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Arthropod diversity of cocoa farms under two management systems in the Eastern and Central regions of Ghana

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Abstract Diversity of insect communities can be used as bioindicators for change in the environment especially in farms under different management systems. In line with that, we conducted a research on insect species associated with cocoa under organic and conventional management systems in the Eastern and Central regions of Ghana. Insect collection was done using Hand height visual count, Canopy, and "Knock down", pitfall, coloured bowl and fruit-baited traps. A total of 13,742 individual insects belonging to 138 species from 63 families and 12 orders were recorded in the study. Insect abundance and diversity were generally higher in organic farms compared to conventional farms with *Oecophylla longinoda* as the most dominant species in both management systems and especially more dominant in organic cocoa farms. Our study revealed that most of the insect species recorded were known cocoa pests although there was high abundance of beneficial insects too. Some of the pest species were *Planococoides njalensis*, *Salhbergella singularis*, *Helopeltis* spp and *Pseudococus* spp, while some of the beneficial insects recorded were *Pheidole* spp, *Tegenaria* spp, *Camponotus* spp, *Crematogaster* spp. We can conclude that cocoa farms are potential habitats for insect biodiversity conservation. We recommend that management and/or agronomic practices used in cocoa farms should be geared towards protecting beneficial organisms for instance pollinators and natural enemies by effectively suppressing insect pest populations while enhancing good seed production.

Keywords Central region · Cocoa · Conventional · Eastern region · Farm · Ghana · Insect · Organic

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Introduction

Insects are known to be good indicators of environmental change (Acquah-Lamptey et al. 2013; Adu-Acheampong et al. 2016; Adu-Acheampong and Samways 2019a, b; Tiede et al. 2017; Kyerematen et al. 2018a; 2018b; 2020; Mensah et al. 2018; Nnoli et al. 2019). This is even so in differently managed agricultural systems such as highly intensive or conventional versus organic production systems and or with different shade levels (Schroth and Harvey 2007; Jacobi et al. 2014; Felicitas et al. 2018). The diversity and abundance of animals, especially insects, can be used to test ecosystems' health and pest management within different agricultural production systems (Loreau et al. 2002; Altieri and Nicholls 2004; Adu-Acheampong et al. 2016, Adu-Acheampong and Samways 2019a, b). For instance, it has been reported that arthropod community acted as indicators for disturbed, undisturbed and restored sites in coastal sage scrubs in California (Longcore 2003). In line with such studies it can be assumed that arthropod community in a highly intensive agricultural production environment, such as cocoa farms, could be used to show differences in environmental health or different production systems within comparable production practices and/or the impact of climate on production in different agro-ecological zones (Adu-Acheampong et al. 2016; Felicitas et al. 2018).

Cocoa was first introduced to Ghana in 1879 by Tetteh Quarshie (Manu and Tetteh 1987) and quickly became one of the major important export commodities with high foreign exchange inputs (Cashin et al. 2004; Piermartini 2004). Ghana has steadily increased cocoa production since the first introduction and has become one of the leading producers in the world currently (Kolavalli and Vigneri 2011; Läderach et al. 2013). Cocoa is one of the major pillars that sustain Ghana's economy contributing close to 30% of the total export earnings and proving livelihood to over six million people (Gockowski et al. 2011; Bangmarigu and Qineti 2018). The cocoa industry provides direct and indirect employment to over 2 million people through beans processing, farming, transportation and trade (World Bank 2011). Ghana is a leading producer of cocoa in the world after Ivory Coast with close to 20% of the total production on the international market (ICCO annual reports 2019). The total land size used for cocoa cultivation in Ghana is approximately 1.5 million hectares (Danso-abbeam et al. 2014). Although cocoa is invaluable to the Ghanaian economy, it is also beset with numerous problems that reduce yield and production quality (Pumariño et al. 2015). Some of these problems are poor soil fertility, climate change, weed, diseases and pests (Läderach et al. 2013; Kumi and Daymond 2015). Among the pest problems insect damage ranks high on the list although not all insects associated with cocoa production are pests (Pumariño et al. 2015; Rajendran 2016; Syarief et al. 2018).

