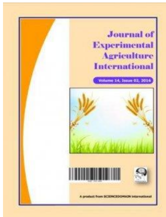

Journal of Experimental Agriculture International

29(6): 1-20, 2019; Article no.JEAI.45677
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Abundance and Diversity of Insect Pests on Maize, Cowpea and Okra in a Comparative Experiment Testing Effects of Intercropping and Insecticide in the Cameroonian Guinean Savannah and Sudano Sahelian Agro-ecological Zones

Djidjonri Farsia Patient[1*], Nukenine Elias Nchiwan[1] and Hartmut Koehler[2]

[1]Department of Biological Sciences, University of Ngaoundéré, Cameroon.
[2]UFT, University of Bremen, Germany.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2019/45677
Editor(s):
(1) Dr. Hugo Daniel Solana, Professor, Department of Biological Science, National University of Central Buenos Aires, Argentina.
Reviewers:
(1) Miguel Aguilar Cortes, Universidad Autonoma Del Estado De Morelos, Mexico.
(2) Alan Leslie, University of Maryland, USA.
(3) Adriana Neske, Universidad Nacional de Tucumán, Argentina.
Complete Peer review History: http://www.sdiarticle3.com/review-history/45677

Original Research Article

Received 09 October 2018
Accepted 28 December 2018
Published 19 January 2019

ABSTRACT

Intercropping has been shown as a non-chemical alternative to chemical control of insect pests. 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. We determined the diversity of insect pests of maize, cowpea and okra and evaluated the pest control efficiency of intercropping in comparison to the application of Cypermethrin. Experimental design was a 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.

In unsprayed plots, the cowpea crop was found to be attacked by a total of 19 different insect species. Only three of these were considered major pests at Dang (*Ootheca mutabilis*,

**Corresponding author: E-mail: djidjonri@yahoo.fr;*

Megalurothrips sjostedti, *Aphis craccivora*) and three more species at Gouna (*Maruca vitrata, Clavigralla tomentosicolis, Anoplocnemis curvipes*). For maize and okra, we recorded only two major pests (*Spodoptera frugiperda, Busseola fusca* and *Podagrica decolorata, Bemisia tabaci, respectively*). They did not differ in the two sites.
Cypermethrin significantly reduced the number of these insect pests compared to the unsprayed plots in both sites. Also, intercropping significantly reduced the major insect pests. However, in detail the results differ with the crops, with years (2016 and 2017) and between the two sites.

Keywords: Maize; cowpea; okra; insect pest; intercropping; Dang-Ngaoundéré; Gouna-Garoua; Cameroon; Cypermethrin.

1. INTRODUCTION

In Cameroon, agriculture accounts to about 17 % of the gross domestic product and employs 62 % of the population [1]. Unfortunately, the agriculture 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 [2]. To achieve this goal, total productivity of predominant crops should be increased.

Maize (*Zea mays* L., Poaceae) is the cereal with highest production worldwide. This crop can be grown on large commercial farm or as a garden crop and in industrial agriculture. In Africa alone, more than 300 million people depend on maize as their main food crop [3]. In addition, it is important as feed for farm animals and for alcohol fabrication (biofuel). In Cameroon, its production amounted by 2013 to 1.65 million t and the West region is the first producer followed by North, Center and the Adamawa region [4].

Cowpea (*Vigna unguiculata* (L) Walpers, Fabaceae), is an important edible legume crop in many parts of the world. This crop can be grown on large commercial farm or as a garden crop. The largest production is in the moist and dry savannah of Sub-Saharan Africa, where it is intensively grown as an intercrop with other cereal crops like millet, sorghum and maize. It is used as human food and also as livestock feed to make silage and hay. Cowpea grains are well known for their protein and carbohydrate content [5]. 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 [6]. In Cameroon, its production amounted by 2013 to 0,48 million t and the Far North region is the first producer followed by North, Center and the Littoral region [4].

Okra constitutes a major economic activity in Africa. This crop can be grown on 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 %, carbohydrates and vitamins A, B [8]. In dried form it is used as soup thickener. The mature seed is known to have superior nutritional quality. In Cameroon, its production amounted by 2013 to 72661 t and the Far North region is the first producer followed by North West, West and the South region [4].

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. The insect pest diversity varies with the agro-ecological zones. In Cameroon, research on maize insect pests was done in the humid forest with monomodal rainfall agro-ecological zone [9,10,11]. Cowpea insect pests were reported also in the humid forest with monomodal rainfall agro-ecological zone [12], and in the Guinean savannah agro-ecological zone of Cameroon [13,14]. Okra insect pests were reported in the humid forest with bimodal rainfall agro-ecological zone [15]. Some of the insect species regarded as major pests were *Busseola fusca, Sesamia calamistis* for maize, *Megalurothrips sjostedti*, *Maruca vitrata* for cowpea and *Bemisia tabaci*, *Aphis gossypii* and *Dysdercus* sp. for okra [15,16,17].

The high crop losses attributed to insects lead farmers to use chemical insecticides for controlling these agricultural pests. Among the synthetic insecticides, Cypermethrin is one of the highly used in agriculture. It is a mixture of all eight possible chiral isomers [18] with broad-spectrum efficiency. From the Northern regions of Cameroon, it is more available at farmer level and less expensive. Unfortunately, chemicals are judged to be unfriendly with the environment [19,20]. Moreover, they have caused many health hazards which result, among others, from their neurotoxicity, reproductive toxicity, cancerogeneity [21]. An alternative to the application is intercropping, which is the practice of growing more than one crop simultaneously on the same field. The efficiency of intercropping in pest control results from an increase of biological diversity (plants, animals, microflora). The complex interactions result in the biological control of insect gradation, leading to pests.

