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Entomofauna associated with the crop of okra, *Abelmochus esculentus* L. Moench according to the phenological stages and evaluation of the damage caused by insect pests (Daloa, Côte d'Ivoire)

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Abstract

The need to control insect pests of okra crops has led to inventory of insects and evaluation of damage caused by insect pests of this plant. This study was conducted an experimental plot of Jean Lorougnon Guédé University of Daloa during the period from November 2018 to February 2019. Insect captures were made using colorful trap, light trap, trap pit and with sweep net. For the damage caused by the insect pests, the plants were controlled. A total, 5164 insects belonging 40 species regrouped in 29 families and 8 orders were collected. Coleoptera with 52.25% were the most abundant at the flowering stage. *Podagrica decolorata* was represented highest population (1677 individuals), then *Bemissia tabaci*, *Jacobiasca lybica* and *Dysdercus voelkeri* with respectively 690, 679 and 646 individuals. The colorful trap captured 3761 insects or 72.83% of the total collected insects. Defoliators caused the highest damage to stage before flowering and flowering stage with attack rates of 87.41 and 95.33%, respectively. At fruiting stage, the highest attack rate (61.64%) was induced by piercing-sucking.

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Introduction

Okra, *Abelmochus esculentus*, is a vegetable native to Africa whose crop covers the tropical, subtropical and mediterranean regions. It is an essential component of the diet of urban and rural populations because of its high nutritional value (Kahlon *et al.*, 2007; Khomsug *et al.*, 2010). Annual production in Côte d'Ivoire is about 100000 tonnes (Fondio *et al.* 2007). This production is provided by live producers in rural and urban areas and is a real instrument struggle against poverty (Fondio *et al.*, 2011). Unfortunately, this crop is constrained by many biotic factors, the most important of which are insect pests and diseases. Diseases are of several types: virus diseases (mosaic, leaf roll) and fungal diseases (Cercospora leaf spot, Fusarium wilt) (Ugwoke and Onyishi, 2009). Insects cause considerable damage to okra through their defoliation, drill, sucking and even virus vectors (Fondio *et al.*, 2007; PIP 2008, Soro *et al.*, 2016). To control these pests, several methods of are used, of which chemical control is the most used. But this method is harmful to humans and the environment (Kadri *et al.*, 2013; Hénault-Ethier, 2015). "Sassandra" region is the largest okra production areas in Côte d'Ivoire. However, the literature does not mention any studies on the distribution of okra insects in this region. It was therefore, useful to make an inventory to update the list of insect pests and auxiliaries. The purpose of the present study is therefore to inventory all the insects of the plant in order to set up an effective method to control the pests that takes into account the phenology of the plant.

Material and methods

Study area

The study was conducted from November 2018 to February 2019 at the university Jean Lorougnon Guédé, located in the department of Daloa "Haut-Sassandra" region in the center-west of Côte d'Ivoire. Daloa is located at 6 ° 53 north latitude and 6 ° 27 west longitude of Côte d'Ivoire. This locality was subject to a humid tropical climate with an average annual rainfall ranging between 1400 and 1800 mm. The region is characterized by two rainy seasons (April to mid-July and September to November) and two dry seasons (mid-July to August and December to March). The average temperature and relative humidity conditions were 26.20 ± 2.19 ° C and 80 ± 3% respectively.

Biological material

It consists of okra plants, *Abelmoschus esculentus*, and the local variety commonly known as "Koto". The average time cycle of this variety is 120 to 150 days (Fondio *et al.*, 2007). The animal material consists of insects captured in the experimental plot.

Technical material

It consists of colored traps used for the insects capture that move on the aerial parts of okra plants. A light trap was used to collect nocturnal insects. Pit traps used for collecting crawling insects. A sweep n*et a*llowed the collection of flying insects. A forceps has been used for the capture of insects were highly developed mandible. Small jars containing 70 ° alcohol were used for the collection and preservation of insects. A binocular loupe of mark LEICA EZ4 was used for the observation of insects. The manuals of Bordat and Laurence (2004) and George (2005) were used to identify insects.