Insect pests remain a major constraint to cocoa production in Ghana causing huge economic losses. For instance, it is estimated that attacks from insect pests such as *Distantiella theobroma* (Distant) (Hemiptera: Miridae), *Sahlbergella singularis* Haglund (Hemiptera: Miridae), *Bathycoelia thalassina* (Herrich-Schaeffer) (Hemiptera: Pentatomidae) and *Eulophonotus myrmeleon* (Felder) (Lepidoptera: Cossidae) reduce cocoa yield by 30–40 percent (Wessel and Quist-Wessel 2015). Due to pest menace in the cocoa industry and the difficulties in their management, farmers for some time now have resorted to the indiscriminate use of insecticides for their control (Bentum et al. 2006). This is partly because knowledge on other forms of pest management is not well disseminated and/or available. But even when such management methods are available, they are relatively expensive with slow impacts compared to the quick fix that chemical control offers (Hajek and Eilenberg 2018). The best practices in pest management control must be economical, effective against the target pest and simple to apply (Fening et al. 2013). Also, pest management should be aimed towards good environmental management practices.

In Ghana there are various methods of controlling pests within cocoa farms. These methods range from cultural, mechanical, chemical and biological. Various studies conducted on pest management and insect diversity assemblages show that organic farms are more diverse in insect assemblages and relatively more successful in implementing other forms of pest control such as biological control aside chemical use (Lichtenberg et al. 2017; Masoni et al. 2017; Hajek and Eilenberg 2018). For instance, studies conducted in Cameroon on the impact of different shades in different farm management systems on termite diversity show that there are more termite pests in lowly shaded cocoa farms compared to heavily shaded canopies (Felicitas et al. 2018) and also plant community structure influences termite invasion (Djuideu et al. 2020). However, there is little knowledge of insect diversity (including both pest and beneficial) in conventional versus organic cocoa farms in Ghana. This study was conducted to provide baseline information of insect diversity within cocoa farms under conventional and organic management systems in cocoa growing areas in the Eastern and Central regions of Ghana.

Specifically, we aimed to find the differences (if any) of insect diversity and/or abundance between organic and inorganic cocoa farms and their capacity to promote insect diversity, especially beneficial ones such as natural enemies of pests or pollinators of cocoa and decrease pest infestation on cocoa farms. Our hypothesis for this study was that there are differences in insect diversity of organically managed cocoa farms and conventionally managed (intensive chemical use) farms. Based on results from previous studies in other farms, we expected higher insect diversity in organic cocoa farms compared to conventionally managed farms. We also discussed possible explanations for differences in abundance of insect guilds in each production type and provided some recommendations for improved production practices in cocoa farms in Ghana.

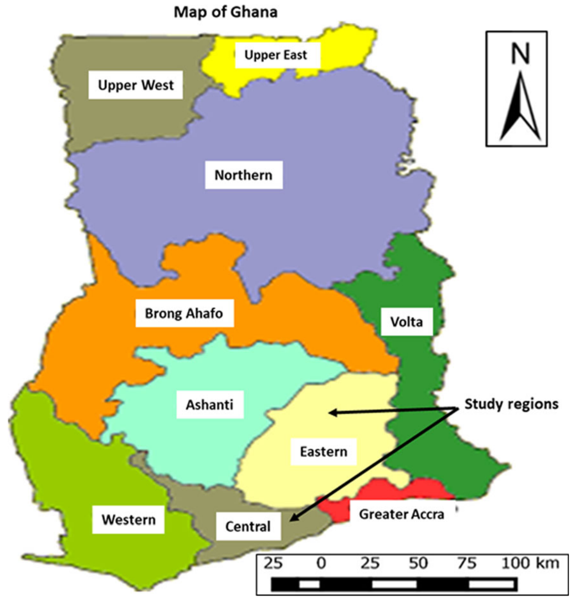


Fig. 1 A map of Ghana showing Eastern and Central Regions where organic cocoa farms and conventional cocoa farms were sampled for the study