Field trials with maize in West Africa showed that mixed cropping reduced lepidopteran borer density by 44.4 % - 83.0 %, depending on the crop association [22]. A study from Cameroon showed that maize intercropped with grain legumes or cassava reduced the number of eggs laid by the potential pests *Sesamia calamistis* and *Busseola fusca*, compared to monoculture [11]. A study from Nigeria reported less damage from pod borers on cowpea when intercropped with maize [23]. Another study from Nigeria was demonstrated that cowpea + sorghum intercrop reduced significantly the population of *Aphis craccivora* compared to sole cowpea culture [24]. Another author reports that intercropping of okra with sorghum reduced the potential pest *Podagrica* [25]. Possible mechanisms responsible for reducing pest infestation from target crop in mixed cropping system are complex: a second non-host plant species may disrupt the ability of the pest to attack its proper host plant species (target crop), reduce infestation by attracting the pest from its primary host, and support predator and parasitoid populations [26]. Moreover, insect pests settle on crops only when host factors such as visual stimulus, taste and smell are satisfied, and this is more likely in monocultures where the chances of meeting a wrong stimulus is lower [27].

Our study focusses on the Sudano-Guinean and Sudano-Sahelian agro-ecological zones of Cameroon. Here, 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. To develop effective pest management systems, we need to have reliable baseline information on the spectrum of the major insect pests of the three crops and on their distribution and activity.

The present work was therefore conducted to document the spectrum of insects being potential pests associated with cowpea, okra and maize and determine the major pests; to evaluate the effect of intercropping (maize-cowpea, maize-okra, okra-cowpea, maize-okra-cowpea) and assess the efficiency of intercropping in relation to pesticide application.

2. MATERIALS AND METHODS

2.1 Study Sites

Studies were conducted in 2016 and 2017 in the mid and late rainy season and beginning of dry season (harvest; June to November) at Dang-Ngaoundéré (07°24'08.2" N; 13°33'01.6 E; 1094 ASL; Sudano-Guinean agro-ecological zone) and Gouna-Garoua (08°29'53.4" N; 13°31'00.3 E; 402 ASL, Sudano-Sahelian agro-ecological zone) of Adamawa and North, respectively, Cameroon. The sites selected for our field experiments differ in many factors, such as climate, soil and vegetation. The climate of Ngaoundéré is characterized by a rainy season (March to October) and a dry season (November to February). The annual rainfall varies from 1230 mm to 1675 mm [28]. The mean annual temperature is 22°C while the mean annual relative humidity is 70% [29]. The soil is brown reddish developed on basaltic rock, with pH 5.45 [30]. The surroundings of the study site are agricultural or fallow, with wild and cultivated species like maize, cowpea, peanut, millet and bean. In Garoua, the rainy season is from April to October and the dry season from November to March. The annual rainfall is 900 mm. The mean annual temperature is about 28°C [31]. The soil is ferruginous with pH 6. [32]. The vegetation near the study site was represented by wild and cultivated species like maize, cowpea, cotton, peanut, millet and bean.

2.2 Experimental Set-up, Sowing and Weeding

On the 25th and 30th of June 2016 and 2017 at Dang and Gouna, a field of 1375 m^2 was ploughed. We implanted the seven cropping systems (Table 1) in four replications without and with Cypermethrin application, resulting in a total of fifty-six plots per site. Size of each plot was 4.5 m x 3.2 m, with 1m spacing. They were ploughed and arranged in a randomized complete block design. The main factor was assigned for the application of Cypermethrin and the sub plots were devoted for cropping systems. The spacing in planting was according to traditional farming: maize in monoculture spacing with 80 cm apart and 50 cm between plants; cowpea in monoculture spacing with 80 cm apart and 30 cm between cowpea plants; okra in monoculture spacing with 80 cm x 40 cm. For maize/cowpea, maize/okra and okra/cowpea, the first plant was sown as in monoculture and the seeds of the second intercropped plant were seeded in the middle of the lines of the first plant. For maize-cowpea-okra intercropping, maize was sown as in monoculture; the okra seeds were planted at 30 cm and the cowpea seeds at 55 cm from the first line of maize. For all treatments, 3 - 4 seeds of maize, 3 - 4 seeds of cowpea 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 3, 7 and 10 weeks after planting by hand using a hoe.

Table 1. Cropping systems implanted in the experimental fields

	Maize	Cowpea	Okra
Maize	m	inter	inter
Cowpea		m	
Okra		inter	
inter			

m: monoculture (sole); inter: intercropping. All without and with Cypermethrin

2.3 Cypermethrin Application

Spraying of the control plot began two weeks after sowing till the crops got matured with intervals of one week. Slowly spraying was done to ensure adequate coverage of multiple crop plants in the intercropped systems.

2.4 Assessment of Insect Pest Populations

- Maize

The diversity and density of different maize insect pest species across systems was performed on 40 maize plants per treatment, sampled randomly on the experimental plots at plant physiological maturity. Observation was done first on the whole plant. After then, 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.

- Cowpea

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 five times, twice a week until 3 weeks. It is at this time where insects are more abundant [33]. Observation was done on the whole plant and insect pests 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 numbers of insects found were recorded [34].

- Okra

Sampling was done five times 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. Observations were done on the leaves, stem, flowers and fruits. Insect pests found were identified and counted.

2.5 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 [35]. Considered data were those recorded on maize, cowpea and okra in monoculture unsprayed.

2.6 The Diversity Indices

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

Relative abundance: this indicates the chance (p) to "meet" an individual insect in the field [36]. It was calculated using this formula: $\mathrm{Ra_i} = \frac{\mathrm{Ni}}{\mathrm{N}}$ Where: Ra_i: relative abundance of species i; Ni: the number of individuals of a species i; N: total number of insects;

The index of Simpson measures the probability that two randomly selected individuals 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.

The Shannon-Weaver index is based on the formula: $H' = - \Sigma ((Ni / N) * \log2 (Ni / N))$, with Ni: the number of individuals of a given species, and N: total numbers of insects. H' often lies between 1.5 and 3.5. 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 [37]. The formula is : $J = H'/Hmax$; $Hmax = \log2S$. S is the number of species in the sample.

2.7 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.

3. RESULTS

3.1 Diversity and Major Insect Pests of Maize, Cowpea and Okra at Dang and Gouna

3.1.1 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 2. 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 were present at Dang.

The density of lepidopterans 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). At 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 major pests (Fig. 1).