Experimental design and planting of crops

The experimental plot, with a surface area of 350 m² (25 m x 14 m), was subdivided into 3 blocks separated to 2 m. Each block consisted of 3 elementary plots (7m x 4m). Two consecutive elementary plots are separated to 1 m. In each elementary plot, the seedlings are arranged on 4 lines of 7 m length separated from each other to 1 m. The seedlings are made to equidistant of 0.5 m. Two to three okra seeds were put in each hole. Thinning plant per hole was carried out 15 days after sowing. Each elementary plot is composed of 52 plants or 468 plants throughout the experimental plot.

Capture and identification of insects

The colorful trap consists of yellow plastic plates and filled to about two-thirds of soapy water, arranged on each elementary plot at the form of an isosceles

triangle. The plates were based on iron racks of 0.5 m heigh. Insects that fly near the trap were attracted by the yellow color, fall into the liquid and drown (Franck, 2008). In total 27 traps were arranged in the 9 elementary plots. The collections were made to every three days starting at 7 am with a mini strainer and a soft tong. The soapy water was renewed after each collection.

The light trap, was composed of a white cloth stretched between two stakes of 2 m height illuminated with a flashlight hanging on a stake placed 5 cm from the sheet. At the base of the sheet is a basin filled with two-thirds of soapy water. The flashlight was switched on from 7 pm to 6 am. The nocturnal insects attracted by the light, clash with the sheet, fall into the basin and die to drowning. The collections were effectuated every three days and soapy water was renewed after each collection.

As for the technique of sweep net, it consisted in advancing in the field to capturing by hand and by mowing the insects present on the plants, by fast movements using the sweep net. This capture was performed every three days from 7 am to 10 am.

The pit trap, consists of a cylindrical container filled with two-thirds of soapy water and pressed into the ground. The upper edge of the container remains on the surface. Creeping insects fall into the trap and drown. Two traps were installed per elementary plot for a total of 18 traps throughout the plot.

Evaluation of damage caused by insect pests

Observations were made on the central plants of an elementary plot of each block (N'gbesso *et al.*, 2013). Thus, 26 plants (2 central lines of 13 indoor plants) per elementary plot were inspected. At each observation, the evaluation of the damage caused by defoliators, piercing-sucking and borer was effectuated by counting the attacked plants at the level of leaves, flower buds, stems and fruits in the each elementary plot. For each group of insects, the attack rate of the plants was calculated by the ratio of the number of plants attacked to the total number of plants in each elementary plot multiplied by one hundred (Isirima *et al.*, 2010, N'ta *et al.*, 2013).

$$\text{Attack rate (\%)} = \frac{\text{Number of plants attacked}}{\text{Total number of plants}} \times 100$$

Then, the average attack rates caused by the three groups of insects were calculated for each phenological stage of the crop.

Statistical analysis

The data was processed using the statistica version 7.1 software. The variance analysis (ANOVA) and the Sudent-Newman-Keuls (SNK) test at the 5% threshold allowed to analyze and compare attack rates of okra organs according to the three groups of insects. The relative abundance of the species was determined by the formula of Zame and Gautier (1989):

$$Ar(\%) = \frac{Ni}{N} \times 100$$

Ar (%): relative abundance; Ni: number of individuals of the species taken into consideration; N: total number of individuals of all species combined.

Results

Specific richness of insects captured

The different techniques used were allowed to capture 5164 insects belonging to 8 Orders distributed in 29 families and 40 species. The number of species varied according to the Orders. Coleoptera were most represented with 9 species corresponding to 22.50% of the total species. Then come the Orthoptera (8 species) which represented 20% of the species. Diptera with 6 species represented 15% of the species followed by Hymenoptera with 5 species representing 12.5%. The Homoptera and Heteroptera were the same richness with 4 species each, or 10% of the species. Lepidoptera were represented with 3 species, or 7.5%. Dermaptera was the lowest abundance with a species representing 2.5% of the species (Table 1). The number of insects by phenological stage was 1589 at stage before flowering, 1594 at flowering stage and 1981 at fruiting stage respectively 30.77; 30.87 and

38.36% of total captured insects. The species with the highest total population (1677 individuals) was *Podagrica decolorata*. Then come *Bemissia tabaci, Jacobiasca lybica* and *Dysdercus voelkeri* with respectively 690; 679 and 646 individuals. The number of 36 other species each were lowest than 400 individuals (Table 1).