Materials and methods

Sampling zones

The research was carried out in the Central and Eastern Regions of Ghana. Three conventional farms were randomly selected from Dunkwa (Central Region) and divided into six sampling areas. Likewise, three organic farms were randomly selected from Suhum in the Eastern Region which was divided into six sampling areas. The Eastern Region is a place where the majority of organic cocoa farming is practiced. Selected farms in both areas were one acre in size. Both the Central and Eastern Regions of Ghana have tropical climate with temperatures ranging from 21 to 32 °C. In the southern part of Ghana where both regions are located, there are two rainy seasons: April to July and September to October. The southern part of Ghana is humid with annual rainfall averaging 1200–1300 mm (Ofosu-Budu 2019; GMA 2017). The sampled global positioning system coordinates of the cocoa farms were 6° 01′ 21″ N, 0° 34′ 05″ W, 6° 01′ 25″ N, 0° 31′ 58″ W, 6° 00′ 47″ N, 0° 32′ 30″ W (Fig. 1) and the predominant vegetation within the sampled areas in the regions are *Chromolaena odorata, Panicum maximum and Pueraria phasoloides*. Cocoa farms within this zone contain both the Amazon and Amelonado cocoa varieties. Cocoa farms within the Central Region were located based on the Global positioning coordinates at 5° 58′ 04″ N 1° 47′47″ W, 5° 57′ 00″ N, 1° 47′ 38″ W, 5° 53′ 52″ N, 1° 50′12″ W (see Fig. 1) and the predominant vegetation within the studied area is also *C. odorata* and *P. maximum*. Cocoa farms within these areas are dominated by the Amazon and hybrid varieties of Amazon and Amelonado. Planting distances between cocoa trees in these farms were 3 m × 3 m. Tree ages of selected farms ranged from 8–22 years.

Insect collection

This study was carried out following insect collection protocols suggested by Gibb et al. (2006) and Samways et al. (2010), from August 2015 to January 2016. There were six main sampling methods used for insect collection. In the Hand-height-visual-count method, all visible parts of cocoa trees within a hand reach (1–2 m above the ground) were carefully searched for the presence of insects by observing nest distribution, co-existing and antagonism, foraging and mating positions. In the Ladder method, a count of insects was made from 2 m above ground ladder on 100 trees per acre. All tree parts below the ladder height were inspected for available insects. For the Knock-down method trees were sprayed with Bifenthrin known locally as ("Akate Master") within the inorganic farms and neem (*Azadirachta indica* L.) extract sprays within organic farms. The most important active ingredient of neem plant is azadirachtin. The inorganic cocoa trees were sprayed with Bifenthrin at a rate of 500 ml/ha while the organic farms were sprayed with Crude Aqueous Neem Seed Extract (ANSE) at a concentration of 20 kg in 100 litters of water per one hectare. Each of these methods was effective for knocking down and or killing different insect species in the different land uses. The farms were sprayed using a mist blower machine in the early morning between the hours of 5:30–6:00 am (insects are less active this period and easy to trap). We also collected insects using pitfall traps made of plastic buckets of 20 cm in diameter and 30 cm in height. These buckets were inserted into the ground with the rim level with the ground. The buckets were filled with a mixture of water and a detergent to break the surface tension of the mixture. We set three of these trap 30 m apart from each selected sampling site. Three yellow and pink coloured bowls each were placed on each farm litter. These bowls measured 20 cm x 8 cm and placed 20 m apart in each selected sampling site containing soapy solutions. Using different collection methods ensured as many insect species can be collected as possible within each land use. Insects were collected on weekly basis and transported in a container containing 70% ethanol into the laboratory identification. In all, we collected insects from three farms from each of the production types (organic vs. conventional), in 12 sampling locations (six for each land use type) for the study period. Fifty trees were sampled in each farm or sampling location. Six hundred trees were sampled for the study in total and each tree was sampled twice. Insects were sorted into orders using a stereomicroscope. Insect identification was done using voucher specimens from the Entomology museum of the African Regional Postgraduate Programme in Insect Science (ARPPIS), University of Ghana, Legon.

Data analysis

The relative abundance (R) of insects was calculated using the expression; $R = \frac{N_i \times 100}{T_n}$ where N_i = total number of individuals of the *i*th species and T_n = total number of individuals of all species. Shannon–Wiener diversity index (H') using $H' = -\Sigma pi \times \ln(pi)$ where n_i = number of individuals in the *i*th species and N = total number of individuals sampled, Pielou's Evenness was calculated by using the expression EH= H'/Hmax where H max = ln (S) = the maximum value that H′ can have for a particular sample, i.e. total even distribution, S = total number of species in the sample. Alpha SD, Berger Parker dominance was also calculated. Species richness was obtained using Estimate S (version 9.1.0) and was used to check for the completeness of species inventory in cocoa farms. Student's t test constructed in Statistica 13.2 (StatSoft 2013) was used to test for differences in insect diversity and/or abundance between organically managed and conventional cocoa farms. The list of insects in the two farm management options were generated by pulling together all insect species recorded for all sites under each management option. Species accumulation curves showing the species richness against the sample effort (monthly) were plotted using Microsoft excel.