3.1.2 Simpson and Shannon diversity indices for the maize insect at Dang and Gouna

The Simpson diversity indices were 0.44 and 0.44 at Dang and 0.37 and 0.29, 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 1.13 and 0.94 at Dang and 0.94 and 0.94, respectively, in 2016 and 2017 cropping seasons. These indices show unequal distribution of the species of insects on maize in both agro-ecological zones.

3.1.3 Diversity and major insect pest species of cowpea at Dang and Gouna

A number of insect pests attacking cowpea plants at Dang and Gouna were collected and identified (Table 4). It appears from this table that 19 insect species from 05 orders and 10 families attack cowpea crops in the both agro-ecological zones. All the 19 insect species were present at Gouna and 08 of the harmful species (mainly *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 at Gouna where *Aphis craccivora and Megalurothrips sjostedti* were 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 at Dang and Gouna.

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

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

Order	Family	Scientific names	Plant part attacked	Dang				Gouna			
				2016	2017	Total	Ra	2016	2017	Total	Ra
Lepidoptera	Noctuidae	*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
Dermaptera	Forficulidae	*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: leaf; st: stem; co: cob; Ra : relative abundance

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

	Dang 2016	Dang 2017	Gouna 2016	Gouna 2017
Simpson index	0.44	0.44	0.37	0.29
Shannon index	1.13	0.94	1.04	1.31
Evenness index	0.70	0.58	0.94	0.94

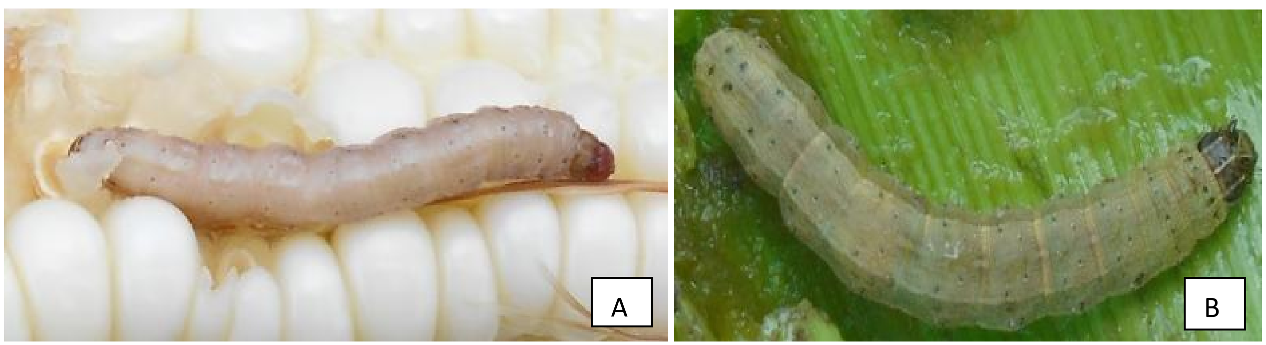

Fig. 1. Major insect pests of maize at Dang and Gouna: A- larva of *Busseola fusca*; B- larva of *Spodoptera frugiperda*.

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

Higher population of *Bemisia tabaci* was observed in the both 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 at Gouna. It mainly fed on flowers and pods which led to a fall in yield. The higher population of *M. vitrata* observed at 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 at 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*. At 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* (Fig. 2).

3.1.4 Simpson and Shannon diversity indices for the cowpea insects 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 5). 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.

3.1.5 Diversity and majors insect pests of okra

The list of insect pests, plant part attacked and their abundance is presented in Table 6. It appears from this table that 15 insect species from 05 orders and 10 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 at Gouna where the relative abundance of *Bemisia tabaci* and *Podagrica decolorata* was 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 its higher abundance.

Okra disease observed on the field showed that Aleyrodidae *Bemisia tabaci* was also the most harmful insect in 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 numbers in both sites. They were not classified as major insect pests.

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

3.1.6 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 eco-zones (Table 7).

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 agro-ecological zones.

Table 4. Insect pests collected on cowpea, plant part attacked and their abundance at Dang and Gouna during the 2016 and 2017 cropping seasons

Order	Family	Scientific name	Plant part attacked	Abundance							
				Dang				Gouna			
				2016	2017	Total	Ra	2016	2017	Total	Ra
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
Lepidoptera	Crambidae	*Maruca testulalis*	Fl, Pod	12	0	12	0.00	114	101	215	0.01
Thysanoptera	Thripidae	*Megalurothrips sjostedti*	Fl	1344	1985	3329	0.16	1367	1736	3103	0.13
Hemiptera	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
		Clavigralla tomentosicollis	Pod	37	38	75	0.00	154	158	312	0.01
		Anoplocnemis curvipes	Pod	50	33	83	0.00	121	104	225	0.01
	Coreidae	*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: leaf; St: stem; Fl: flower; Ra: relative abundance

Table 5. 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	0.50	0.62	0.56
Shannon index	0.77	0.95	0.91	1.01
Evenness index	0.32	0.43	0.31	0.34

