Diversity of maize, cowpea and okra insect pests and influence of intercropping system on their major insect pests in the Cameroonian Guinean Savannah and Sudano Sahelian agro-ecological zones

Abstract

Intercropping has been shown as a non-chemical solution of insect pest problem. Field experiments were conducted during the 2016 and 2017 cropping seasons in the Guinean Savannah (Dang-Ngaoundéré) and Sudano Sahelian agro-ecological zones (Gouna-Garoua), Cameroon, to determine the diversity of maize, cowpea and okra insect pests and to evaluate the influence of intercropping system on their major insect pests. The experiment was designed by split plot arrangement in a randomized complete block with four replications. The main factor was assigned for the use of insecticide and sub plots were devoted for cropping systems. From data collected in unsprayed plots, the cowpea crop was found to be attacked by a total of 19 different species. Only 03 of these were considered major pests at Dang, namely *Ootheca mutabilis*, *Megalurothrips sjostedti* and *Aphis craccivora* and 06 at Gouna, namely *O. mutabilis, M. sjostedti, Maruca vitrata, Clavigralla tomentosicolis, Anoplocnemis curvipes,* and *A. craccivora*. The major insect pests of maize and okra did not differ in the two sites. For maize we recorded *Spodoptera frugiperda* and *Busseola fusca, for* okra *Podagrica decolorata* and *Bemisia tabaci*. Cypermetrin reduced significantly the number of these insect pests compared to the unsprayed plots in the sites of both agro-ecological zones. Among the unsprayed plots intercropping showed in most comparisons significant reductions ($P < 0.001$) of the major insect pests. However, in detail the results differ with the crops, with years (2016 and 2017) and between the two locations.

Keywords: maize, cowpea, okra, insect pest, Cypermetrin, intercropping, Dang-Ngaoundéré, Gouna-Garoua

1. INTRODUCTION

In Sub-Sahara Africa, agriculture accounts for 15 % of gross domestic product and employs more than half of the total population [1]. Since the 1960's, this sector has had an average economic growth rate of 1.7 % to 1.9 % per annum [2]. In Cameroon, it contributes to about 17 % of the gross domestic product and employs 62.01 % [3]. Unfortunately, this sector which is one of the priority areas for development has become less productive. One of the key objectives of agricultural research in Cameroon is to obtain high and sustainable yields to feed the growing population [4]. To achieve this goal, total productivity of predominant crops should be increased.

Maize is the most produced cereal worldwide. In Africa alone, more than 300 million people depend on maize as their main food crop [5]. In addition, it is also very important as feed for farm animals and used for alcohol fabrication. In Cameroon it production amounted by 2013 to 1 647 036 t and the West region is the first producer followed by North, Center and the Adamawa region [6].

Okra constitutes a major economic activity in Africa. This crop can be grown on a large commercial farm or as a garden crop as maize [7]. The immature pods are used as boiled vegetable and contain protein of about 1.6-2.2 %, carbohydrate, vitamin A, B and [8]. In dried form it is used as soup thickener. The mature seed is known to have superior nutritional quality. In Cameroon, the Far north region is the first producer followed by North West, West and the South regions [6].

Cowpea (*Vigna unguiculata* (L) Walpers, Fabaceae), is an important edible legume crop in many parts of the world. The largest production is in the moist and dry Savannas of Sub-Saharan Africa (SSA), where it is intensively grown as an intercrop with other cereal crops like millet, sorghum and maize as well as rice fallows [9]. It is used as human food and also as livestock feed to make silage and hay. Cowpea grains are well known for their protein content. The grain contains 26.61 % protein, 3.99 % lipid, 56.24 % carbohydrates, 8.60 % moisture, 3.84 % ash, 1.38% crude fiber, 1.51 % gross energy, and 54.85% nitrogen free extract [10]. The young leaves and immature pods are eaten as vegetables. Cowpea also plays an important role in providing soil nitrogen to cereal crops (such as maize, millet, and sorghum) when grown in rotation [11]. In Cameroon, the Far North region is the first producer followed by North, Center and the littoral region [6].

One of the major constraints in crop production in Africa is the high incidence of insect pests which cause heavy losses. Maize, cowpea and okra were reported to be heavily attacked by insect pests. In Cameroon, research on maize insect pests were done in the forest and mid-altitude zones [12, 13, 14, 15]. Cowpea insect pests were reported in the southwest forest and western derived savannah zones [16], in the Guinean savannah zone of Cameroon [17, 18]. Some of the insect species regarded as majors pests by these authors where *Busseola fusca, Sesamia calamistis*, for maize plant, *Megalurothrips sjostedti*, *Maruca vitrata* for cowpea.

The high crops losses attributed to insects lead farmers to use chemical insecticides for controlling these agricultural pests whereas chemicals are judged to be unfriendly with environment [19, 20]. Moreover, they has caused many health hazards which results into physiological impact, neurotoxicity, reproductive toxicity, molecular toxicity [21]. Intercropping, the practice of growing more than one crop simultaneously on the same field has been shown as a non-chemical solution of this problem.

Incorporating intercropping principles into an agricultural operation increases diversity and interaction between plants, and others organisms. Many authors studied the effects of intercropping system on the infestation rates of insect pests in various crops. Field trials in West Africa showed that, depending on the crop association, mixed cropping reduced lepidopteran borer density by 44.4 % - 83.0 % on maize crop [22]. Maize intercropped with grain legumes or cassava reduced amount of noctuid eggs laid by *Sesamia calamistis* and *Busseola fusca* than those in monocrops in Cameroon [15]. Some study reported a less damage by pod borers on cowpea intercropped with maize [23]. It was demonstrated that cowpea + sorghum intercrop reduced significantly the population of *Aphis craccivora* compared to sole cowpea crop in Nigeria [24]. Intercropping of okra with sorghum was also reported as a solution of *Podagrica* population in Nigeria [25].

In the Sudano-Guinean and Sudano-Sahelian agro-ecological zones of Cameroon, farmers cultivate maize in association with cowpea and okra, but according to our knowledge, there have been no scientific studies to test the efficiency of these intercropping systems against harmful insects. Moreover, no previous research has been conducted to document the spectrum of the major insect pests of maize, cowpea, and okra in these agroecologial zones whereas knowledge of insect pest complexes are the basis to develop effective pest management systems.

The present work was therefore conducted to:

- Document the spectrum of insect pests associated with cowpea, okra and maize in the two agroecologial zones;
- Determine the major insect pests associated with cowpea, okra and maize in the two agroecologial zones;
- Evaluate the effect of intercropping system between maize-cowpea, maize-okra and maize-okra-cowpea on the population of their major insect pests in two agroecologial zones

2. Material and Methods

2.1. Study sites: Studies were conducted from July to November 2016 and 2017 in the Sudano-Guinean agro-ecological zone (Dang-Ngaoundéré Latitude 07°24’08.2” N; Longitude 13°33’01.6 E; Altitude 1094 (± 2m).) and Sudano Sahelian agro-ecological zone (Gouna-Garoua Latitude 08°29’53.4” N; Longitude 13°31’00.3 E; Altitude 402 (± 2m).) of Adamaoua and North, respectively, Cameroon.