Results

A total of 13,742 individual insects were recorded from both organic and inorganic farms in the study, with 8071 and 5671 individual insects from organic and inorganic farms, respectively. In total 138 insect species were collected from both farms, belonging to 12 orders and 63 families. The total number of entomofauna collected from organic cocoa farms was significantly higher compared to that of conventional cocoa farms. Insects belonging to the orders Hymenoptera, Coleoptera and Diptera were the most diverse in both management systems (Table 1). A hundred and nine (109) insect species were recorded within the organic cocoa farms while eighty-seven species (87) were recorded within conventional cocoa farms. The percentage relative abundance of the entomofaunal families collected from cocoa farms in both management options is given in Fig. 2. The four most dominant orders recorded within organic cocoa farms were Hemiptera (43.2%), Hymenoptera, Orthoptera and Coleoptera accounting for 41.3%, 5.3% and 5.3%, respectively, while Hemiptera had the highest count with a relative abundance of 54.7% followed by Hymenoptera, Coleoptera and Diptera with 32.3%, 5.1% and 2.8%, respectively, in conventional cocoa

Table 1 A list of insect species belonging to the three major insect orders collected in organic (ORG) and inorganic (INORG) cocoa farms in Ghana

Order	Family	Species	Org	Inorg
Coleoptera	Chrysomelidae	*Chrysomela* sp1	2	0
		Ootheca mutabilis	1	2
		Chrysomela populi	1	0
	Scarabaeidae	*Sisyphus scaefferi* (Fab)	399	227
		Circellium bacchus	1	0
		Gymnopleurus sp1	5	0
		Geotrupes sp1	8	53
		Colobopterus sp1	0	1
		Geotrupes splendidus (Fab)	0	3
		Geotrupes stercorosus	0	1
		Maladera holoserica	1	0
	Curculionidae	*Proicetes curvipes* (Hust)	1	0
		Haplocorynus sp1	1	0
	Carabidae	*Brachinus* sp1	1	0
		Bembidion stomoides (Dejean)	0	2
		Bembidion sp1	0	1
	Cerambycidae	*Lascia* sp1	1	0
	Eleteridae	*Adrastus pallen*	1	0
		Actenicerus sp1	1	0
	Mycetophagidae	*Berginus tamarisci* (Wollaston)	2	0
	Tenebrionidae	*Tenebrio molitor*	1	0
	Phalanoridae	*Stilbus nitidus*	3	0
	Anobiidae	*Stegobium paniceum* (Linn)	2	0
Diptera	Asilidae	*Efferia pogonias* (Wiedemann)	2	0
	Ceratopogonidae	*Forcipomyia ingrami* (Carter)	34	2
		Forcipomyia ashanti	13	11
		Heteromyia sp1	8	26
	Rhagionidae	*Rhagio* sp1 (Linn)	1	0
		Rhagio scolopacea	1	0
		Rhagio mystraceus	0	3
	Chiromidae	*Chironus* sp1	2	0
		Chironus plumosus	0	1
	Anthomyidae	*Delia brassicae*	5	0
	Tachinidae	*Tachina* sp1	20	93
	Caliphoridae	*Lucilia Caesar* (Linn)	4	0
		Lucilia sericata (Meigen)	1	0
		Lucilia sp1 (Linn)	1	0
	Tipulidae	*Tipula abdomalis*	0	2
		Tipula acuta (Doane)	0	5
		Tipula sp1	0	1
	Conopidae	*Mayops* sp1	0	1
		Sicus sp1	0	12
	Sciomyidae	*Sepedon fuscipennis* (Loew)	0	1
		Chaelopsis sp1	0	1

Table 1 continued

Order	Family	Species	Org	Inorg
	Muscidae	*Musca domestica* (Linn)	1	0
Hymenoptera	Formicidae	*Camponotus saunderi* (Fab)	47	78
		Polyrachis sp1 (Wlk)	37	4
		Pheidole sp1.	351	187
		Polyrhachis sucata	15	0
		Camponotus pennsylvanicus (Bolton)	6	0
		Odontomacus sp1 (Linn)	173	29
		Parthothyrus sp1	20	37
		Catagraphis tortis	2	0
		Camponotus compresus	12	56
		Crematogaster sp1 (Emery)	340	411
		Cylindromyrmex whymperi (Wheeler)	1	0
		Oecophylla longinoda (Latreille)	2031	948
		Crematogaster striatula (Emery)	0	67
		Tetragonula carbonaria	19	1
		Myopias concava (W&B)	0	2
		Solenopsis xyloni (Mc cook)	2	2
		Pachycondyla sp1	1	0
		Sphinctomyrmex sp1 (Mayr)	1	0
		Camponotus sp1	260	1
		Tetramorium sp1 (Mayr)	4	0
	Sphecidae	*Sceliphron* sp1	3	0
		Sphex sp1 Linn	0	2
		Podaloma sp1 (Scopoli)	0	1
		Ectemnius sp1	3	0
		Trypoxylon sp1.	0	1
	Braconidae	*Bracon* sp1	2	1
	Berthylidae	*Pristocera* sp1	0	2
		Laelius pedatus	0	1
	Pompilidae	*Auplopus carbonarius*	0	1