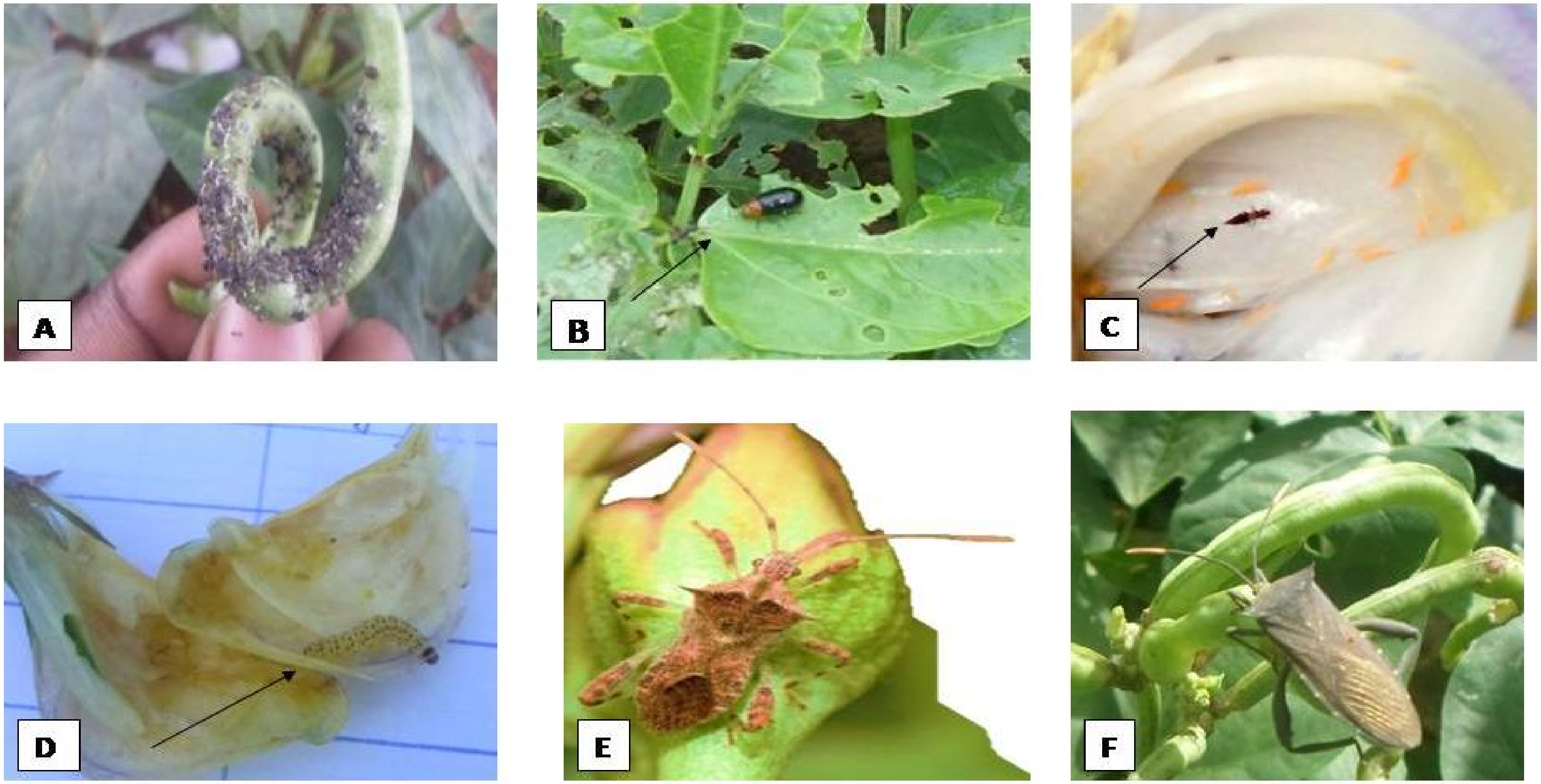

Fig. 2. Some major insect pests of cowpea at Dang and Gouna: A- *Aphis craccivora*; B- *Ootheca mutabilis*; C- *Megalurothrips sjostedti*; D- *Maruca vitrata*; E- *Clavigralla tomentosicollis*; F- *Anoplocnemis curvipes*

Table 6. Insect pests collected on okra, plant part attacked and their abundance *at Dang* and *Gouna* during the 2016 and 2017 cropping seasons

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	*Lagria vilosa*	Le	32	36	68	0.01	27	34	61	0.01
	Coccinellidae	*Cycloneda* sp.	Fl, Fb	23	20	43	0.00	32	27	59	0.01
Hemiptera	Aleyrodidae	*Bemisia tabaci*	Le	3243	4408	7651	0.63	2781	2565	5346	0.54
	Pyrrocoridae	*Dysdercus* sp.	Le, Fb, Fr	69	61	130	0.01	83	79	162	0.02
	Coreidae	*Anoplocnemis curvipes*	Le	0	0	0	0.00	4	7	11	0.00
Hymenoptera	Formicidae	*Crematogaster* sp.1	Le, Fl, Fb, Fr	188	213	401	0.03	139	111	250	0.03
		Crematogaster sp. 2	Le, Fl, Fb, Fr	68	106	174	0.01	117	166	283	0.03
Lepidoptera	Noctuidae	*Earias* sp.	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 sp.	Fl	0	5	5	0.00	0	0	0	0.00
		Spodoptera littoralis	Le	0	0	0	0.00	29	39	68	0.01
	Crambidae	*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: leaf; Fl: flower; Fb: flower bud; Fr: fruit; Ra: relative abundance

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

Table 7. 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	0.50	0.42	0.40
Shannon index	1.02	0.96	1.17	1.21
Evenness index	0.47	0.51	0.43	0.36

3.2 Influence of Intercropping on the Major Insect Pest Populations of Maize, Cowpea and Okra

3.2.1 Influence of intercropping on the major insect pest populations of maize

Table 8 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.

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

3.2.2 Influence of intercropping on the major insect pest populations of cowpea

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

Table 9 reveals the density of *Ootheca mutabilis* on cowpea as influenced by intercropping system in 2016 and 2017 at Dang and Gouna. The application of insecticide gave significant results compared to sole cowpea and cowpea in intercropping unsprayed in 2016 (P < 0.001, F = 45.74, at Dang 2016; P < 0.001, F = 191.73, at Gouna 2016). The same trend was observed during the 2017 cropping season in both agro-ecological zones. The population of *O. mutabilis* on cowpea sole unsprayed was significantly higher at Gouna than at Dang (t = 14.99, P < 0.001; in 2016; t = 11.12, P < 0.001 in 2017). The same trend was observed on the cowpea intercropped unsprayed.

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.