2.2. Experimental set-up, sowing and weeding: The experiment was designed through split plot arrangement in a randomized complete block with four replications. The main factor was assigned for the use of insecticide and sub plot were devoted for cropping systems consisting of:

1) Maize in monoculture spacing with 80 cm apart and 50 cm between plants;

2) Cowpea in monoculture spacing with 80 cm apart and 30 cm between cowpea plants;

3) Okra in monoculture spacing with 80 cm x 40 cm;

4) Maize intercropped with okra. Maize was planted as in monoculture and the seeds of okra were planted in the middle of the lines of maize;

5) Maize intercropped with cowpea. Maize was planted as in monoculture and the seeds of cowpea were planted in the middle of the lines of maize;

6) Okra intercropped with cowpea. Okra was planted as in monoculture and the seeds of cowpea were planted in the middle of the lines of okra;

7) Maize-cowpea-okra intercropping. Maize was sown as in monoculture. The okra seeds were planted at 30 cm from the first line of maize and the cowpea seed were planted at 55 cm from the same maize line.

For all treatments, 3 - 4 seeds of cowpea, 3 - 4 seeds of maize and 4 to 6 seeds of okra were sown per hole. After germination (two weeks), the plots were thinned to one plant per planting hole for maize and okra plants and to two plants per hole for cowpea.

Weed control was done by hand using a hoe when needed. Cypermetrin a chemical insecticide recommended for the plant protection against arthropods was used. It is a mixture of all eight possible chiral isomers [26]. Pulverization of the control plot began two weeks after sowing till the crops got matured with intervals of one week.

2.3- Assessment of maize insect pest's population

The diversity and density of different maize insect pests species, across systems was performed on 40 maize plants per treatment sampled randomly on the experimental plots at plant physiological maturity. Stems picked were split and lepidopteran borers at the larval stages were collected identified and counted. Afterwards, the cobs found were shelled and the insect pest species present were collected, identified and counted.

2.4- Assessment of okra insect pest population

Observation was done between 6 and 10 am on 10 plants tagged at random from each sub plot. Assessments were done from 4 weeks after sowing at 2 week intervals for 5 weeks. Observation was done on the leaves, stem, flowers and fruits. Insects species found were identified and counted.

2.5- Assessment of cowpea insect pest population: The number of insects present in each plot was determined through counting when plants were at the flowering stage between 6 and

10 am on 10 plants tagged at random from each sub plot. Assessments were done twice a week until 3 weeks. It is at this time where insect are more abundant [27]. Observation was done on the whole plant and insect found were recorded. Data on insects which damaged flowers were recorded on 10 flowers chosen on the 10 plants per sub plot and placed in vials containing 30% ethanol. Flowers were later desiccated in the laboratory and the number of insects found were recorded [28].

2.6- Classification of insects found into 'major' and 'minor' pests

Classification of insects into 'major' and 'minor' pests was based on observations on the incidence, abundance and the degree of importance of the damage caused by these pests in the field [29].Considered data were those recorded on maize, cowpea and okra in monoculture unsprayed.

2.7 The diversity indices

In each study site and for each cropping system, we assessed diversity by species number and the indices of diversity of Shannon Weaver and Simpson. Considered data were those recorded on maize, cowpea and okra in monoculture not protected by insecticide.

The diversity index of Shannon-Weaver is based on the formula: H' = - Σ ((Ni / N) *log2 (Ni / N)), with Ni: the number of individuals of a given species, and N: total numbers of insects, H' lies between 1 and 5. The maximum index is attained when all the individuals are equally distributed for all species.

Evenness index: This index makes sense to consider species richness and species evenness as two independent characteristics of biological communities that together constitute its diversity [30]. The formula using is : J = H'/Hmax; Hmax = logS. S is the number of species in the sample.

The index of Simpson (1949) measures the probability that two randomly selected individuals to belong to the same species: D = Σ Ni (Ni-1)/N (N-1), where Ni: the number of individuals of a given species and N is the total number of insects. The diversity index of Simpson is calculated by 1-D. Maximum diversity is represented by 1, and minimal diversity by 0. This index of diversity gives greater importance to dominant species.

Relative abundance: this indicates the chance (p) to "meet" an individual insect in the field [31]. It was calculated using this formula: $\mathrm{Ra_i} = \frac{\mathrm{Ni}}{\mathrm{N}}$ Where: $\mathrm{Ra_i}$: relative abundance of species i; Ni: the number of individuals of a species i; N: total numbers of insects;

Data analysis: data obtained were subjected to descriptive statistics, Analysis of variance (ANOVA) and the Tukey test for separation of more than two means using the SPSS software 16.0. The Student's t -test was used for comparison of means of two samples from the agro ecological zones using XLSTAT.

RESULTS

1. Diversity and major insect pests of maize, cowpea and okra at Dang and Gouna

1.1- Diversity and major insect pest species of maize

The list of maize insect pest species, plant part attacked and their abundance in both zones is presented in Table 1. It appears from that 05 insect species from 02 orders and 03 families attack maize crops in the both agro ecological zones. Lepidopterans were represented with 04 species, Dermaptera with 01. All the 05 insect species present at Dang.

The density of lepidopteran recorded on maize plants during both cropping seasons at Dang was high. Among them, *Spodoptera frugiperda* was the most represented (Ra = 0.62) followed by *Busseola fusca* (Ra = 0.19). In Gouna among the lepidopterans, *Spodoptera frugiperda* and *Busseola fusca* had the same proportion. They mainly fed on leaves, stems and cobs. Activity of an individual lepidopteran resulted in serious damage to the maize plant. The two species were therefore classified as a major pests (Figure 1).