Table 1. Number of insects captured according to the phenological stages of okra.

			Number per phenological stage			
Orders	Families	species	S.b.flow	Flow	Frui	Total
Diptera	Muscidae	*Musca domestica* Linnaeus, 1758	38	35	7	80
	Stratiomyidae	*Hermetia illucens* Linnaeus, 1758	64	36	20	120
	Calliforideae	*Lucilia seriata* Meigen, 1826	78	60	12	150
		Calliphora vomitoria Linnaeus, 1758	8	7	5	20
	Sarcophagidae	*Sarcophaga carnaria* Linnaeus, 1758	9	11	12	32
	Diopsidae	*Cyrtodiopsis dalmanni* Wiedemann, 1830	0	2	0	2
		Diopsis sp.	7	19	4	30
Coleoptera	Coccinellidae	*Epilachna sp.*	8	4	2	14
		Henosepilachna reticulata Olivier, 1791	2	5	7	14
		Cheilomones sulphurea Olivier, 1791	12	8	10	30
	Chrysomelidae	*Podagrica decolorata* Duvivier, 1892	357	814	506	1677
		Podagrica malvae Illiger, 1807	2	0	0	2
		Nisotra dilecta Dalman, 1823	11	0	7	18
	Meloidae	*Mylabris variabilis* Pallas, 1781	0	2	4	6
	Scarabaeidae	*Kheper aegyptiorum* Latreille, 1827	0	0	8	8
	Tenebrionidae	*Lagria vilosa* Fabricius, 1781	0	0	1	1
	Cetoniidae	Pachnoda cordata Drury, 1773	0	0	4	4
Heteroptera	Coreidae	*Anoplocnemis curvipes* Fabricius, 1781	2	1	4	7
	Pentatomidae	*Nezara viridula* Linnaeus, 1758	0	0	17	17
		Acrosternum millierei Mulsant & Rey, 1866	3	7	4	14
	Pyrrhocoridae	*Dysdercus voelkeri* Schmidt, 1932	0	7	639	646
	Lygaeidae	*Oxycarenus sp.*	0	0	1	1
Homoptera	Aleyrodidae	*Bemissia tabaci* Gennadius, 1889	346	125	219	690
	Cicadellidae	*Empoasca dolichi* Paoli, 1930	11	9	4	24
		Jacobiasca lybica Bergevin & Zanon, 1922	315	207	154	676
	Pseudococcidae	*Ferrisia virgata* Cockerell, 1893	9	6	11	26
		Pseudococcus sp.	4	1	0	5
	Membracidae	*Membracis sp.*	137	8	2	147
		Umbonia sp.	1	0	2	3
Hymenoptera	Apidae	*Apis melifera* Linnaeus, 1758	0	4	2	6
		Tetragona sp.	0	2	0	2
	Formicidae	*Camponotus sp.*	17	24	5	46
		Lasius sp	7	9	21	37
		Crematogaster sp.	0	112	226	338
		Dorylus nigricans Illiger, 1802	2	0	4	6
		Polyrhachis sp.	4	8	11	23
Lepidoptera	Erebidae	*Nyctemera apicalis* Walker, 1854	8	6	3	17
	Nymphalidae	*Acraea acerata* Hewitson, 1874	9	3	2	14
	Noctuidae	*Spodoptera littoralis* Boisduval, 1833	5	1	2	8
Dermaptera	Forficulidae	*Forficula lucasi* Dohrn, 1865	1	2	0	3
Orthoptera	Pyrgomorphidae	*Zonocerus variegatus* Linnaeus, 1758	26	14	11	51
		Chrotogonus trachypterus Blanchard, 1836	18	11	9	38
	Gryllidae	*Brachytrupes membranaceus* Drury, 1770	30	7	6	43
	Acrididae	*Acrida acuminata* Stål, 1873	18	9	10	37
		Chorthippus biguttulus Linnaeus, 1758	5	1	1	7
		Schistocera gregaria Forsskål, 1775	9	0	0	9
	Tettigoniidae	*Tettigonia viridissima* Linnaeus, 1758	2	3	0	5
	Tetrigidae	*Tetrix sp.*	4	4	2	10
8 Orders	29 Families	40 species	1589	1594	1981	5164

S.b.flow: Stage before flowering; Flow: Flowering stage; Frui: Fruiting stage.

