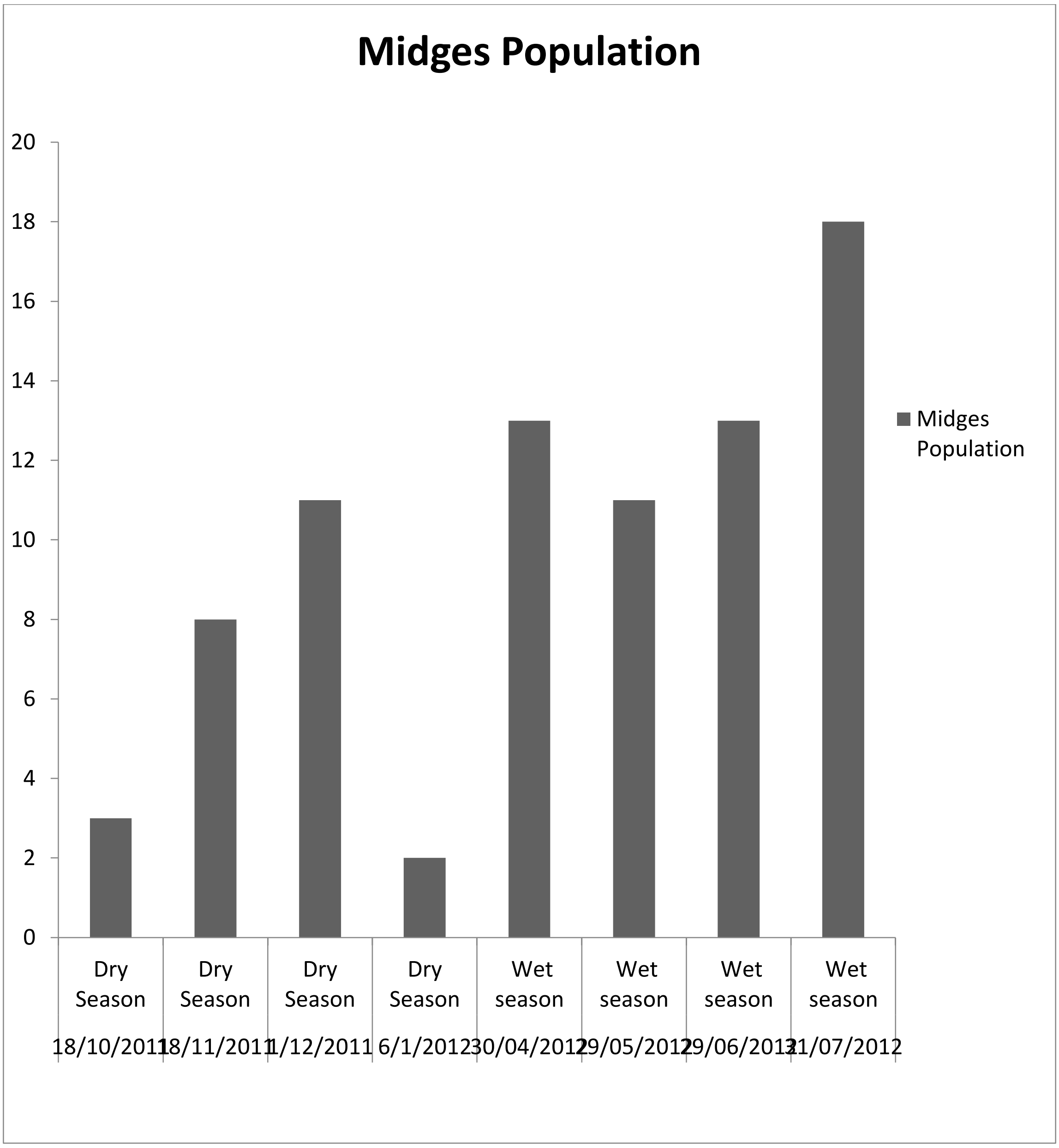

Fig 8: Population trends of midges in the dry and wet seasons

DISCUSSION

Apart from the *Forcipomyia* midges which are well-known insect pollinators in cocoa farms in Ghana (Frimpong, *et. al*., 2011; Adjaloo and Oduro, 2013), most of the insect species recorded in this study area were mostly Hymenoptera (ants, honey bees, wasps and stingless bees). Among the Hymenopterans ants dominated with a significant number. This may be due to their natural abundance and the important role in the tropical environment. Accordingly as stated by Hölldobler and Wilson, (1990) ants are ubiquitous, diverse, and abundant representing about 80% of the animal biomass in tropical ecosystems. Their abundance in the cocoa ecosystem may prove to be beneficial as some species have been identified as natural enemies to some pests. For example, in Ghana, Williams (1954) showed that cocoa trees with *T. aculeatum* and *Oecophylla longinoda* colonies were less damaged by mirids than neighbouring trees. Nonetheless, the presence of some ant species in the cocoa ecosystem may have negative economic effect to the cocoa farm. Accordingly, as observed by Evans 1973, some ants in Ghana are directly responsible for the propagation of the "black-pod" of cocoa (*Phytophtora palmivora*) causing considerable pod losses.

Within the same hymenopteran group honey bee and stingless bee populations were numerically small representing 3 (0.6%) and 15 (3.02%) respectively. This may suggest that even though these bees constitute a significant functional group due to their mutualistic interactions with plants, and belong to one of the most vital groups of globally acclaimed pollinators, they might not be pollinators of cocoa as suggested by Adjaloo *et al* (2012). Frimpong *et. al*., (2009) also observed low bee catches by pan traps and indicated that although this method has been found to be efficient in sampling bees, it appears inefficient under the cocoa farm architecture. This might also be the reason for the low numbers of bees recorded in this study.

Midges were significantly represented numerically in the order Diptera. This would prove to be very valuable as midges have been identified as key pollinators of cocoa (Kaufmann, 1975; Young, 1982a). In general insects in the order Diptera and Hymenoptera were most abundant in the cocoa ecosystem as observed by Adjaloo and Oduro (2013), which noted that regular visitors observed largely belonged to

Hymenoptera and Diptera. Coleoptera (beetles) and Lepidoptera were also numerically dominant representing 52 (10.48%) and 77 (15.52%), respectively.