Table 1. number of insect pests collected on maize, plant part attacked and their abundance at Gouna and Dang during the 2016 and 2017 cropping seasons

Order	**Family**	**Scientific names**	**Plant part attacked**	**Dang**		**Total**	**Ra**	**Gouna**		**Total**	**Ra**
				2016	2017			2016	2017		
Lepido-ptera	Noctu-idae	*Spodoptera frugiperda*	Le, st, cob	44	43	87	0.62	2	6	8	0.30
		Busseola fusca	Le, st, cob	10	16	26	0.19	5	3	8	0.30
		Sesamia calamistis	Le, st, cob	4	4	8	0.06	0	2	2	0.07
	Crambidae	*Coniesta ignefusalis*	Le, st, cob	4	3	7	0.05	0	0	0	0.00
Derma-ptera	Forficul-idae	*Forficula* sp.	st, cob	7	5	12	0.09	4	5	9	0.33
Total	2	5	-	69	71	140	1	11	16	27	1

Le: leave ; st: stem ; co: cob ; Ra : relative abundance

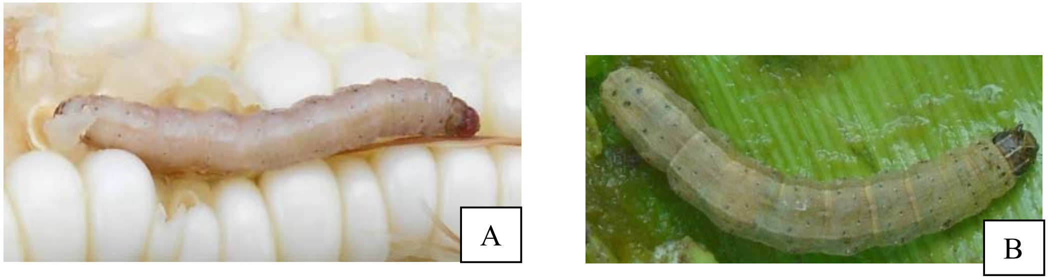

Figure 1. Major insect pests of maize at Dang and Gouna: A- larva of *Busseola fusca* ; B- larva of *Spodoptera frugiperda*.

1.2-Diversity and major insect pest species of cowpea at Dang and Gouna

A number of insect pests attacking cowpea plants in Dang and Gouna were collected and identified (Table 2). It appears from this table that, 19 insect species from 06 orders and 10 families attack cowpea crops in the both agro ecological zones. All the 19 insect species were present Gouna and 08 of the harmful species (*Nezara virudula, Mylabris senegalensis, Riptortus sp* ….) were absent at Dang. Many of these insects damaged either the vegetative or reproductive parts of the plant.

At Dang, during the both cropping seasons, *Aphis craccivora* was the most abundant species followed by *Megalurothrips sjostedti* with a relative abundance of 0.72 and 0.16 respectively. The same trend was observed in Gouna where *Aphis craccivora and Megalurothrips sjostedti* were the most abundant.

Aphis craccivora was collected mainly from leaves, stems, flowers and green pods on which it caused severe damage through sucking of juice from these plant parts affecting the amount and quality of seed yield. It was therefore classified as a major pest in Dang and Gouna.

Megalurothrips sjostedti were collected from flowers where they caused flower lost thus earning it the status of major pest for the both agro-ecological zones.

Coleopterans recorded were observed feeding on foliage and *Ootheca mutabilis* was the only species with a higher relative abundance on the both agro-ecological zones. It fed mainly on leaves and higher populations resulted to serious damage on cowpea plants. It was therefore classified as a major pest.

Higher population of *Bemisia tabaci* was observed on the both e agro-ecological zones but no significant damage due to this pest was recorded.

The legume pod borer *Maruca vitrata* was absent at Dang in the 2017 cropping season and was most represented in Gouna. It mainly fed on flowers and pods which led to a fall in yield. The higher population of *M. vitrata* observed in Gouna indicated that it is a major pest in this zone.

Among the sucking bug complexes *Clavigralla tomentosicollis and Anoplocnemis curvipes* were present on the both zones. Their population was higher in Gouna. These two insects were also qualified to be classified as major pests for this zone.

Three of the cowpea insect pests were then classified as major harmful cowpea insects at Dang. These were: *Ootheca mutabilis*, *Megalurothrips sjostedti* and *Aphis craccivora*. In Gouna, 06 cowpea insect pests were recorded as major harmful insects. These included: *Ootheca mutabilis, Megalurothrips sjostedti, Maruca vitrata, Clavigralla tomentosicolis, Anoplocnemis curvipes,* and *Aphis craccivora* (Figure 2).

Table 2. Insect pests collected on cowpea, plant part attacked and their abundance at Gouna and Dang during the 2016 and 2017 cropping seasons

Order	**Family**	**Scientific name**	**Plant part attacked**	**Abundance**							
				Dang			**Ra**	**Gouna**			**Ra**
				2016	**2017**	**Total**		**2016**	**2017**	**Total**	
Coleoptera	chrysomelidae	*Ootheca mutabilis*	Le ; Fl	115	131	246	0.01	414	343	757	0.03
		Podagrica uniformis	Le ;	12	16	28	0.00	41	56	97	0.00
	Lagriidae	*Lagria vilosa*	Le	21	21	42	0.00	29	22	51	0.00
	Meloïdae	*Mylabris senegalensis*	Fl	0	0	0	0.00	28	9	37	0.00
Lepidopteran	crambidae	*Maruca testulalis*	Fl, Pod	12	0	12	0.00	114	101	215	0.01
Homoptera	Aphididae	*Aphis craccivora*	Le ;Fl ;St ; Pod	7846	6965	14811	0.72	9709	8458	18167	0.75
	Cicadellidae	*Empoasca* sp	Le	1	0	1	0.00	8	19	27	0.00
	Aleyrodidae	*Bemissia tabaci*	Le ; st	673	1201	1874	0.09	438	504	942	0.04
Thysanoptera	Thripidae	*Megalurothrips sjostedti*	Fl	1344	1985	3329	0.16	1367	1736	3103	0.13
Heteroptera		*Clavigralla tomentosicollis*	Pod	37	38	75	0.00	154	158	312	0.01
	Coreidae	*Anoplocnemis curvipes*	Pod	50	33	83	0.00	121	104	225	0.01
		Riptortus sp	Pod	0	0	0	0.00	23	27	50	0.00
		Nezara virudula	Pod	0	0	0	0.00	19	16	35	0.00
		Mirperus jaculus	Pod	0	0	0	0.00	11	14	25	0.00
Orthoptera	Acrididae	*sp* 1	Le	0	0	0	0.00	9	11	20	0.00
		sp 2	Le	0	0	0	0.00	13	7	20	0.00
		sp 3	Fl	0	0	0	0.00	10	9	19	0,00
		sp 4	Fl	0	0	0	0.00	8	13	21	0.00
Total		19	-	10111	10390	20501	1.00	12516	11607	24123	1.00