Number of insects caught with different types of traps

For all orders combined, the colorful trap captured a large number of insects with number of 3761 compared to 754 for sweep net, 459 for pit trap and 190 for light trap. Among the 8 orders listed, the colorful and light traps captured mainly beetles.

The pit trap captured more Hymenoptera. Heteroptera were the most numerous to be captured by the sweep net (Table 2).

Table 2. Total number of insects captured according type of trap.

Orders	Capture methods				Total
	Colorful trap	Light trap	Pit trap	Sweep net	
Diptera	434	0	0	0	434
Coleoptera	1639	81	18	36	1774
Heteroptera	9	6	13	657	685
Homoptera	1567	0	0	4	1571
Hymenoptera	40	17	401	0	458
Lepidoptera	28	8	0	3	39
Dermaptera	0	0	3	0	3
Orthoptera	44	78	24	54	200
Total	3761	190	459	754	5164

Relative abundance of orders according to the phenological stages of okra

Stage before flowering

Eight (8) orders were collected. Order of Homoptera, with relative abundance of 51.79%, was most abundant at this stage. Then come Coleoptera (24.66%), Diptera (12.83%) and Orthoptera (7.04%). Orders of Hymenoptera, Lepidoptera, Heteroptera and Dermaptera were minority (Fig.1A).

Flowering stage

During flowering, eight (8) orders were collected. Coleoptera with 52.25% were the most abundant at this stage. They were followed by Homoptera (22.33%), Diptera (10.66%) and Hymenoptera (9.97%). Orders minority were Orthoptera, Heteroptera, Lepidoptera and Dermaptera (Fig.1B).

Fruiting stage

Seven (7) orders were recorded at the fruiting stage. Heteroptera, were the most abundant with a relative abundance of 33.56%. Then come the Coleoptera with of 27.71%, Homoptera and Hymenoptera were represented respectively at 19.78% and 13.57%. Orders captured a minority compared to others were Diptera, Orthoptera and Lepidoptera (Fig.1C).

Relative abundance of species

During Stage before flowering, the most abundant species was *P. decolorata* with a relative abundance of 23.01% followed by *B. tabaci* with 22.30%. The other species recorded were less represented. At the flowering stage, *P. decolorata* was also the most abundant with 52.21% of total insects caught. It was followed by *J. lybica* representing 13.27% of the capture. During fruiting, the most abundant species was *D. voelkeri* with a relative abundance of 32.37% followed by *P. decolorata* with 25.63%. The other species representing each a relative abundance of less than 10%.

Action of insects caught on okra plants

The insect pests caught were classified into three categories according attacked organ of the plant.

Thus, defoliators, piercing-sucking, and borer were distinguished. Auxiliarie insects were represented by predators and pollinators.