Table 8. Density of *Spodoptera frugiperda* and *Busseola fusca* per maize plant as influenced by insecticidal treatment and intercropping system in 2016 and 2017 at Dang and Gouna

Treat	*Spodoptera frugiperda*						*Busseola fusca*					
	Dang 2016	Gouna 2016	*t*	Dang 2017	Gouna 2017	*t*	Dang 2016	Gouna 2016	*t*	Dang 2017	Gouna 2017	*t*
M	1.10a	0.05a	3.33	1.05a	0.15a	3.77	0.25a	0.12a	0.94	0.40a	0.08a	2.07
M+I	0.20b	0.05a	1.38	0.18b	0.08a	1.88	0.12a	0.02a	1.08	0.05b	0.05a	0.38
MC	0.60ab	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	0.60ab	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	0.10a	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	-	0.37	0.10	-	0.14	0.05	-	0.13	0.04	-
F	3.49**	0.54ns	-	6.75**	0.76ns	-	0.56ns	0.92ns	-	2.71*	0.29ns	-

*Treat: treatment; M: maize; MO: maize+ okra; MC: maize + cowpea; MCO: maize + cowpea + okra; +I: with insecticide. In column, means followed by same letter are not significantly different at the 5% level. * (P< 0.05);** (P < 0.01); *** (P < 0.001)*

Table 9. 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*
C+I	0.05c	0.06d	0.21	0.12c	0.06d	1.69
C	0.58a	2.07a	14.99	0.66a	1.72a	11.12
MC+I	0.03c	0.07d	1.60	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	-	0.30	0.71	-
F	45.74***	191.73***	-	38.18***	107.26***	-

*Treat: treatment; C: cowpea; MC: maize+ cowpea; OC: okra + cowpea; MCO: maize + cowpea + okra; +I: with insecticide. In column, means followed by same letter are not significantly different at the 5% level. * (P< 0.05);** (P < 0.01); *** (P < 0.001)*

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

Table 10 presents the density of *A. craccivora* on cowpea as influenced by insecticidal treatments and intercropping system in 2016 and 2017 at Dang and Gouna. Insecticide completely reduced the density of *A. craccivora* compared to the plots not protected ($P < 0.001$, F = 15.81, at Dang 2016; $P < 0.001$, F = 18.75, at Gouna 2016). The same trend was observed during the 2017 cropping season on the both agro-ecological zones. Among the plots not protected by insecticide in both zones and cropping seasons, 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 both zones.

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

Table 11 presents the density of *Megalurothrips sjostedti* and *Maruca vitrata* as influenced by insecticidal treatment and intercropping system. Cypermethrin reduced significantly the number of *Megalurothrips sjostedti* compared to the intercropping ($P < 0.001$, F = 167.26, at Dang 2016; $P < 0.001$, F = 142.45, at Gouna 2016). The same trend was observed during the 2017 cropping season. The population of *M. sjostedti* observed on cowpea sole unsprayed at Dang in 2017 was significantly lower than at Gouna (t = 2.02, P = 0.045). The same trend was observed on maize-cowpea-okra intercropping (t = 2.05, P = 8.31).

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.

At Gouna, Cypermethrin significantly reduced the number of *M. vitrata* compared to the unsprayed plot ($P < 0.001$, F = 33.85, in 2016; $P < 0.001$, F=37.90, 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 to the cowpea in intercropping.

d. Influence of intercropping on cowpea pod insect pest population

Table 12 presents the density of *Clavigralla tomentosicolis* and *Anoplocnemis curvipes* per cowpea plant as influenced by insecticidal treatments and intercropping system in 2016 and 2017 at Dang and Gouna. Cypermethrin significantly reduced the density of *C.*

tomentosicolis (*P* < 0.001, F = 10.74.26, at Dang 2016; *P* < 0.001, F = 17.1, at Gouna 2016) and *A. curvipes* (*P* < 0.001, F=13.75, at Dang 2016; *P* < 0.001, F=18.67, at Gouna 2016) in the both agro ecological zones and cropping year. On cowpea sole unsprayed *C. tomentosicolis* were significantly more abundant at Gouna than at Dang during both cropping seasons (*P* < 0.001, t = 8.43, 2016; *P* < 0.001, t = 6.31, 2017). The same tendency was observed on cowpea in intercropping.

In Gouna, among the unsprayed plots, cowpea-maize intercropping reduced significantly the number of *C. tomentosicolis* compared to sole cowpea during 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. curvipes* compared to the cowpea in monoculture.

3.2.3 Effect of intercropping system on the density of major insect pests of okra

a. Effect of intercropping on *Bemisia tabaci* population

Table 13 presents the density of *Bemisia tabaci* and *Podagrica decolorata* per okra plant as influenced by insecticidal treatment and intercropping system in 2016 and 2017 at Dang and Gouna. Cypermethrin reduced significantly the density of these pests in the both agro-ecological zones and cropping years. On okra sole, unsprayed *Bemisia tabaci* were significantly more abundant at Dang than at Gouna during both cropping seasons (*P* < 0.001, t = 5.32, 2016; *P* < 0.001, t = 11.81, 2017). The same tendency was observed on okra in intercropping.

Among the cropping unsprayed, maize-okra intercropping reduced significantly the density of *B. tabaci* compared to okra monocropped. However, the higher number of *B. tabaci* was observed on okra-cowpea intercropping.

b. Effect of intercropping on *Podagrica decolorata* population

It appears from the Table 13 that, insecticide reduced significantly the density of *Podagrica decolorata* in both agro-ecological zones and cropping years compared to unsprayed.

On okra sole unsprayed, the abundance of *P. decolorata* was the same at Dang and Gouna during both cropping seasons. The same tendency was observed on okra in intercropping in 2016.