Le: leave; St: stem; Fl: flower; Ra: relative abundance

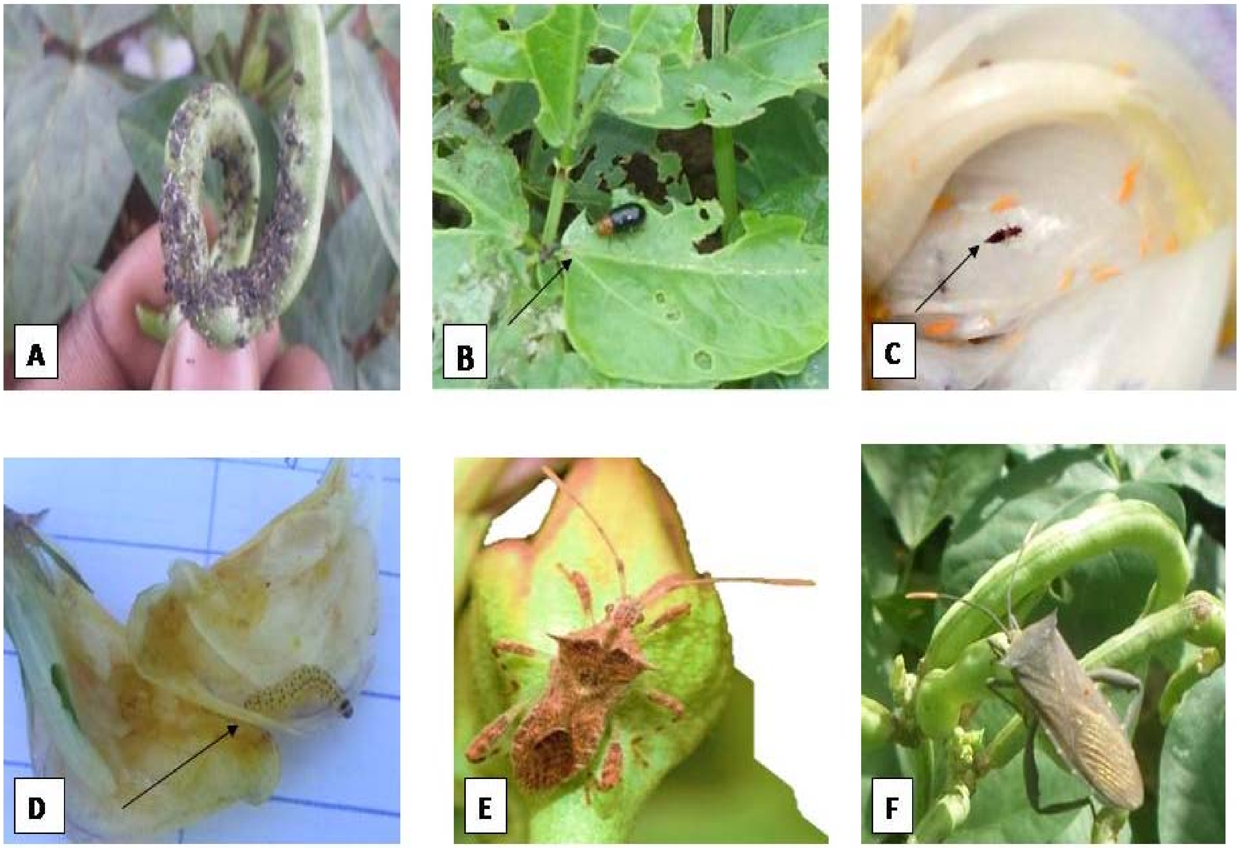

Figure 2. Some major insect pests of cowpea at Dang and Gouna: A- *Aphis craccivora*; B- *Ootheca mutabilis*; C- *Megalurothrips sjostedti*; D- *Maruca vitrata*; E- *Clavigralla tomentosicollis*; F- *Anoplocnemis curvipess*.

Simpson and Shannon diversity indices for the cowpea insect at Dang and Gouna

The Simpson diversity indices were 0.62 and 0.5 at Dang and 0.62 and 0.56 respectively in 2016 and 2017 cropping seasons (Table 3). These indices show the low diversity of the species of insects on cowpea in all the two agro-ecological zones.

The Shannon diversity indices were 0.77 and 0.95 at Dang and 0.91 and 1.01 respectively in 2016 and 2017 cropping seasons. These indices show unequal distribution of the species of insects on cowpea in both agro-ecological zones.

Table 3. Simpson and Shannon diversity indices for the cowpea insect pests at Dang and Gouna in 2016 and 2017

	Dang 2016	Dang 2017	Gouna 2016	Gouna 2017
Simpson index	0.62	0.5	0.62	0.56

Shannon index	0.77	0.95	0.91	1.01
Evenness index	0.32	0.43	0.31	0.34

1.3- Diversity and majors insect pests of okra

The list of insect pests, plant part attacked and their abundance is presented in Table 4. It appears from this table that, 15 insect species from 06 orders and 08 families attack okra crops in the both agro ecological zones. Lepidoptera was the most represented order followed by Coleoptera with 05 and 04 species respectively. Among the 15 species recorded, 10 were present in the both agro ecological zones. At Dang, for both cropping seasons, *Bemisia tabaci* were the most abundant species on okra followed by *Podagrica decolorata* with a relative occurrence of 0.63 and 0.28 respectively. The same trend was observed in the in Gouna where the relative abundance of *Bemisia tabaci* and *Podagrica decolorata* were 0.54 and 0.34 respectively.

The Coleopteran damage observed on the field showed that they were the most damaging insect of okra. *Podagrica decolorata* was the first due to it higher abundance.

Okra disease observed on the field showed that Aleyrodidae *Bemisia tabaci* was also the most harmful insect in the both agro ecological zones.

Crematogaster spp appeared in higher number but they caused no significant damage in the okra plants.

*Earia*s sp., *Spodoptera littoralis, Syllepte derogata*, *Xanthodes* sp. and the two insects in the Orthoptera order appeared in lower number in the both sites. They were not be classified as a major insect.

Two insect pests were recognized as the major harmful insects of okra at Dang and Gouna. These were: *Podagrica decolorata* and *Bemisia tabaci* (Figure 3).