farms. The dominant insect pests and natural enemies recorded in both the organic and inorganic cocoa farms were *P. njalensis* and *O. longinoda*. Our study also recorded a very high *Crematogaster* spp in conventional cocoa farms compared with organic farms.

The majority of the insects were collected during the period between September and November where most cocoa farms have reached their peak pod bearing stage. Also, our study showed that there was a relatively high abundance of predatory insects such as *Pheidole* spp, *O. longinoda*, *Tegenaria* spp, *Camponotus* spp and *Crematogaster* spp in organic cocoa farms compared to conventionally managed farms and might have accounted for high insect predation and population management compared to the former. The results also showed that, Shannon, $H' = 0.478$, Evenness, 0.10, Alpha $SD = 0.49$ and Berger Parker, $d = 1.72$ were lower in the organic farms compared to conventionally managed cocoa farms. Species evenness was relatively low for both organic and conventional cocoa farms (Table 2). Estimated species richness of insects captured using Incidence-based estimator (Chao 1), Abundance-based estimator (Chao 2), First-order jackknife estimator (Jack 1), Second-order jackknife estimator (Jack 2),

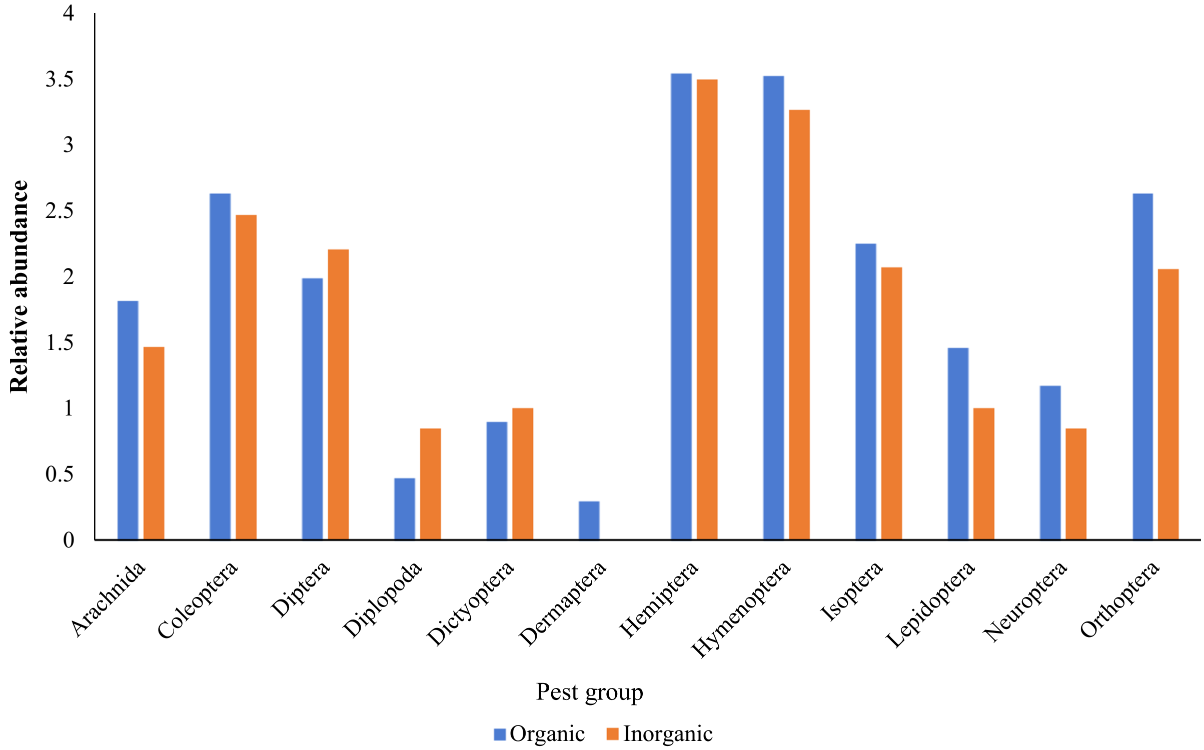


Fig. 2 The relative abundance of the 12 orders of arthropod (insects) pests recorded in the study