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 10. 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*
C+I	0.00c	0.33c	-	0.12c	0.18c	0.50
C	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	0.20	13.73b	16.88b	0.66
Mean	11.66	14.09	-	10.29	12.96	-
F	15.81***	18.75***	-	15.90***	18.52***	-

*Treat: treatment; C: cowpea; MC: maize+ cowpea; OC: okra + cowpea; MCO: maize + cowpea + okra; +I: with insecticide. In column, means followed by same letter are not significantly different at the 5% level. * (P< 0.05);** (P < 0.01); *** (P < 0.001)*

Table 11. Populations of *Megalurothrips sjostedti* and *Maruca vitrata* per cowpea flower as influenced by intercropping at Dang and Gouna

Treat	*Megalurothrips sjostedti*						*Maruca vitrata*					
	Dang 2016	**Gouna 2016**	***t***	**Dang 2017**	**Gouna 2017**	**t**	**Dang 2016**	**Gouna 2016**	***t***	**Dang 2017**	**Gouna 2017**	***t***
C+I	0.14d	0.15d	0.32	0.17d	0.16d	0.21	0.00a	0.01c	-	0.00a	0.02b	-
C	6.72a	6.84a	0.24	9.93a	8.68a	2.02	0.06a	0.57a	6.95	0.00a	0.51a	-
MC+I	0.07d	0.18d	1.84	0.2d	0.19d	0.12	0.00a	0.02c	-	0.00a	0.01b	-
MC	4.03b	3.30bc	1.73	5.12b	5.12bc	0.00	0.05a	0.46ab	6.66	0.00a	0.47a	-
OC+I	0.17d	0.10d	1.31	0.21d	0.16d	0.74	0.00a	0.01c	-	0.00a	0.02b	-
OC	4.13b	4.16b	0.09	5.98b	5.81b	0.38	0.02a	0.43ab	6.50	0.00a	0.43a	-
MCO+I	0.15d	0.10d	1.04	0.24d	0.14d	1.77	0.01a	0.02c	0.34	0.00a	0.01b	-
MCO	2.75c	3.13c	1.27	3.76c	4.53c	2.05	0.06a	0.37b	5.69	0.00a	0.36a	-
Mean	2.27	2.24	-	3.20	3.10	-	0.03	0.23	-	0.00	0.23	-
F	167.26***	142.45***		173.51***	258.48***	-	1.17ns	33.85***	-	0.00ns	37.90***	-

*Treat: treatment; C: cowpea; MC: maize+ cowpea; OC: okra + cowpea; MCO: maize + cowpea + okra; +I: with insecticide;. In column, means followed by same letter are not significantly different at the 5% level. *(P< 0.05);** (P < 0.01); *** (P < 0.001)*

Table 12. Density of *Clavigralla tomentosicolis* and *Anoplocnemis curvipes* per cowpea plant as influenced by insecticidal treatments and intercropping system in 2016 and 2017 at Dang and Gouna

Treat	*Clavigralla tomentosicolis*						*Anoplocnemis curvipes*					
	Dang 2016	**Gouna 2016**	***t***	**Dang 2017**	**Gouna 2017**	**t**	**Dang 2016**	**Gouna 2016**	***t***	**Dang 2017**	**Gouna 2017**	***t***
C+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
C	0.19a	0.77a	8.43	0.19a	0.79a	6.31	0.25a	0.61b	5.20	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	5.40	0.18a	0.45bc	4.48	0.13a	0.35b	4.38
Mean	0.08	0.28	-	0.08	0.31	-	0.11	0.29	-	0.08	0.22	-
F	10.74***	17.1***	-	7.9***	32.11***	-	13.75***	18.67***	-	8.59***	44.91***	-

*Treat: treatment; C: cowpea; MC: maize+ cowpea; OC: okra + cowpea; MCO: maize + cowpea + okra; +I: with insecticide. In column, means followed by same letter are not significantly different at the 5% level. *(P< 0.05);** (P < 0.01); *** (P < 0.001)*

Table 13. 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	Gouna 2017	*t*
O+I	0.29d	0.36d	0.77	0.37e	0.30d	1.02	0.32c	0.30c	0.21	0.28c	0.35d	0.98
O	16.22b	12.75a	5.32	22.04b	13.51b	11.81	8.24a	8.96a	1.61	8.96a	8.43a	1.10
MO+I	0.22d	0.17d	0.77	0.33e	0.17d	2.24	0.31c	0.27c	0.61	0.32c	0.38d	0.69
MO	10.72c	9.56c	2.29	12.23d	9.92c	4.65	6.24b	6.53b	0.74	6.46b	6.22c	0.59
OC+I	0.20d	0.27d	1.17	0.30e	0.28d	1.02	0.22c	0.30c	1.10	0.22c	0.48d	3.02
OC	18.29a	13.91a	5.71	25.32a	14.75a	13.09	8.26a	8.13a	0.29	8.66a	7.37b	2.53
MCO+I	0.21d	0.30d	1.23	0.22e	0.12d	1.88	0.22c	0.25c	0.50	0.23c	0.27d	0.61
MCO	10.80c	10.90b	0.20	14.23c	10.68c	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	-	3.76	3.85	-	3.86	3.60	-
F	538.39***	489.63***	-	777.52***	606.3***	-	315.62***	324.04***	-	302.74***	263.33***	-

*Treat: treatment; O: okra; MO: maize+ okra; OC: okra + cowpea; MCO: maize + cowpea + okra; +I: with insecticide. In column, means followed by same letter are not significantly different at the 5% level. *(P< 0.05);** (P < 0.01); *** (P < 0.001)*

4. DISCUSSION

Our studies have demonstrated that lepidopterans were the most abundant and the major insect pests of maize in the Sudano-Guinean savannah and Sudano-Sahelian agro-ecozone. Lepidopterans were reported as major pests of maize in some countries [38,39,40]. Among the lepidopterans, *Spodoptera frugiperda* was the most represented species. In contrast, *B. fusca* was accounted for 95 % of all the individuals found on maize in Cameroon [9]. 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 [41]. Moreover, farmers in this region stock maize stems to feed their cattle in the dry season 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 monoculture is sensitive to higher insect pest populations [42].

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 Sudano-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 zone are favourable 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 zone [6]. 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 loss in Nigeria [43,44].

In our study *Ootheca*, aphids and thrips recorded in the cowpea in intercropping were lower than those in the sole cowpea crop. This trend was observed at 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 disrupt the insects' visual search for preferred host. It has been demonstrated that all crops like traditional cereal varieties can disrupt insects' visual search for preferred host [45].

The study revealed that cowpea in monoculture recorded a highest number of *Maruca* but there was not a significant difference to the cowpea in intercropping in the both cropping seasons. Similar results were reported previously [23]. This could be an activity of some predators.

At Gouna, in the 2016 cropping season, cowpea-maize intercropping reduced significantly the density of *A. curvipes* 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. curvipes*.