Table 4. insect pest collected on okra, plant part attacked and their abundance at Gouna and Dang during the 2016 and 2017 cropping season years

Order	**Family**	**Scientific name**	**Plant part attacked**	**Abundance**							
				DANG				**GOUNA**			
				2016	**2017**	**Total**	**Ra**	**2016**	**2017**	**Total**	**Ra**
Coleoptera	Chrysomelidae	*Podagrica decolorata*	Le ;Fl ;Fb ;Fr	1647	1791	3438	0.28	1626	1789	3415	0.34
		Nitrosa delecta	Le ;Fl ;Fb ;Fr	81	78	159	0.01	76	66	142	0.01
	Lagriidae	*Largria vilosa*	Le	32	36	68	0.01	27	34	61	0.01
		Cycloneda sp.	Fl ;Fb	23	20	43	0.00	32	27	59	0.01
Homoptera	Aleyrodidae	*Bemisia tabaci*	Le	3243	4408	7651	0.63	2781	2565	5346	0.54
Heteroptera	Pyrrocoridae	*Dysdercus* sp.	Le ; Fb ;Fr	69	61	130	0.01	83	79	162	0.02
	Coreidae	*Anoplocnemis curvipess*	Le	0	0	0	0.00	4	7	11	0.00
Hymenoptera	Formicidae	*Crematogaster* sp1	Le ;Fl ;Fb ;Fr	188	213	401	0.03	139	111	250	0.03
		Crematogaster sp2	Le ;Fl ;Fb ;Fr	68	106	174	0.01	117	166	283	0.03
Lépidoptera	Noctuidae	*Earias* spp.	Fl, Fr	0	7	7	0.00	11	12	23	0.00
		Cosmophila flava	Fl, Fr	9	6	15	0.00	12	13	25	0.00
		Xanthodes spp	Fl	0	5	5	0.00	0	0	0	0.00
		Spodoptera littoralis	Le	0	0	0	0.00	29	39	68	0.01
		Syllepte derogata	Le	0	0	0	0.00	24	25	49	0.00
Orthoptera	Acrididae	*sp* 5	Le	0	0	0	0.00	8	11	19	0.00
Total		15	-	5360	6731	12091	1.00	4969	4944	9913	1.00

Le: leave; Fl: flower; Fb: flower bud; Fr: fruit; Ra: relative abundance

Figure 3. Major insect pests of okra at Dang and Gouna: A- *Podagrica decolorata*; B- Bemisia *tabaci*.

Okra diversity index

The Simpson diversity indices were 0.46 and 0.5 at Dang and 0.42 and 0.40 respectively in 2016 and 2017 cropping seasons. These indices show the low diversity of the species of insects on okra in all the ecozones (Table 5).

The Shannon diversity indices were 1.02 and 0.96 at Dang and 1.17 and 1.21 respectively in 2016 and 2017 cropping seasons. The lower Shannon indices obtained show the unequal distribution of okra insect pest in both agroecologial zones.

Table 5. Simpson and Shannon diversity indices for the okra insect pests at Dang and Gouna in 2016 and 2017

	Dang 2016	**Dang 2017**	**Gouna 2016**	**Gouna 2017**
Simpson index	0.46	0.5	0.42	0.4
Shannon index	1.02	0.96	1.17	1.21
Evenness index	0.47	0.51	0.43	0.36

2- Influence of intercropping on the major insect pest populations of maize, cowpea and okra

2.1- Influence of intercropping on the major insect pests population of maize

Table 6 presents the density of *Spodoptera frugiperda* and *Busseola fusca* per maize plant as influenced by insecticidal treatments and intercropping system in 2016 and 2017 at Dang and Gouna. Overall, the population of *Spodoptera frugiperda* was significantly higher at Dang than at Gouna ($t = 5.10$ $P < 0.0001$ $df = 78$ in 2016; $t = 5.09$ $P < 0.0001$ $df = 78$ in 2017). Similarly, the population of *Busseola fusca* was significantly higher at Dang than at Gouna (*t*

= 2.50 *P* = 0.013 *df* = 78 in 2016; t= 3.09 *P* = 0.002 *df* = 78 in 2017).

At dang, maize sole recorded a highest number of *S. frugiperda* per plant (1.1 and 1.05 respectively in 2016 and 2017) and maize-cowpea-okra intercropping recorded a lower number. But among the unsprayed plots, no significant differences were observed between the density of these stem borers on maize sole, and on maize in intercropping. At Gouna no significant difference was observed between the treatments.

The population of *S. frugiperda* on maize sole was higher at Dang than in Gouna (*t* = 3.33 *P* = 0.001; in 2016; *t* = 3.77 *P* < 0.0001 in 2017). Exception of maize-okra unsprayed where higher population of *S. frugiperda* was observed at Dang in the 2016 cropping season (*t* = 2.38; *P* = 0.02; *df* = 78) there was no significant difference between the other treatments at Dang and Gouna.

Table 6. Density of *Spodoptera frugiperda* and *Busseola fusca* per maize plant as influenced by insecticidal treatments and intercropping system in 2016 and 2017 at Dang and Gouna

	Spodoptera frugiperda						***Busseola fusca***					
Treat	Dang **2016**	Gouna **2016**	***t***	Dang **2017**	Gouna **2017**	***t***	Dang **2016**	Gouna **2016**	***t***	Dang **2017**	Gouna **2017**	***t***
MS	1.1a	0.05a	3.33	1.05a	0.15a	3.77	0.25a	0.12a	0.94	0.40a	0.08a	2.07
MS+I	0.2b	0.05a	1.38	0.18b	0.08a	1.88	0.12a	0.02a	1.08	0.05b	0.05a	0.38
MC	0.6ab	0.15a	1.93	0.25b	0.15a	1.19	0.18a	0.05a	0.94	0.13ab	0.03a	1.46
MC+I	0.22b	0.12a	0.78	0.15b	0.08a	1.06	0.15a	0.02a	1.32	0.05b	0.05a	0.00
MO	0.6 ab	0.12a	2.38	0.30b	0.13a	1.52	0.15a	0.08a	0.70	0.15ab	0.05a	1.32
MO+I	0.22b	0.05a	1.59	0.23b	0.05a	1.89	0.05a	0.02a	0.45	0.05b	0.03a	0.58
MCO	0.30b	0.1a	1.36	0.20b	0.10a	0.00	0.18a	0.02a	1.19	0.10ab	0.05a	0.00
MCO+I	0.15b	0.05a	0.91	0.15b	0.05a	1.45	0.02a	0.02a	0.00	0.10ab	0.03a	1.38
Mean	0.42	0.09	5.10	0.37	0.10	5.08	0.14	0.05	2.50	0.13	0.04	3.10
F	3.49**	0.54ns		6.75**	0.76ns		0.56ns	0.92ns		2.71*	0.29ns	

Treat: treatment; +I: with insecticide; MS: maize sole; MO: maize+ okra; MC: maize + cowpea; MCO: maize + cowpea + okra. In column, means followed by same letter are not significantly different at the 5% * Significant. ** Highly significant. *df*= 78;

2.2- Influence of intercropping on the major insect pest populations of cowpea

a. Influence of intercropping on the *Ootheca mutabilis* population density

Table 7 reveals the density of *Ootheca mutabilis* on cowpea as influenced by intercropping system in 2016 and 2017 at Dang and Gouna. Overall, it appears from this table that the population of *Ootheca mutabilis* was significantly higher at Gouna than at Dang (*t* = 13.71 *P* < 0.0001 *df* = 3198 in 2016; *t* = 14.13 *P* < 0.0001 *df* = 3198 in 2017). Moreover, the application of insecticide gave significant result compared to sole cowpea and cowpea in intercropping unsprayed in 2016 (*P* < 0.001, F = 45.74, *df* = 3198 at Dang 2016; *P* < 0.001, F

= 191.73, *df* = 78 at Gouna 2016). The same trend was observed during the 2017 cropping season on the both agro-ecological zone.

