GSC Biological and Pharmaceutical Sciences, 2020, 13(02), 105-115

Available online at GSC Online Press Directory

GSC Biological and Pharmaceutical Sciences

e-ISSN: 2581-3250, CODEN (USA): GBPSC2

Journal homepage: https://www.gsconlinepress.com/journals/gscbps

(RESEARCH ARTICLE)

Inventory of entomofauna associated with crop of okra (*Abelmoschus esculentus*) and assessment of damage caused by insect pests in Man, west of Côte d'Ivoire

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Publication history**:** Received on 09 November 2020; revised on 15 November 2020; accepted on 16 November 2020

Article DOI: https://doi.org/10.30574/gscbps.2020.13.2.0365

Abstract

Okra (*Abelmoschus esculentus*) is one vegetable crops most cultivated in Côte d'Ivoire. However, the plant is attacked by insects which caused important damage. This study was carried out to inventory entomofauna associated with okra crop and assess the damage caused by the pests. The insects were captured using pliers, sweep net by mowing technique and colored traps. Overall, a total of 61 species belonging to 36 families grouped into 10 orders were identified. During the plant cycle, 11602 insects were collected, including 3663 individuals at before stage flowering (31.57%); 3757 individuals at the flower bud stage (32.38%) and 4182 individuals at the flowering-fruiting stage (36.05%). Analysis of the occurrence frequency showed that *Podagrica decolorata* was ubiquitous in the crop, causing considerable damage to all organs of the plant. The damage assessment revealed that the defoliators, induced the highest average attack rates at all phenological stages. During the collections, six species (*Rhinocoris albopilosus*, *R. rapax*, *R. bicolor*, *Hediocoris fasciatus, Cosmolestes pictus* and *Coranus* sp) belonging to the family of Reduviidae were identified as predators of *P. decolorata*. This study therefore made it possible to identify *P. decolorata* as a major pest of okra and its predators, thus opening up a perspective of biological control as an alternative to chemical control.

Keywords: *Abelmoschus Esculentus*; Entomofauna; Damage; Pests Insect; Côte d'Ivoire.

1. Introduction

Okra (*Abelmoschus esculentus*) belonging to the Malvaceae family is a widely vegetable crop grown in the tropical, subtropical and temperate regions of the world [1], [2]. Annual world production of okra is estimated at six million tonnes [3]. Accordind to Nzikou et al [4], it contains high content of protein, carbohydrates, vitamins A and C, phosphorus, potassium and magnesium. An alcoholic extract of okra leaves is able to eliminate free radical oxygen, improve kidney function and reduce proteinuria [5]. The leaves are sometimes used as a base for poultices, a sudorific emollient or used locally for making fishing lines and game traps. Okra cultivation is highly valued for its edible immature leaves and fruits used in soup and sauce [6]. In Côte d'Ivoire, okra is grown and consumed in all regions. [7], and its local consumption amounts to 90,000 tons/year [8]. However, okra undergo to many damage due to insects and diseases, which seriously limits its cultivation [9]. Of all the vegetables grown in Côte d'Ivoire, okra is the second most ravaged fruit by pests and diseases after tomatoes. [10]. Among the diseases of okra, we are noted virus diseases, fungal

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diseases, bacteriosis, diseases transmitted by nematodes and insects [11]. This study was undertaken within the framework of food security to inventory the entomofauna associated at the crop of okra and to assess the damage caused by insect pests in order to carry out an effective control against insect pests.

2. Material and methods

2.1. Study area

This study was carried out in Gbintta (7 ° 40 W and 7 ° 20° N), a peri-urban area of the city of Man, from June to September 2018 during the rainy season. Man is located in the forest mountainous zone in the west of Côte d'Ivoire. The soil is highly conducive to agriculture, which favorable to many cultures [12]. During study period, average temperatures ranging from 17.5 to 32.9 °C and total rainfall of 869.3 mm.