Table 2 Diversity indices of insect species in both Semi Deciduous Forest and Rain Forest Agro-ecological Zones of Ghana

Diversity indices	Organic cocoa farms	Inorganic cocoa farms
Shannon, H'	0.478	0.83
Evenness	0.10	0.19
Alpha SD	0.49	0.648
Berger Parker, d	1.72	2.43

Abundance-based coverage Estimator (ACE) and Incidence-based coverage Estimator (ICE) per farm management type is shown in the species accumulation curves for organic and conventional cocoa farms, respectively. Species accumulation curves constructed for both organic and conventionally managed cocoa farms were approaching asymptotically infinite showing that both sampling efforts and species realized in the study were adequate (Figs. 3 and 4). Results of the student *t* test showed that insect abundance was significantly higher in organic cocoa farms compared to conventional cocoa farms ($P > 0.01$). Also, student t-test result in insect diversity was significantly lower in organic cocoa farms compared to conventional farms ($P > 0.01$). Mann–Whitney U test of significance difference in seasonal abundance of insects at the two land uses showed that there were no significant differences between the trapping systems used with the exception of the fruit-baited traps which was highly significant $P > 0.0001$.

Discussion

The study recorded all the major pests of cocoa in Ghana. These include mealy bugs, stem borers mirids,

Fig. 3 Species accumulation curve for insects associated with conventional cocoa farms in Ghana

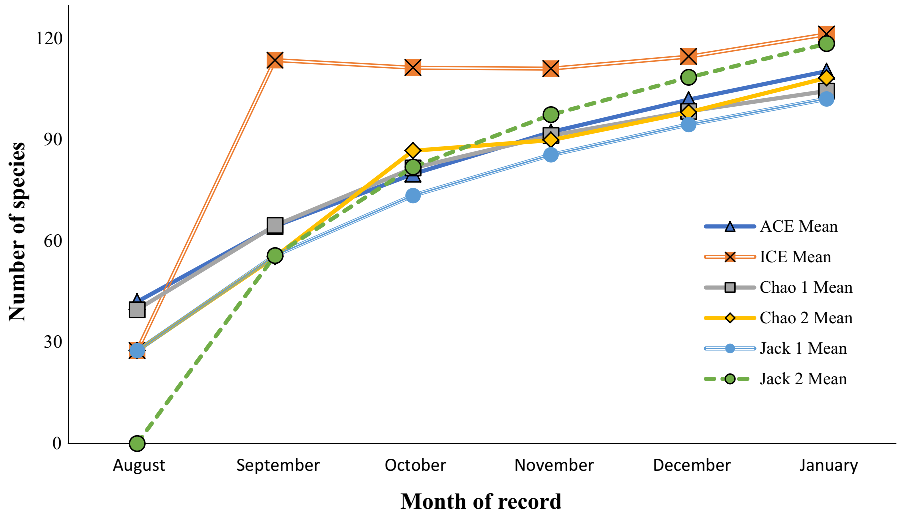
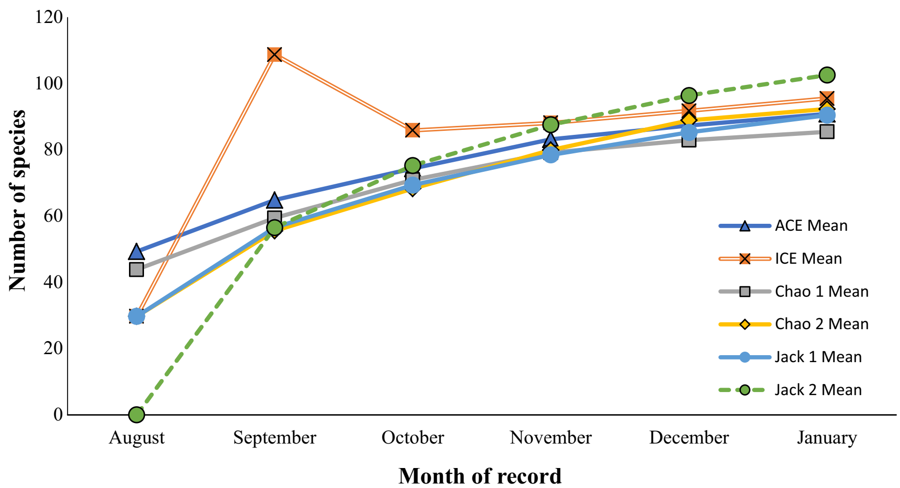