At Gouna, among the unsprayed plots, all the intercropping systems significantly reduced the number of *O. mutabilis* compared to cowpea in monoculture during the both cropping seasons.

At Dang, during the 2016 cropping season, only cowpea-maize-okra intercropping reduced significantly the density of *O. mutabilis* compared to cowpea sole. But in 2017, in addition to cowpea-maize-okra intercropping, cowpea-maize reduced significantly a number of *O. mutabilis* compared to cowpea sole.

The population of *O. mutabilis* on cowpea sole unsprayed was significantly higher in Gouna than in Dang (t = 14.99 P < 0.001; df = 398 in 2016; t = 11.12 P < 0.001 df = 398 in 2017). The same trend was observed on the cowpea intercropped unsprayed.

Table 7. Density of *Ootheca mutabilis* per cowpea plant as influenced by intercropping system in 2016 and 2017 at Dang and Gouna

Treat	Dang 2016	Gouna 2016	*t*	Dang 2017	Gouna 2017	*t*
CS+I	0.05c	0.06d	0.21	0.12c	0.06d	1.69
CS	0.58a	2.07a	14.99	0.66a	1.72a	11.12
MC+I	0.03c	0.07d	1.6	0.10c	0.04d	1.91
MC	0.49ab	1.59b	11.18	0.43b	1.32bc	10.86
OC+I	0.04c	0.08d	1.33	0.08c	0.04d	1.55
OC	0.46ab	0.81c	4.02	0.53ab	1.36b	9.14
MCO+I	0.06c	0.07d	0.36	0.04c	0.03d	0.26
MCO	0.37b	0.66c	3.77	0.44b	1.11c	8.31
Mean	0.26	0.67	13.71	0.30	0.71	14.13
F	45.74***	191.73***		38.18***	107.26***	

Treat: treatment; +I: with insecticide; CS: cowpea sole; MC: maize+ cowpea; OC: okra + cowpea; MCO: maize + cowpea + okra. In column, means followed by same letter are not significantly different at the 5% * Significant. ** Highly significant. *df* = 398.

b. Influence of intercropping on the *Aphis craccivora* population

Table 8 presents the Density of *A. craccivora* on cowpea as influenced by insecticidal treatments and intercropping system in 2016 and 2017 at Dang and Gouna. Generally, the population of *Aphis craccivora* was not significantly different at Gouna and Dang during the both cropping seasons (t = 1.26 P = 0.21 df = 398; in 2016; t = 1.52 P = 0.13; df = 398 in 2017). Insecticide completely reduced the density of *A. craccivora* compared to the plots not protected (P < 0.001, F=15.81, df = 398 at Dang 2016; P < 0.001, F=18.75, df = 398 at Gouna 2016). The same trend was observed during the 2017 cropping season on the both agro-ecological zones. Among the plot not protected by insecticide in the both zones and cropping season, cowpea in intercropping recorded a significantly lower density of *A. craccivora* compared to cowpea in monoculture. No significant difference was observed between the density of aphids found on cowpea-okra, cowpea-maize and cowpea-okra-maize intercropping on the plot not protected by insecticide on the both zones.

Table 8. Density of *Aphis craccivora* per cowpea plant as influenced by insecticidal treatments and intercropping system in 2016 and 2017 at Dang and Gouna

Treat	Dang 2016	Gouna 2016	*t*	Dang 2017	Gouna 2017	*t*
CS+I	0.00c	0.33c	-	0.12c	0.18c	0.50
CS	39.23a	48.55a	0.85	34.83a	42.50a	0.76
MC+I	0.00c	0.20c	-	0.14c	0.20c	0.43
MC	19.14b	23.12b	0.64	15.32b	21.10b	1.08
OC+I	0.00c	0.27c	-	0.09c	0.17c	0.85
OC	19.17b	23.32b	0.67	18.02b	22.68b	0.78
MCO+I	0.02c	0.17c	1.66	0.08c	0.21c	0.99
MCO	17.95b	16.76b	0.2	13.73b	16.88b	0.66
Mean	11.66	14.09	1.26	10.29	12.96	1.52
F	15.81***	18.75***	-	15.90***	18.52***	

Treat: treatment; +I: with insecticide; CS: cowpea sole; MC: maize+ cowpea; OC: okra + cowpea; MCO: maize + cowpea + okra. In column, means followed by same letter are not significantly different at the 5% * Significant. ** Highly significant. *** Very high significant. *ddl*= 398; t=1.966

c. Influence of intercropping on the *Megalurothrips sjostedti* and *Maruca vitrata* population

Table 9 presents the density of *Megalurothrips sjostedti* and *Maruca vitrata* as influenced by insecticidal treatment and intercropping system. Overall, the population of *Megalurothrips* was the same at Gouna and Dang ($t = 0.2$ $P = 0.85$ $df = 3198$ in 2016; $t = 0.62$ $P = 0.54$ $df = 3198$ in 2017). Higher number of *Maruca vitrata* was observed in Gouna than in Dang in 2016 ($t = 12.23$ $P < 0.0001$ $df = 3198$). *M. vitrata* was absent at Dang during the 2017 cropping season.

Cypermetrin reduced significantly the number of *Megalurothrips sjostedti* than the intercropping ($P < 0.001$, F=167.26, $df = 398$ at Dang 2016; $P < 0.001$, F=142.45, $df = 398$ at Gouna 2016). The same trend was observed during the 2017 cropping season.

Among the unprotected plots, the density of *M. sjostedti* recorded in the cowpea sole was significantly higher than those recorded in cowpea in intercropping on the both agro-ecological zone. This trend was observed in 2016 and 2017 cropping seasons.

At Dang, among the unprotected plot Cowpea-okra-maize recorded the least number of *M. sjostedti* per flower (2.75 and 3.76) followed by cowpea-maize (4.03 and 5.12) and cowpea-okra (4.13 and 5.98) intercropping during the 2016 and 2017 cropping season year respectively. The same trend was observed at Gouna.

The population of *M. sjostedti* observed on cowpea sole unsprayed at Dang in 2017 was significantly lower than in Gouna (t = 2.02 P = 0.045; df = 398). The same trend was observed on maize-cowpea-okra intercropping (t = 2.05 P = 8.31; df = 398).