2.2. Experimental design

Experimental plot with 323 m^2 (19 m x 17 m) consisted of 3 blocks separated from each other of 2 m. Each elementary plot measured 25m^2 (5m x 5m). The elementary plots 1 m apart were each consisted of 6 lines spaced from each other of 1 m. Each line is made up of 10 pockets, which makes 60 pockets per elementary plot. The whole experimental plot was made up of total 540 pockets. In study, hiré was the okra cultivar used as plant material.

2.3. Insect capture and identification

The insects were captured every three days from the 14th day after sowing using pliers, sweep net by mowing technique and colored traps [13], [14]. The traps consisted of four yellow plastic plates, 17 cm in diameter and 9 cm deep, placed on four raks of a trap located at different levels of the ground: 25 cm; 50cm; 75 cm and 100 cm. Insects that fly nearby are attracted to and drown in color [15]. A total, 9 yellow traps were placed in the elementary plots in the middle of the 2 central lines. All the insects collected per block and per elementary plot with the sweep net, the pliers and the colored traps were kept in labeled pill boxes containing alcohol at 70 ° C and brought to the laboratory for identification and counting. The identification was carried out using a Leica EZ4 using binocular magnifier, identification keys [16] and books [17], [18], [19], [20]. Ecological parameters such as relative abundance and frequency of occurrence were used to analyze the data.

Relative abundance, expresses the relationship between the number of individuals of a species (Na) considered and the total number of individuals of all species combined (N) [21].

$$Ar\ (\%) = (Na / N) \times 100.$$

The frequency of occurrence represents the expressed ratio of the number of collections where the species (Pa) and the total number of collections (P) are found [22].

$$C\ (\%) = Pa / (P) \times 100$$

The value of frequency of occurrence allowed to classify the species of insects collected :

- ubiquitous species (C = 100%) observed in all collections;

- constant species (50% ≤C <100%) present in more than 50% of collections

- frequent species (25% ≤C <50%) present in 25% of collections and;

- accessory species present in less than 25% of collections.

2.4. Assessment of damage caused by insect pests

Every three days, damage caused by okra pest insects were observed. To assess the damage, 32 apparently healthy plants were randomly selected from each of the elementary plots in different blocks. At the stage before flowering, all plants with attacked leaves out of the 32 plants were counted. At the flower bud stage, all plants with attacked leaves and flower buds on the 32 plants were counted. At the flowering-fruiting stage, plants with leaves, flower buds, flowers and fruit attacked on the 32 plants were also counted. The rate of attacked plants was calculated using the formula following [23], [24].

$$\text{Rate of attack} = \frac{\text{Number of plants attacked}}{\text{Number of total plants visited}} \times 100$$

Average attack rates caused by defoliators, biting sucking and borers were assessed according to okra phenology.

2.5. Data analysis

The data processing was carried out using statistica version 7.1 software. Analysis of variance and the Newman-Keuls test at the 5% threshold to analyze and compare the average attack rates induced by pests (defoliators, biting-sucking and borers) according to phenological stages.

3. Results

3.1. Insects inventoried, relative abundance and frequency of occurrence according to phenological stages

A total 11,602 insects were caught, it belonging to 61 species grouped into 10 orders and 36 families. The insects collected, by phenological stage, were 3663 individuals at stage before flowering (31.57%), 3757 individuals at the flower bud stage (32.38%) and 4182 insects at the flowering-fruiting stage (36.05%). During stage before flowering, most abundant species was *Aphis gossypii* with relative abundance of 27.71%. At the bud flower stage, *A. gossypii* and *Podagrica decolorata* with respectively abundances of 24.14% and 24.11%. At the flowering-fruiting stage, *P. decolorata* was the most abundant species with a rate of 29.27%. The study of the frequency of occurrence has shown an omnipresent species which is *P. decolorata* and 13 constant species, 26 frequent species then 21 accessory species **(**Table 1).

According action on the okra plants, insects collected were classified into two groups: pests and auxiliaries. The pests consisted of defoliators, biting-sucking and borers.

3.1.1. Pests

- *Defoliators*

This group of pests included Coleoptera, Lepidoptera and Orthoptera. Only, *P. decolorata* (Coleoptera) was present at all phenological stages of the plant and attacked several organs (leaves, flower buds, flowers and fruits). *Mylabris. variabilis* attacked flowers and the remaining species attacked the leaves (Table 2).