Okra intercropped with maize was a promising system for reducing *Bemisia* and *Podagrica* populations 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* [44].

5. CONCLUSION

This work was conducted to document the spectrum of insect pests associated with cowpea, okra and maize, to determine their major insect pests and to evaluate the effect of intercropping system between maize-cowpea, maize-okra, okra-cowpea and maize-okra-cowpea on the population of their major insect pests in the Sudano-Guinean savannah (Dang-Ngaoundéré) and Sudano-Sahelian agro-ecological zones (Gouna-Garoua), Cameroon. As the outcomes, 19 insects attack cowpea crops in both agro-ecological zones. Three of the insect pests were found as cowpea major pests at Dang, namely *Ootheca mutabilis, Megalurothrips sjostedti* and *Aphis craccivora* and three more species at Gouna (*Maruca vitrata, Clavigralla tomentosicolis, Anoplocnemis curvipes*). Fifteen insect species attack okra crops and five insect species attack maize crops in the both agro-ecological zones. 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*. Intercropping showed in most comparisons significant reductions ($P < 0.001$) of the major insect pests. On the basis of the results obtained, we recommend maize-cowpea and maize-okra intercropping as a local sustainable solution to reduce the populations of their major insect pests in Northern Cameroon. But further research should be geared towards identifying the factors responsible for the reduction of insect pests.

ACKNOWLEDGEMENTS

We sincerely thank the reviewers for their comments. We also thank Tchawé, Dikmo and Godwé for providing us the experimental sites and the students of the applied zoology lab of the University of Ngaoundéré for the documentation provided to identify insects. We acknowledge the German Academic Exchange Service (DAAD) for supporting the cooperation of the universities of Bremen (Germany) and Ngaoundéré (Cameroon) from funds of the German Federal Ministry for Economic Cooperation and Development (BMZ).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. World Bank.Gross domestic product share of agriculture, Cameroon; 2017.
2. DSCE. Document de Stratégie pour la Croissance et l'Emploi. MINEPAT, Yaoundé, Cameroun. 2009;112.
3. IPBO. Maize in Africa; University of Ghent. 2017;29.
4. INS. Agriculture, Annuaire statistique, chapter 14. Yaoundé, Cameroun. 2015;24.
5. Owolabi AO, Ndidi US, James BD, Amune FA. Proximate, antinutrient and mineral composition of five varieties (improved and local) of cowpea, *Vigna unguiculata,* commonly consumed in Samaru community, Zaria-Nigeria. Asi. J. of Fo. Sci. and Tech. 2012;4(2):70-72.
6. Dugje IY, Omoigui LO, Ekelem F, Bandyopadhyay R, Kumar P, Kamara AY. Farmers guide to soybean production in Northern Nigeria. 2009;16.
   Available:www.iita.org
   Accessed August 11, 2016
7. Aladele SE, Ariyo OJ, Lapena R. Genetic relationships among West African Okra (*Abelmoschus esculentus*). Ind. J. of Bio. 2008;7(10):1426-1431.
8. Nonnecke IL. Vegetable production. Van Nostrand Reinhold Publishing, Netherlands. 1989;609.
9. Cardwell KF, Schulthess F, Ndemah R, Ngoko Z. A systems approach to assess crop health and maize yield losses due to pests and diseases in Cameroon. Agri. Eco. Envir. 1997;65:33–47.
10. Ndemah R. Towards an integrated crop management strategy for the African stalk borer, *Busseola fusca* Fuller. Lepidoptera: Noctuidae in maize systems in Cameroon. Ph.D. Thesis, University of Hannover, Germany. 1999;136.
11. Chabi-Olaye A, Nolte C, Schulthess F, Borgemeister C. Effects of grain legumes and cover crops on maize yield and plant damage by *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) in the humid forest of southern Cameroon. Agri. Eco. Envir. 2005;108:17–28.
12. Parh. Insect pest incidence on cowpea in the Cameroonian southwest forest and western derived Savanna zones, their contribution to yield loss in Foumbot and their control. Tropi. 1999;2:83-88.
13. Ngakou A, Tamo M, Parh IA, Nwaga D, Ntonifor NN, Korie S, Nebane C. Management of cowpea flower thrips, *Megalurothrips sjostedti* (*Thysanoptera*, *Thripidae*), in Cameroon. Crop Protec. 2008;27:481-488.
14. Barry BR, Ngakou A, Nukenine EN. Pesticidal activity of plant extracts and a mycoinsecticide (*Metarhrizium anisopliae*) on cowpea flower thrips and leaves damages in the field. J. of Exp. Agri. Inter. 2017;18(2):1-15.
15. Singh A, Wolfgang WW, Rachid H, Raissa H, Sharon EZ. Reduce pests, enhance production: Benefits of intercropping at high densities for Okra farmers in Cameroon. Pest Manag Sci. 2017;73: 2017- 2027.
16. Singh SR, Jackai LEN. Insect pests of cowpea in Africa: Their life cycle, economic importance and potential for control. In: Singh SR, Rachie KO. (Eds.), Cowpea Research, Production and Utilization. Wiley, Chichester, UK. 1985;217-231.
17. Ndemah R, Schulthess F, Korie, S, Borgemeister C, Poehling M, Cardwell KF. Factors affecting infestations of the stalk borer *Busseola fusca* (Fuller) on maize in the forest zone of Cameroon with special