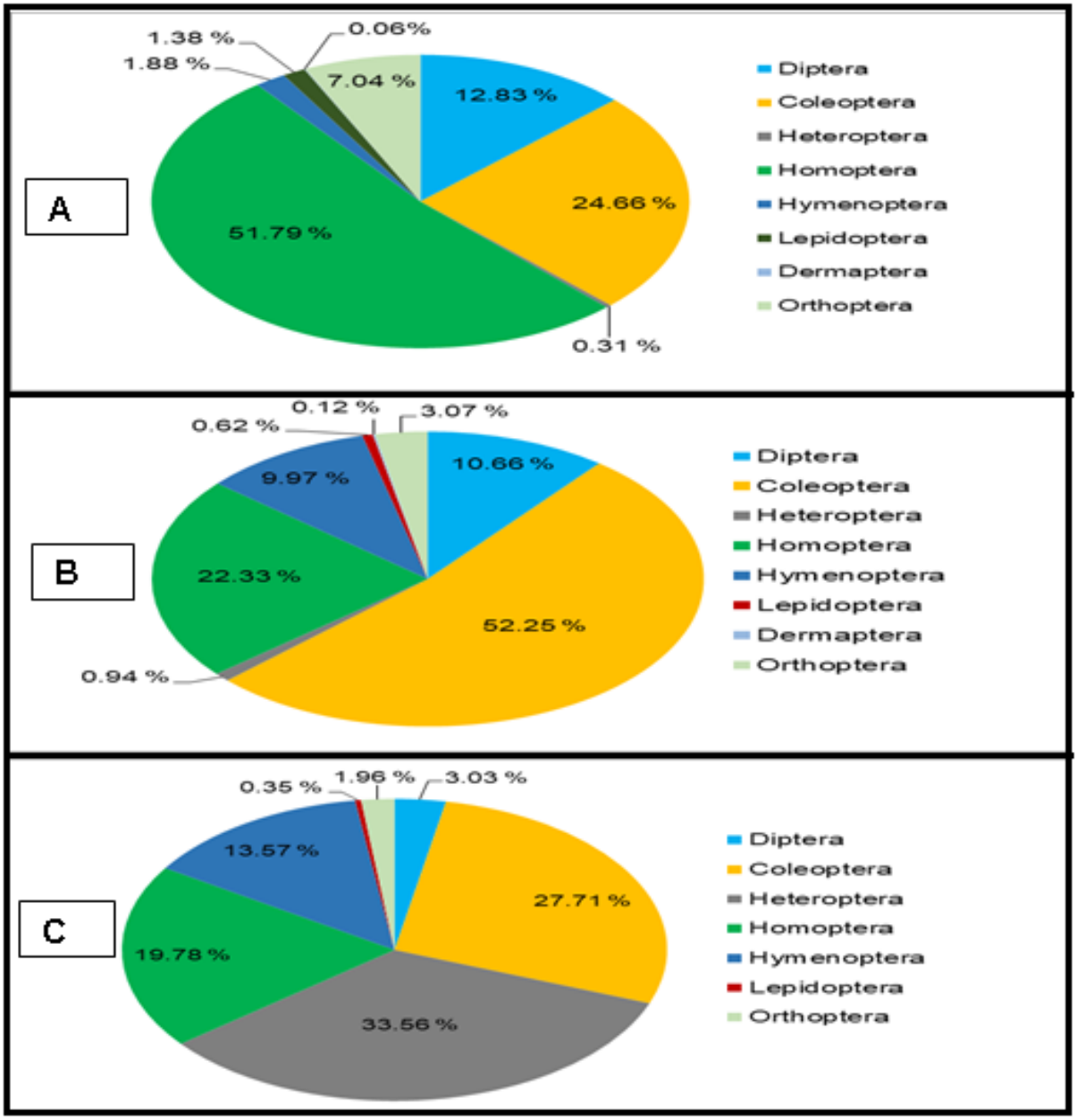

Fig. 1. Relative abundance of the insect orders during of the three phenological stages A: Stage before flowering; B: Flowering stage; C: Fruiting stage.

Defoliators

These pests belong to the Order Coleoptera, Lepidoptera and Orthoptera. Coleoptera (*L. vilosa*, *Epilachna sp*, *P. decolorata*, *P. malvae*) partially devour the leaves of the plants causing perforations of the limb. Lepidoptera (*S. littoralis*) cause damage by their larvae which consume the parenchyma of the underside of the leaves. Orthoptera (*B. membranaceus*, *T. viridissima*, *A. acuminata*, *Z. variegatus*) eat the upper surface of the leaves and sometimes cut the stems of the young plants at their base.

Piercing-sucking

Piercing-sucking belong to the Orders of the Heteroptera and Homoptera.

The Heteroptera (*N. virudula*, *A. curvipes* and *D.voelkeri*.) sting and suck the sap in the pods of the plants that they cover multiple black spots and cause the abortion of seeds.

The Homoptera (*B. tabaci* and *E. dolichi*) sting and suck the sap the leaves, weakening the plant, leading to lower productivity.