- *Biting-sucking*

This group of pests consisted of Homoptera, Thysanoptera and Heteroptera. They attacked the leaves and fruits according the phenology of the plant. *D. voelkeri* was the most dreadful species in this group, and attacked to the fruits (Table 2).

- *Borers*

They are mainly composed of the *Earias vittella* (Lepidoptera) whose larva is a borer of the shoots and fruits of okra. (Table 2).

3.1.2. Auxiliaries

Auxiliaries were Heteroptera, Coleoptera and Hymenoptera. The Heteroptera were represented by the family Reduviidae with the species *Rhinocoris albopilosus*, *R. rapax*, *R. bicolor*, *Hediocoris fasciatus, Cosmolestes pictus* and *Coranus* sp. All these species are predators of several insects including *P. decolorata.* Coleoptera represented by *Cheilomones sulphurae* which is a predatory species of aphids *A. gossypii.* Certain auxiliaries such as pollinators of the species *Apis. mellifera* (Hymenoptera) was appeared in large numbers at flowering.

Table 1 Relative abundance and frequency of occurrence of insect species collected at different phenological stages

			Relative Abundance			**Frequency occurrence (%)**	**Class**
			Phenological stages				
Orders	**Families**	**Species**	**Before flowering**	**Bud flower**	**Flowering-fruiting**		
Coleoptera	Coccinellidae	*Cheilomones sulphurea* Olivier, 1791	0.38	0.21	0.14	27.27	frequent
		Pachnoda cordata Drury, 1773	0	0	0.12	13.64	accessory
	Meloidae	*Mylabris variabilis* Pallas, 1781	0	0	0.53	22.73	accessory
	Chrysomelidae	*Ootheca mutabilis* Sahlberg, 1829	0.27	0.21	0.26	31.82	frequent
		Podagrica decolorata Duvivier, 1892	18.07	24.11	29.27	100	ubiquitous
		Nisotra dilecta Dalman, 1823	1.12	1.6	1.7	54.55	constant
	Tenebrionidae	*Lagria villosa* Fabricius, 1781	0.11	0.19	0.05	18.18	accessory
Lepidoptera	Noctuidae	*Spodoptera littoralis* Boisduval, 1833	0.11	0.24	0.41	36.36	frequent
		Anomis flava Fabricius, 1775	0.49	0.83	0.48	45.45	frequent
		Earias vittella Fabricius, 1794	0.11	0.05	0.22	36.36	frequent
		Xanthodes graellsii Feisthamel, 1837	0.57	0.19	0.1	31.82	frequent
		Xanthodes transversa Guenée, 1852	0.49	0.13	0.07	18.18	accessory
		Agrotis ipsilon Hufnagel, 1766	0.16	0.08	0	18.18	accessory
		Helicoverpa armigera Hubner, 1808	0.22	0.43	0.5	31.82	frequent
		Cosmophila flava Fabricius, 1775	0,52	0.29	0.17	22.73	accessory
	Pyralidae	*Sylepta derogata* Fabricius, 1775	0.35	0.24	0.1	27.27	frequent
Orthoptera	Pyrgomorphidae	*Zonocerus variegatus* Linné, 1758	4.07	1.62	0.69	59.09	constant
		Pyrgomorpha conica Olivier, 1791	0.35	0.13	0	13.64	accessory
	Acrididae	*Acrida acuminata* Stal, 1873	0.44	0.27	0.14	22.73	accessory