reference to scelionid egg parasitoids. Envir. Ento. 2003;32:61–70.
18. Valles SM, Koehler PG. Insecticides used in the Urban environment: Mode of Action. University of Florida. 1997;4. Available:http://edis.ifas.ufl.edu (Accessed September 07, 2018)
19. Prokopy RJ, Mason JL, Christie M, Wright SE. Arthropod pest and natural enemy abundance under second-level versus first-level integrated pest management practices in apple orchards. Agri. Eco. Envir. 1995;57:35-47.
20. Cross JV, Solomon MG, Babandreier D, Blommers L, Easterbrook MA, Jay C, Jenser G, Jolly R, Kuhlmann U, Lilley R, Olivella E, Toepfer S, Vidal S. Biocontrol of pests of apples and pears in northern and central Europe. Bio. Sci. and Tech. 1999;9:277-314.
21. Aman S, Bhuvnesh Y, Shipra R, Baljeet Y. Cypermethrin Toxicity: A Review. J. of Fors. Sci. and Cri. Inves. 2018;9(4): 555767.
22. Calatayud P-A, Bruno PL, Johnnie VD, Fritz S. Ecology of the African maize stalk borer, *Busseola fusca* (*Lepidoptera*: *Noctuidae*) with special reference to insect-plant interactions. Insects. 2014;5: 539-563.
23. Ahoaka-Atta S, Jackai L, Makanjuola W. Cowpea plant architecture in relation to infestation and damage by the legume pod borer, *Maruca vitrata* Fabricius (*Lepidoptera: Pyralidae*), effect of canopy structure and pod position. Ins. Sci. and it Ap. 1993;12:171-176.
24. Hassan S. Effect of variety and intercropping on two major cowpea [*Vigna unguiculata* (L.) Walp] field pests in Mubi, Adamawa State, Nigeria. J. of Hort. and For. 2009;1(2):014-016.
25. Degri MM, Richard IB. Impact of intercropping sorghum and okra on the incidence of flea beetles of Okra *Podagrica* spp in Dalwa, Maiduguri semi-arid zone of Nigeria. Inter. Let. of Nat. Sci. 2014;14:51-58.
26. Vandermeer J. The Ecology of intercropping. Cambridge University Press, Cambridge. 1989;237.
27. Finch S, Collier R. Host-plant selection by insects- a theory based on appropriate/inappropriate landings by pest insects of cruciferous plants. Ento. Exper. et Ap. 2000;96:91-102.
28. Djoufack V, Fontaine B, Martiny N, Tsalefac M. Climatic and demographic determinants of vegetation cover in northern Cameroon. Inter. J. of Rem. Sen. 2012;33(21):6904–6926.
29. Tchuenguem FFN. Activité de butinage et de pollinisation d'*Apis mellifera adansonii* Latreille (*Hymenoptera*: *Apidae*, *Apinae*) sur les fleurs de trois plantes à Ngaoundéré (Cameroun): *Callistemon rigidus* (Myrtaceae), *Sygygium guineense* var. *macrocarpum* (*Myrtaceae*) et *Voacanga africana* (Apocynaceae). Thèse de Doctorat d'Etat, Université de Yaoundé I. 2005;103.
30. Megueni C, Ngakou A, Makalao MM, Kameni TD. Responses of soybean (*Glycine max* L.) to solarization and rhizobia field inoculation at Dang Ngaoundere, Cameroun. As. J. of pl. sci. 2006;5(5):832-837.
31. FAO. L'irrigation en Afrique en chiffres, Enquête AQUASTAT, Cameroun. 2005; 10. Available:http://www.fao.org/nr/water/aquastat/countries_regions/CMR/CMR-CP_fra Accessed December 19, 2018.
32. Vallee G, M'Biandoun M, Forest F. Semis direct dans l'aménagement de Sanguéré-Djalingo, Cameroun; Cahier Agriculture. 1996;5:161-169.
33. Bambara D, Tiemtoré J. Efficacité biopesticide de Hyptis spicigera Lam. *Azadirachta indica* A. Juss. et *Euphorbia balsamifera* sur le niébé *Vigna unguiculata* L. Walp. Tropi. 2008;26:53-55.
34. Alao F, Adebayo TA. Comparative toxicity of botanical and synthetic insecticides against major field insect pests of cowpea (*Vigna unguiculata* (L) Walp). J. of Nat. Prod. and Pl. Res. 2011;1(3):86-95.
35. Mabonga RA. Insect pests of cowpeas *Vigna unguiculata* (l.) walp. and studies on cowpea yield assessment under different chemical spray regimes and minimum use of insecticides against the dominant insect pest species at Katumani dryland research station, Kenya, the University of Nairobi. 1983;133.
36. Help C, Herman P, Soetaert K. Indices of diversity and evenness, Oceanis. 1998;24:61-87.
37. Help C, Engels P. Comparing species diversity and evenness indices. AJar. Biol. Ass. UK. 1974;54:559-563.
38. Sétamou M, Schulthess F, Poehling H, Borgemeister C. Monitoring and modeling

of field infestation and damage by the maize ear borer *Mussidia nigrivenella* Ragonot (*Lepidoptera: Pyralidae*) in Benin, West Africa. J. of Eco. Ento. 2000;93:650-657.
39. Lucius JB, Oniemayin M. Management of stem borers on some quality protein maize varieties. J. of Agri. Sci. 2011;56(3):197-205.
40. Mashwani MA, Farman U, Sajjad A, Kamran S, Syed FS, Muhammad U. Infestation of maize stem borer, *Chilo partellus* (Swinhoe) in maize stubbles and stalks. J. of Bio. and Envir. Sci. 2015;7(1): 180–185.
41. Adesiyun AA, Ajayio. Control of the sorghum stem borer *Busseola fusca* by partial burning of the stalks. Trop. Pest Manag. 1980;26(2):113-117.
42. Kaufmann T. Behavioural biology, feeding habits and ecology of three species of maize stem borers: *Eldana saccharina* (Lepidoptera: Pyralidae), *Sesamia calamistis* and *Busseola fusca* (Noctuidae) in Ibadan, Nigeria, West Africa. J. of the Ento. Res. Soc.1983;18:259–272.
43. Karungi J, Adipala EJ, Ogenga–Latigo MW, Kyanmanyawa S, Oyobo N. Crop prot. 2000;19:343-347.
44. Oyewale RO, Bamaiyi LJ. Management of cowpea insect pest's scholars academic. J of Bio. 2013;1(5):217-226.
45. Ogenga-Latigo M, Ampofo J, Balidawa C. Influence of maize row spacing on infestation and damage of intercropped beans by beans aphids (*Aphis fabae* SCOP.), reduction in bean yields. Field Crop. Res. 1998;30:111-121.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle3.com/review-history/45677