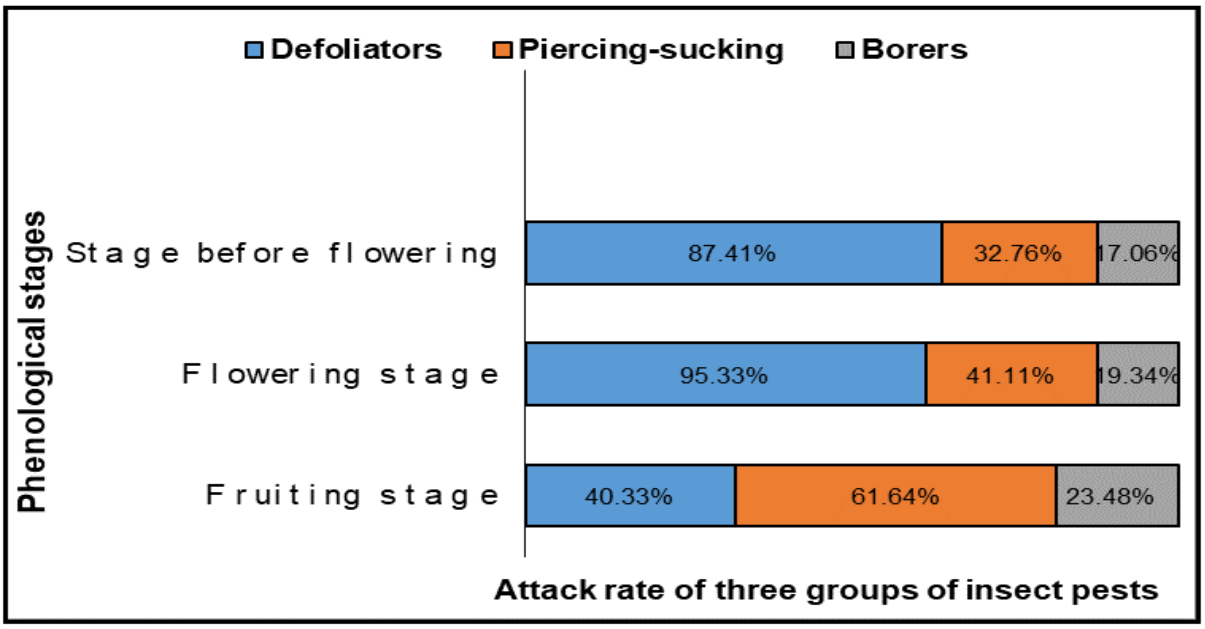

Fig. 2. Attack rates of the okra plants caused by the three group's insect pests during the phonological stages.

Borers

The majority of borers encountered belong to the order Lepidoptera belonging three families: Erebidae (*N. apicalis*), Noctuidae (*S. littoralis*) and Nymphalidae (*A. acerata*). These insects attack the flower buds and fruits by puncturing them to empty of their contents.

Predators

Predators were entomophagous insects that feed on other insects through direct predation. The two predatory insect species of pests collected belong to the orders of Hymenoptera represented by the family Formicidae (*Crematogaster sp.*) and Coleoptera of the family Coccinellidae (*Cheilomones sp.*). The species of the genus *Cheilomones* feed the Homoptera.

Pollinators

These insects facilitate the fertilization of the flowers of many plants. Pollinators observed in the crop belong to the orders of Hymenoptera belonging Apidae family (*A. melifera* and *Tetragona sp.*)

Evaluation of the damage caused by insect pests according to the phenological stages

Stage before flowering

Defoliators caused the highest attack rate (87.41 ± 6.96%), followed by piercing-sucking that caused an attack rate of 32.76 ± 2.47% and finally the lowest rate (17.06 ± 1.48%) was caused by borers. Statistical analysis revealed highly significant differences (ddl = 2, F = 216.39, P <0.001) between the attack rates of the three insect groups (Fig. 2).

Flowering stage

At flowering, the defoliators induced the highest attack rate 95.35 ± 0.95%. Piercing-sucking and borers caused damage with respectively attack rates of 41.11 ± 2.84% and 19.34 ± 1.28%. Statistical analysis showed highly significant differences in attack rates between three groups of insects (ddl = 2, F = 1298.25, P <0.001) (Fig.2).