		Chorthippus brunneus Thunberg, 1815	0.22	0.03	0	27.27	frequent
	Tettgonidae	*Tettigonia viridissima* Linnaeus, 1758	0.22	0.05	0	18.18	accessory
	Gryllotapidae	*Gryllotalpa gryllotalpa* Linnaeus, 1758	0.11	0.03	0	18.18	accessory
	Gryllidae	*Brachytrupes membranaceus*Drury, 1770	0.41	0.21	0.05	36.36	frequent
Homoptera	Aphididae	*Aphis gossypii* Glover, 1877	27.71	24.14	20.9	86.36	constant
	Aleyrdidae	*Bemisia tabaci* Gennadius, 1889	22.19	16.42	11.17	68.18	constant
	Cicadellidae	*Empoasca dolichi* Paoli, 1930	0.79	0.43	0.22	45.45	frequent
		Empoasca vitis Gothe, 1875	0.49	0.21	0.1	27.27	frequent
		Jacobiasca sp.	5.57	4.37	4.73	50	constant
		Jacobiasca hybrida Bergenin et Zano,1922	1.06	0.56	0.31	40.91	frequent
		Amrasca sp.	0.27	0.21	0.07	27.27	frequent
	Diaspididae	*Pinnaspis strachani* Cooley, 1899	0.22	0.16	0.31	22.73	accessory
	Coccidae	*Parasaissetia nigra* Nietner, 1861	0.3	0.21	0.07	13.64	accessory
	Membracidae	*Membracis* sp.	0.35	0.45	0.36	40.91	frequent
Hymenoptera	Apidae	*Apis mellifera* Linnaeus, 1758	0.16	1.68	3.44	63.64	constant
	Vespidae	*Vespula* sp.	0.46	0.24	0.33	40.91	frequent
	Formicidae	*Lasius niger* Linnaeus, 1758	0.74	0.56	0.33	50	constant
		Paltothyreus tarsatus Mayr, 1862	3.52	4.21	2.68	72.73	constant
		Camponatus sp.	0.19	0.13	0.02	31.82	frequent
	Ichneumonidae	*Lathrestes* sp.	0.44	0.35	0.45	27.27	frequent
Odonates	Libellulidae	*Trithemis annulata* Palisot de Beauvois 1807	0.05	0.08	0	9.09	accessory
	Coenagrionidae	*Pseudagrion punctum* Rambur, 1842	0.03	0.11	0.05	13.64	accessory

Thysanoptera	Thripidae	*Thrips tabaci* Lindemann, 1889	0.49	0.21	0.14	36.36	frequent
Dermaptera	Forficudidae	*Forficula auricularia* Linnaeus, 1758	0.03	0.08	0	9.09	accessory
Diptera	Dolichopodidae	*Condylostylus* sp.	0.44	0.11	0.24	45.45	frequent
	Asilidae	*Tolmerus cingulatus* Fabricius, 1781	0.33	0.29	0.38	36.36	frequent
	Scarcophagidae	*Sarcophaga haemorrhoidalis* Fallen, 1816	0.25	0.37	0.26	36.36	frequent
	Calliphoridae	*Calliphora* sp.	0.27	0.16	0.07	27.27	frequent
Heteroptera	Pentatomidae	*Nezara viridula* Linnaeus, 1758	0.22	0.51	0.29	59.09	constant
		Acrosternum acutum Dallas, 1851	0.27	0.64	0.38	54.55	constant
		Aspavia armigera Fabricius, 1775	0.16	0.11	0.22	36.36	frequent
	Lygaeidae	*Oxycarenus hyalinipennis* A. Costa, 1843	0	0.19	0.31	27.27	frequent
	Reduviidae	*Coranus griseus* Rossi, 1790	0.05	0.13	0	13.64	accessory
		Rhinocoris albopilosus Signoret, 1858	0.85	2.08	2.73	63.64	constant
		Rhinocoris rapax Stal, 1855	0.35	0.59	0.84	40.91	frequent
		Rhinocoris bicolor Fabricius, 1781	0.25	0.45	1.41	54.55	constant
		Hediocoris fasciatus Reuter, 1882	0	0.05	0.02	9.09	accessory
		Cosmolestes pictus Klug, 1830	0.03	0.11	0.22	22.73	accessory
	Pyrrhocoridae	*Dysdercus voelkeri* Schmidt, 1932	2.59	7.93	11.45	77.27	constant
	Coreidae	*Anoplocnemis curvipes* Fabricius, 1781	0	0.08	0.05	9.09	accessory
		Cletus sp	0.05	0.16	0.24	18.18	accessory
	Alydidae	*Riptortus pedestris* Fabricius, 1775	0	0.11	0.22	22.73	accessory
10 Orders	36 Families	61 Species	100	100	100	100	