At Gouna, Cypermetrin significantly reduced the number of *M. vitrata* than the unsprayed plot (P < 0.001, F = 33.85, df = 398 in 2016; P < 0.001, F=37.90, df = 398 in 2017). Among the unsprayed, during the 2016 cropping season, maize-cowpea-okra intercropping significantly reduced the density of *M. vitrata* compared to cowpea in monoculture. In 2017, cowpea in monoculture recorded a highest number of *M. vitrata* (0.51) but there was not a significant difference between the cowpea in intercropping.

Table 9. Population of *Megalurothrips sjostedti* and *Maruca vitrata* per cowpea flower as influence by intercropping at Dang and Gouna

	Megalurothrips sjostedti.						***Maruca vitrata***					
Treat	**Dang 2016**	**Gouna 2016**	***t***	**Dang 2017**	**Gouna 2017**	***t***	**Dang 2016**	**Gouna 2016**	***t***	**Dang 2017**	**Gouna 2017**	***t***
CS+I	0.14d	0.15d	0.32	0.17d	0.16d	0.21	0.00a	0.01c	-	0.00	0.02b	
CS	6.72a	6.84a	0.24	9.93a	8.68a	2.02	0.06a	0.57a	6.95	0.00	0.51a	
MC+I	0.07d	0.18d	1.84	0.2d	0.19d	0.12	0.00a	0.02c	-	0.00	0.01b	
MC	4.03b	3.30bc	1.73	5.12b	5.12bc	0.00	0.05a	0.46ab	6.66	0.00	0.47a	
OC+I	0.17d	0.10d	1.31	0.21d	0.16d	0.74	0.00a	0.01c	-	0.00	0.02b	
OC	4.13b	4.16b	0.09	5.98b	5.81b	0.38	0.02a	0.43ab	6.5	0.00	0.43a	
MCO+I	0.15d	0.10d	1.04	0.24d	0.14d	1.77	0.01a	0.02c	0.34	0.00	0.01b	
MCO	2.75c	3.13c	1.27	3.76c	4.53c	2.05	0.06a	0.37b	5.69	0.00	0.36a	
Mean	2.27	2.24	0.2	3.2	3.1	0.62	0.03	0.23	12.23	0.00	0.23	
F	167.26***	142.45 ***		173.51 ***	258.48 ***		1.17ns	33.85***		0.00ns	37.90***	

Treat: treatment; +I: with insecticide; CS: cowpea sole; MC: maize+ cowpea; OC: okra + cowpea; MCO: maize + cowpea + okra. In column, means followed by same letter are not significantly different at the 5% * Significant. ** Highly significant. *** Very high significant; ddl= 398; t=1.966

d. Influence of intercropping on cowpea pod insect pest population

Table 10 presents the density of *Clavigralla tomentosicolis* and *Anoplocnemis curvipess* per cowpea plant as influenced by insecticidal treatments and intercropping system in 2016 and 2017 at Dang and Gouna. Overall, higher population of *C. tomentosicolis* was observed at Gouna than at Dang (t = 10.43 P < 0.0001 df = 3198 in 2016; t= 10.34 P < 0.0001 df = 3198 in 2017). Similarly, the population of *Anoplocnemis curvipess* was significantly higher at Gouna than at Dang (t = 10.1 P < 0.0001 df = 3198 in 2016; t = 9.33 p < 0.0001 df = 3198 in 2017).

Moreover, Cypermetrin significantly reduced the density of *C. tomentosicolis* (P < 0.001, F=10.74.26, df = 398 at Dang 2016; P < 0.001, F=17.1, df = 398 at Gouna 2016) and *A. curvipess* (P < 0.001, F=13.75, df = 398 at Dang 2016; P < 0.001, F=18.67, df = 398 at

Gouna 2016) in the both agro ecological zones and cropping year.

In Gouna, among the unsprayed plots, cowpea-maize intercropping reduced significantly the number of *C. tomentosicolis* compared to sole cowpea during the both cropping seasons. In contrast to Gouna, no significant difference was observed between the density of *C. tomentosicolis* population on cowpea in monoculture and in intercropping at Dang.

At Gouna, in the 2016 cropping season, cowpea-maize intercropping reduced significantly the density of *A. curvipess* compared to the cowpea in monoculture.

Table 10. Density of *Clavigralla tomentosicolis* and *Anoplocnemis curvipess* per cowpea plant as influenced by insecticidal treatments and intercropping system in 2016 and 2017 at Dang and Gouna

Treat	***Clavigralla tomentosicolis.***						***Anoplocnemis curvipess***					
	Dang 2016	**Gouna 2016**	***t***	**Dang 2017**	**Gouna 2017**	***t***	**Dang 2016**	**Gouna 2016**	***t***	**Dang 2017**	**Gouna 2017**	***t***
CS+I	0.02b	0.02c	0.00	0.02c	0.02c	0.38	0.05bc	0.02d	1.62	0.02c	0.03c	0.34
CS	0.19a	0.77a	8.43	0.19a	0.79a	6.31	0.25a	0.61b	5.2	0.17a	0.52a	5.95
MC+I	0.02b	0.02c	0.00	0.02c	0.05c	1.23	0.02c	0.02d	0.00	0.02c	0.02c	0.00
MC	0.14a	0.43b	5.23	0.4ab	0.48b	5.67	0.18a	0.38c	3.63	0.16a	0.41ab	4.62
OC+I	0.02b	0.03c	0.71	0.05bc	0.03c	0.95	0.02c	0.02d	0.00	0.03bc	0.02c	0.64
OC	0.13a	0.47b	5.63	0.11abc	0.56ab	5.16	0.15ab	0.77a	9.34	0.13ab	0.43ab	5.73
MCO+I	0.02b	0.03c	0.58	0.03c	0.03c	0.28	0.02c	0.03d	1.01	0.03c	0.03c	0.00
MCO	0.13a	0.47b	4.00	0.10abc	0.56ab	5.4	0.18a	0.45bc	4.48	0.13a	0.35b	4.38
Mean	0.08	0.28	10.43	0.08	0.31	10.38	0.11	0.29	10.1	0.08	0.22	9.33
F	10.74 ***	17.1***		7.9***	32.11***		13.75 ***	18.67***		8.59***	44.91***	

Treat: treatment; +I: with insecticide; CS: cowpea sole; MC: maize+ cowpea; OC: okra + cowpea; MCO: maize + cowpea + okra. In column, means followed by same letter are not significantly different at the 5% * Significant. ** Highly significant. *** Very high significant; *df*= 398; t=1.966

2.3- Effect of intercropping system on the density of major insect pests of okra

a. Effect of intercropping on *Bemisia tabaci* population

Table 11 presents the density of *Bemisia tabaci* and *Podagrica decolorata* per okra plant as influenced by insecticidal treatments and intercropping system in 2016 and 2017 at Dang and Gouna. Overall, lower population of *B. tabaci* was observed at Gouna than at Dang (t = 3.89 P < 0.0001 df = 3198 in 2016; t = 9.5 P < 0.0001 df = 3198 in 2017).