Fruiting stage

During the fruiting stage, piercing-sucking caused the severe damage with an attack rate of 61.64 ± 3.91%. The attack rates induced by defoliators and borers were respectively 40.33 ± 1.53 and 23.48 ± 1.34%.

Statistical analysis indicated highly significant differences between the attack rates of the three insect groups (ddl = 2, F = 169.56, P <0.001) (Fig. 2).

Discussion

Inventory of insects in the okra crop of Daloa showed

a total of 5164 individuals regrouped in 8 orders, 29 families and 40 species. This number reveals that okra crop in this area of Côte d'Ivoire attracts many insects. Seventeen (17) species cause damage to okra. Similar work has been done by Obeng-Ofori *et al.* (2003) in Ghana who listed five (5) orders of okra insects that are Homoptera, Heteroptera, Coleoptera, Lepidoptera and Orthoptera. The difference in number is due to the fact that the work was not done in the same area.

The relative abundance of orders recorded at different phenological stages showed that Homoptera, Coleoptera and Heteroptera were most abundant at stage before flowering, flowering and fruiting, respectively. This may be due to the variability of food sources during the okra crop cycle. In fact, Homoptera feed essentially the fresh and tender leaves. Coleoptera with mouthparts crusher type feed of both leaves and flowers. As for the Heteroptera, with their mouthparts in the form a rostrum, take the sap contained in the fruits. The highest number of insects was observed during the fruiting stage. This could be due to the presence of all the pests of the okra crop. The results obtained are similar to those of Séri-Kouassi (2004) who obtained a higher number of insects on cowpea than fruiting than in flowering and stage before flowering. Obodji *et al.* (2016) during work on entomofauna of eggplant in southern Côte d'Ivoire also reported a very high insect population during the fruiting stage.

The relative abundance of species recorded at different phenological stages showed that *P. decolorata* was most abundant in the stage before flowering and flowering. This is related to the fact that this Chrysomelidae was captured during the stage before flowering, flowering and fruiting stages of the crop with high numbers in each of these phenological stages. This observation is related to the presence of tender leaves, flower buds and flowers that they gnawed. The results obtained are similar to those of Ossey *et al.* (2017) who reported a most abundance of Chrysomelidae *Ootheca mutabilis* on cowpea at the flowering and fruiting stages compared to other insects. White flies (*B. tabaci*), beetles (*P. decolorata.)* and bedbugs (*D. voelkeri*) were found to be okra pests. The different insects collected are divided into three groups according to the trophic status.

At the stage flowering and flowering, defoliators induced a higher attack rate than those caused by piercing-sucking and borers. The high attack rate is justified by the omnipresence and abundance of *P. decolorata* and other defoliators that have a preference for tender leaves. These observations are similar to those of Ossey *et al.* (2017) who reported a high attack rate of defoliators at these two phenological stages of cowpea crop. At the fruiting stage, the piercing-sucking caused the highest attack rate that those induced by defoliators and borers. This high rate is due to the fact at this stage of the plant, high numbers of two piercing-sucking insects, *D. voelkeri* and *B. tabaci*, have been observed on the plot. Similar results were obtained by Atachi (1998) and Séri-Kouassi (2004) who reported cowpea pod attack by this category of pests. Among the predators caught on the plot, *Cheilomenes sulphurea* attacked various prey. Larvae and adults of this insect consume of a large number of aphids. Mrosso *et al.* (2013) reported that *C. sulphurea* is an excellent predator of aphids.

Conclusion

The inventory of the entomofauna associated with the crop of okra in Daloa located in the west-central of Côte d'Ivoire revealed the presence of 5164 individuals belonging 8 orders, 29 families and 40 species. The highest number of insects captured (1981 individuals) was observed at fruiting stage. The species with the highest number (1677 individuals) was *P. decolorata* followed by *B. tabaci, J. lybica* and *D. voelkeri* with 690, 679 and 646 individuals respectively. The colorful trap captured the highest number of insects or 72.83% of the total collected insects. The relative abundance of orders varied according to the phenological stages of okra. Coleoptera with 52.25% were the most abundant at the flowering stage. This study will allow to organize

the control the insect pests according to the phenology of okra.

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