Fig. 4 Species accumulation curve for insect species associated with organic cocoa farms in Ghana



pod borers, shield bugs, defoliators and termites. Also, the most abundant species and/or natural enemy that was encountered for this study was *O. longinoda* in both conventional and organic cocoa farms. Although *O. longinoda* was found to be common in both land uses, population in organic farms was significantly higher than that of conventional farms. We also observed that other natural enemies such as *Camponotus* spp, *Phiedole* spp, *Tegenaria* spp, *Crematogasto*r spp. *Odontomacus* spp. and *Heteropoda venatoria* were significantly higher in organic cocoa farms compared to conventional farms. This could be because of the continuous use of pesticides in conventional farms that might have had adverse effect on natural enemy population (Altieri and Nicholls 2004; Bawa et al. 2011; Muneret et al. 2018). Taking natural enemy population into consideration, we can confirm that our hypothesis for this study has been proved. The relatively large presence of *O. longinoda* in organic cocoa farms is an indication that organic farms are better protected from insect pests attacks because of the protection they give to close to 12 different crops by their predatory activities on about 40 insect pest species (Way and Khoo 1992; Gotwald 1995; Peng and Christian 2005; van Mele 2008; Bisseleua et al. 2017).

The most abundant pest recorded in organic farms was *P. njalensis*. Some other pests recorded in organic farms were *Macrotermis* spp, *S. singularis* and *Helopeltis* spp. This finding agrees with that of Padi

Table 3 A list of arthropod species collected in organic (ORG) and inorganic (INORG) cocoa farms in Ghana

Order	Family	Species	Org	Inorg
Arachnida	Sparassidae	*Heteropoda venatoria* (Linn)	6	0
		Phidippus audax	0	3
	Agelenidae	*Tegenaria gigantea*	0	1
		Tegenaria sp1	59	19
	Gnaphosidae	*Zelotes* sp1	0	3
	Araneidae	*Mastophora gasteracanthoides*	0	2
Diplopoda	Spirostreptidae	*Peridontopyge* sp1	1	1
	Platyracidae	*Polycleamida* sp1	1	0
		Blamulus sp1	0	3
	Spirobolidae	*Narceus annilaris*	0	2
Dictyoptera	Blattidae	*Periplanita americana* (Linn)	0	1
		Platyzosteria sp1 (McCaffrey)	2	0
		Blatella germanica (Linn)	0	7
	Mantidae	*Mantis religiosa* (Linn)	5	1
Dermaptera	Forficulidae	*Anisolabus* sp1	1	0
Hemiptera	Miridae	*Helopeltis antonii* (Signore)	19	48
		Sahlbergella singularis (Hagl)	67	483
		Chamus sp1	2	0
	Pentatomidae	*Bathycoelia thalassina* (HS)	48	91
		Halymorpha sp1	1	0
	Ricanidae	*Ricania cervina*	1	0
	Pyrrhocoridae	*Dysdercus supertitious*	3	0
		Dysdercus sp1 (SF)	496	59
	Coriedae	*Cletomorpha larcigera*	1	0
		Rhyparochromus sp1 (Raglius)	0	4
		Largus sp1	0	2
	Cydnidae	*Sherus cinitus*	1	0
	Cicadelidae	*Cicadelida* sp1	0	1
	Derbidae	*Kamendaka albomaculata* (Muir)	269	87
	Reduviidae	*Glymmatophora* sp1	1	1
	Pseudoccocidae	*Pseudoccocus* sp1 (Gahani)	939	692
		Planococcoides njalensis (Laing)	1557	1389
	Cicadellidae	*Typhlocyha* sp1	2	0
	Psyllidae	*Tyora tessmanni*	43	102
	Aphididae	*Toxoptera aurantii* (Boy)	38	145
Isoptera	Termitidae	*Macrotermis* sp1	171	69
		Microtermis sp2	7	47
Lepidoptera	Noctuidae	*Characoma* sp1 (Wlk)	2	0
		Earias biplaga	0	2
		Eublemma sp1	1	0
		Prodenia litura (Fab)	1	0
	Zygaenidae	*Praezygaena agria* (Distant)	1	0
	Pyralidae	*Sylepta* sp1	1	1
		Musidia pectinconiella	1	0
	Satyridae	*Dysdercus mimulus*	1	0
	Papilionidae	*Papilio demodocus* (Linn)	21	6