Cypermetrin reduced significantly the density of these pests in the both agro ecological zones and cropping year. Among the cropping unsprayed, maize-okra intercropping reduced significantly a density of *B. tabaci* compared to okra monocroped. However the higher number of *B. tabaci* was observed on okra-cowpea intercropping. The population of *B. tabaci* on the plot unsprayed was higher at Dang than at Gouna.

b. Effect of intercropping on *Podagrica decolorata* population

It appears from the Table 11 that, overall, the population of *Podagrica decolorata* was the same at Gouna and Dang (t = 0.55 P = 0.58 df = 3198 in 2016; t = 1.54 P = 0.12 df = 3198 in 2017). Moreover, insecticide reduced significantly the density of *Podagrica decolorata* in the both agro-ecological zones and cropping year compared to unsprayed. Among the unsprayed cropping system, significant lowest number of *P. decolorata* was observed on maize-okra-cowpea and okra-maize intercropping in comparison to okra in monoculture which recorded the highest number. There was no significant difference between the density of *P. decolorata* on the okra-cowpea intercropping and the okra in monoculture on the agro-ecological zone and cropping season.

Table 11. Density of *Bemisia tabaci* and *Podagrica decolorata* per okra plant as influenced by insecticidal treatments and intercropping system in 2016 and 2017 at Dang and Gouna

Treat	***Bemisia tabaci***						***Podagrica decolorata***					
	Dang 2016	**Gouna 2016**	***t***	**Dang 2017**	**Gouna 2017**	***t***	**Dang 2016**	**Gouna 2016**	***t***	**Dang 2017**	**Goun a 2017**	***t***
OS+I	0.29d	0.36d	0.77	0.37e	0.30	1.02	0.32c	0.3c	0.21	0.28c	0.35d	0.98
OS	16.22b	12.75a	5.32	22.04b	13.51	11.81	8.24a	8.96a	1.61	8.96a	8.43a	1.1
MO+I	0.22d	0.17d	0.77	0.33e	0.17	2.24	0.31c	0.27c	0.61	0.32c	0.38d	0.69
MO	10.72c	9.56c	2.29	12.23d	9.92	4.65	6.24b	6.53b	0.74	6.46b	6.22c	0.59
OC+I	0.20d	0.27d	1.17	0.30e	0.28	1.02	0.22c	0.3c	1.1	0.22c	0.48d	3.02
OC	18.29a	13.91a	5.71	25.32a	14.75	13.09	8.26a	8.13a	0.29	8.66a	7.37b	2.53
MCO+I	0.21d	0.30d	1.23	0.22e	0.12	1.88	0.22c	0.25c	0.5	0.23c	0.27d	0.61
MCO	10.80c	10.90b	0.2	14.23c	10.68	6.78	6.27b	6.08b	0.45	5.78b	5.32c	1.26
Mean	7.12	6.02	3.89	9.38	6.21	9.5	3.76	3.85	0.55	3.86	3.60	1.54
F	538.39 ***	489.63 ***		777.52 ***	606.3 ***		315.6 2***	324.0 4***		302.7 4***	263.3 3***	

Treat: treatment; +I: with insecticide; OS: okra sole; MO: maize+ okra; OC: okra + cowpea; MCO: maize + cowpea + okra. In column, means followed by same letter are not significantly different at the 5% * Significant. ** Highly significant. *** Very highly significant. *Ddl*= 398; t=1.966

DISCUSSION

These studies have demonstrated that lepidopterans were the most abundant and the major insect pests of maize in the Sudano savannah and Sudano sahelian ecozone. Lepidopterans were reported as a major pests of maize in some countries [32, 33, 34]. Among the Lepidopterans, *Spodoptera frugiperda* was the most represented species. In contrast, *B. fusca* was accounted for 95 % of all the species found on maize in Cameroon [12]. The lower population of maize stem borers observed in the Sudano sahelian zone might be the result of the burning of bushes often practiced by farmers. Simple superficial burning suffices to eradicate stem borer larvae [35]. Moreover farmers on this region stock maize stems to feed their cattle on the dry seasons when grass is scarce. At Dang Maize sole recorded a highest number of *Spodoptera frugiperda* and *Busseola fusca* and maize-cowpea-okra intercropping recorded a least number. These results are in the same line with the findings of some authors that monocroped is sensitive to the higher insect pest's population [38].

Cowpea plant is attacked by a large number of insects. Among the 19 species recorded, only 03 of these were considered major pests in the Guinean Savannah zone, and 06 in the Soudano sahelian. The difference on species numbers could be a result of the climatic difference between the two regions. The lower precipitation, humidity and higher temperature that characterize the Soudano sahelian agro ecological is favorable for the development of cowpea insects. The population of cowpea insect pests increases when we leave the Guinean savannah to the Sudano sahelian agro ecological [9]. All of the harmful insects observed on cowpea have been reported to be serious pests of cowpea in some countries. *Megalurothrips sjostedti, Maruca vitrata, Clavigralla tomentosicollis, Anoplocnemis curvipes, Ootheca sp* and *Aphis craccivora* have been implicated to have caused major economic lost in Nigeria [36, 37].

In this study *Ootheca*, aphids and trips recorded in the cowpea in intercropping were lower than those in the sole cowpea crop, this trend was observed in both sites. The reasons for this population reduction in the intercrop may be due to the micro-environmental effect of the associated crop which may attract predators and or disruption of insect visual search for preferred host. It has been demonstrated that tall crops like traditional cereal varieties can disrupt insect's visual search for preferred host [39].

The study had revealed that cowpea in monoculture recorded a highest number of *Maruca* but there was not a significant difference between the cowpea in intercropping in the both cropping seasons. Similar results were reported [23]. This could be an activity of some predators like ants and spiders which were more observed on the crops in intercropping.

At Gouna, in the 2016 cropping season, cowpea-maize intercropping reduced significantly the density of *A. curvipess* compared to the cowpea in monoculture and cowpea intercropped with okra. This could be the fact that okra plant is also the host plant of *A. curvipess*.

Okra intercropped with maize was a promising system for reducing *Bemisia* and *Podagrica* population in comparison to okra sole. Intercropping of okra with sorghum was also reported as a solution of *Podagrica* population in Nigeria [25]. In contrast, higher number of *Bemisia tabaci* was observed on Okra-cowpea intercropping in this study. This could be the fact that cowpea plant is also the host plant of *Bemisia tabaci* [37].

Recommendation

On the basis of results obtained, we recommend maize-cowpea and maize-okra intercropping as a local sustainable solution to reduce the population of their major insect pest in northern Cameroon. But further researches should be geared towards identifying the factors responsible for the reduction of insect pests.

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