Table 2 Different groups of okra pests insect

Group of insects	**Orders**	**Families**	**Species**
Defoliators	Coleoptera	Chrysomelidae	*Ootheca mutabilis*
			Podagrica decolorata
			Nisotra dilecta
		Cetoniidae	*Pachnoda cordata*
		Meloidae	*Mylabris variabilis*
		Tenebrionidae	*Lagria villosa*
	Lepidoptera	Noctuidae	*Spodoptera littoralis*
			Anomis flava
			Xanthodes graellsii
			Xanthodes transversa
			Agrotis ipsilon
			Helicoverpa armigera
			Cosmophila flava
		Pyralidae	*Sylepta derogata*
	Orthoptera	Pyrgomorphidae	*Zonocerus variegatus*
			Pyrgomorpha conica
		Acrididae	*Acrida acuminata*
			Chorthippus brunneus
		Tettigonidae	*Tettigonia viridissima*
		Gryllotalpidae	*Gryllotalpa gryllotalpa*
		Gryllidae	*Brachytrupes membranaceus*
Biting-sucking	Homoptera	Aphididae	*Aphis gossypii*
		Aleyrodidae	*Bemisia tabaci*
		Cicadellidae	*Empoasca dolichi*
			Empoasca vitis
			Jacobiasca sp.
			Jacobiasca hybrida
			Amrasca sp.
	Thysanoptera	Thripidae	*Thrips tabaci*
	Heteroptera	Pentatomidae	*Nezara viridula*
			acrosternum acutum
			Aspavia armigera
		Lygaeidae	*Oxycarenus hyalinipennis*
		Pyrrhocoridae	*Dysdercus voelkeri*
		Coreidae	*Anoplocnemis curvipes*
			Cletus spp
Borers	Lepidoptera	Noctuidae	*Earias vittella*

3.2. Assessment of damage caused by insect pests according to the phenological stages of okra

3.2.1. Stage before flowering

Defoliators induced an average attack rate of 27.26 ± 3.26% and biting-sucking induced an average attack rate of 21.01 ± 1.59%. Statistical analysis showed insignificant differences between the average attack rates of the two groups of insects (DF = 1; F = 2.96 and P> 0.094) (Figure 1A).