Table 3 continued

Order	Family	Species	Org	Inorg
Neuroptera	Cryosopidae	*Crysopa oculata* (Say)	14	6
Orthoptera	Acrididae	*Acanthacris ruficornis* (Fab)	1	0
	Occanthidae	*Occanthus* sp1	1	2
		Occanthus pellucens	1	0
	Tettigonidae	*Zabalius lineolatus* (Stal)	3	0
		Scuddena forcata (Porum)	1	0
	Gryllidae	*Gryllus similis* (Chap)	5	13
		Gryllus sp1	17	84
		Gryllus lucens (Chopard)	0	1
		Gryllus sigillatus (Wlk)	1	0
	Tetrigidae	*Pantelia horrenda* (Wlk)	1	0
		Tetrix sp1	1	0
		Valanga irregularis	3	0
		Tettigonia viridissina	0	12
		Microcentrum rhonbifolium (Saus)	4	0

and Acheampong (2001) who reported that *S. singularis* is the most dominant mirid species on cocoa farms in Ghana. Although *Pseudococus* spp. and *T. aurantii* were highly present in both land uses, they are reported to be minor pests in West Africa unlike Peru where these insects are known to be major pests (Willie 1944; Awudzi et al., 2009). Most of the insect pests recorded for this study occurred at the fruiting stages of the cocoa trees as has already been reported in another study in the Eastern Region of Ghana (Bawa et al. 2011). Bawa et al. (2011) reported that there is a positive correlation between food availability and insect abundance within cocoa plantation.

The study further revealed that, organic farms had significantly fewer number of mirid attacks compared to conventional farms (see Table 3). In general, there were more records of insect pest species in conventional farms compared to organic cocoa farms. Nevertheless, it has been reported that cocoa that grow under shady environment are relatively less biodiverse compared to less shaded environment (Bentley et al. 2004; Felicitas et al. 2018), but this did not affect our results because sampling was conducted under a mixture of shaded and unshaded cocoa farms for both land uses for the study. Our results further showed that the diversity indices in the organically managed cocoa farms were relatively lower than conventionally managed farms. The majority of the insects were obtained during the period between September to November when most cocoa farms have reached their peak in terms of pods bearing indicating that the peak insect activity also coincide with the peak production period within cacao farms. Our results further show that most of the insect species associated with cocoa are not pests.

The absence of pesticides in organic cocoa farms has undoubtedly positively impacted the natural enemy population in organic cocoa farms in this study. Recorded species in the study such as *O. longinoda* can be encouraged as potential biocontrol agent against *S. singularis*, *P. njalensis*, *Helopeltis* spp, *T.aurantii* and *B. thalassina* as done elsewhere (Bagny Beilhe et al. 2018). Lessons from this study have provided further proof that insect diversity especially predators guild can be used as potential bioindicators to check production practices and health within farming systems. It further shows that although conventional farming practices may seem to promote biodiversity of insects, there is an increase in pestiferous insects at the expense of natural enemies. This has led to continuous pesticides use which is cyclical within conventional cocoa farms in Ghana. Promoting organic cocoa farming is likely to lead to well established biological pest control systems as a result of increasing natural enemy populations in the study areas (Bagny Beilhe et al. 2018). Many hundreds of insects and pathogens have been recorded on cocoa, but only a small number of these are economically significant in West Africa (CABI Commodities 2004). Based on evidence from this study and the report from CABI in 2004, we can state that the cocoa farm environment has served as refugia for insects and hence has been a sanctuary for insect conservation.

Conclusion

Our study provides a species list of some of the insects in cocoa farms in the Central and Eastern Regions of Ghana. The study also revealed that conventional cocoa farms recorded a relatively higher diversity of insect pest species compared to organic cocoa farms with high abundance of the major cocoa pest species such as *H. antonii*, *S. singularis*. On the other hand, organic cocoa farms recorded a relatively lower pest diversity in general but higher natural enemies such as predatory insects, e.g. *Pheidole* spp, *O. longinoda*, *Tegenaria* spp, *Camponotus* spp. and *Crematogaster* spp. compared to conventional cocoa farms. Due to the relatively lower presence of pest species in organic cocoa farms because of the high presence of natural enemies, we believe that promoting population build-up of these natural enemies on the farms could contribute in the control of the major cocoa pests in Ghana. We can also conclude that, due to the relatively high insect population recorded in cocoa farms, it can be regarded as an environment where insect biodiversity could be promoted especially for beneficial insects.

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