The yellow coloured trap recorded the highest mean number of midges and ants. It also attracted other pollinators as such wasps, stingless bees, and a significant number of beetles. White coloured traps also attracted a significant number of pollinators dominated by ants and beetles. Cocoa pollinator midges were also attracted to the white coloured traps. Trap colour blue attracted the least number of insect throughout the monitoring cycle. The attraction of midges to the white and yellow traps would prove to be economically important in the cocoa ecosystem as yellow and white colour appear closer to the yellowish white cocoa flower.

The number of midges recorded significantly declined from the peak of the main cropping season (December) to the last period of the season (January) due to flower scarcity as most of the cocoa flowers being fertilized to developed into fruits during this period of harvesting. Accordingly, as stated by Glendinning (1971), cocoa flower declines to almost nil during the peak of the main cropping period, but increases somewhat as this crop is removed from the tree. Also at the beginning of the minor season which also coincides with the wet season the midge population increased in the cocoa ecosystem. Key pollinators such as honey bees and stingless bees were less represented throughout the monitoring period in the minor and major seasons. According to Cheeseman (1932) and Urquhart (1961), the cocoa flower produces no nectar and has no discernible scent. As a result the shortage of bees in the cocoa ecosystem could be due to the odourless nature of the cocoa flower which prevented bees from inhabiting the cocoa ecosystem. Ants were dominant throughout the main and minor cocoa season. Predominately more ant species were captured in the minor season.

Midge population in the cocoa ecosystem proved to be high in the wet season. Their population in the cocoa ecosystem started increasing at the beginning of the wet season and most intense at the later periods of the season. The results of the study are however similar to Entwistle (1958) who observed that midges appear in April-May, increase in numbers in October, and remain numerous to the end of the year. The abundance of midges in the wet season provided favourable conditions for breeding of midges. However a reverse of this occurred in the dry season. Midges' population significantly declined throughout the dry season especially in the severe dry season. This results support the findings of Glendinning (1971), that midges populations fall abruptly with the advent of the harmattan and continues to decline throughout the dry season.

CONCLUSION

The diversity of insects in the cocoa agroecosystem was mainly in the order Diptera, Hymenoptera, Coleoptera and Lepidoptera. Among these taxonomic orders, Diptera and Hymenoptera dominated in the cocoa ecosystem. Key pollinators such as the honey bees and stingless bees were few. Trap colour yellow and white were most attractive to pollinators in the study area. Cocoa pollinator midges were dominated in the cocoa ecosystem in both the main and major season, with majority of the midges being captured during the wet season.

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