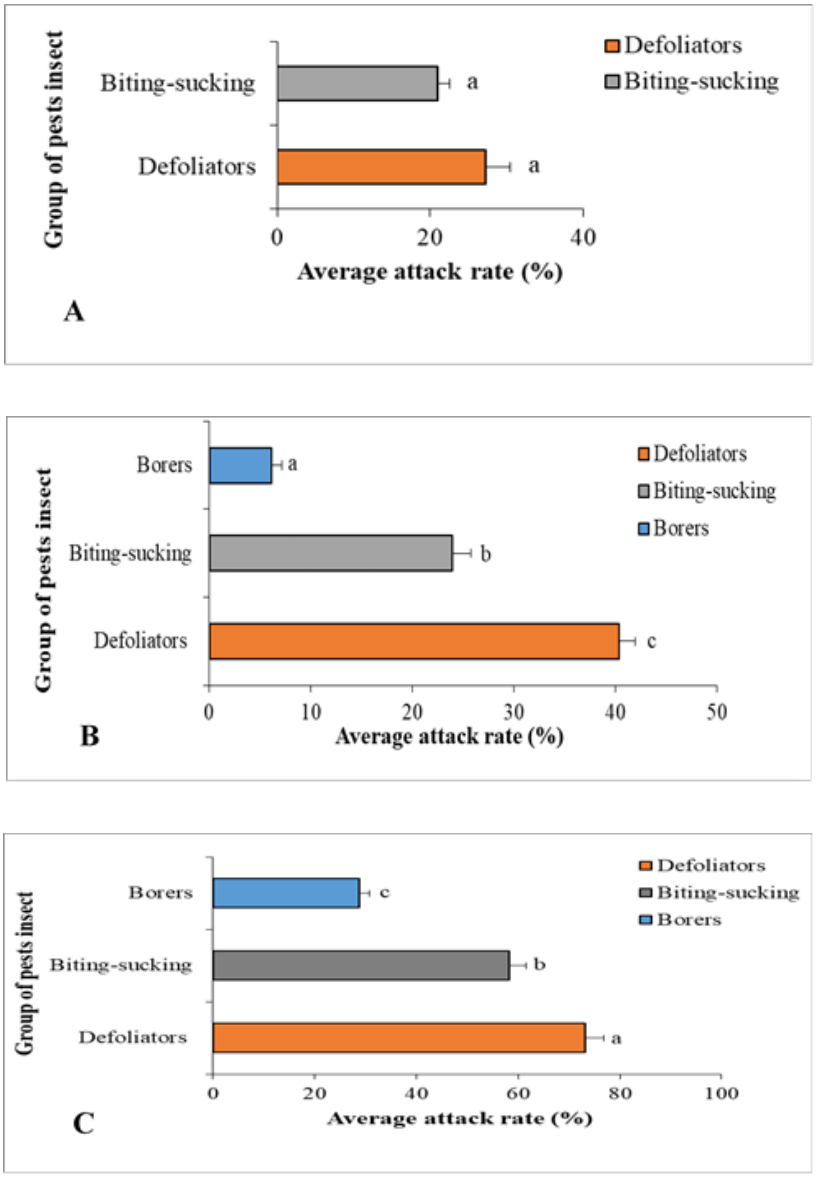

Figure 1 Average attack rate induced by insect pests at different phenological stages of okra.
A: Stage before flowering; B: Flower bud stage; C: Flowering-fruiting stage

3.2.2. Flower bud stage

At the flower bud stage, the average attack rate caused by defoliators was 40.33 ± 1.63% and biting-sucking were induced average attack rate of 23.96 ± 1.83%. The borers induced an average attack rate of 6.10 ± 1.07%. Statistical analysis showed significant differences between the average attack rates of the three groups of insects (DF = 2; F = 122.99; P <0.01) (Figure1B).

3.2.3. Flowering fruiting stage

The average attack rate induced by defoliators was high at 73.24 ± 3.54%. Biting-sucking, caused an average attack rate of 58.25 ± 3.22% and borers caused an average attack rate of 28.77 ± 1.94%. Statistical analysis showed significant differences between the average attack rates of the three groups of insects (DF = 2; F = 57.62; P <0.01) (Figure 1C).

4. Discussion

A total, 61 species belonging to 36 families and grouped into 10 orders were identified during study. Among species inventoried *P. decolorata*, *A. gossypii*, *B. tabaci*, *D. voelkeri*, *S. derogata*, *M. variabilis* and *Jacobiasca* sp were identified previously in Côte d'Ivoire by authors during their work as main insects okra pest [25], [26]. Same species have also been identified in Pakistan and India as okra pests [27], [28].

Concerning auxiliaries insect, *A. mellifera* was identified as a pollinator of okra flowers our results are similar with those Angbanyere and Matthew [29] in Burkina Faso who showed that *A. mellifera* is the major pollinator of *A. esculentus*. Other auxiliaries were identified as predators. It is *C.sulphurea* which is aphid predator. Our results are similar to those of Adja et *al*., [26] and Mrosso et *al*., [30] who during their work showed that *C. sulphurea* is an excellent predator of aphids. The predator group was also represented by the family Reduviidae, five species of this family were identified as predators of *P. decolorata*. These are *R. albopilosus*, *R. bicolor*, *R. rapax*, *H. fasciatus, C. pictus*, and *Coranus* sp. Our results are close to those of Kwadjo et *al*., [31] who identified *R. albopilosus* during their work as predators of *D. voelkeri* and *P. decolorata*. In their work on cowpea entomofauna, Ossey et *al*., [32] showed that *R. albopilosus*, *R. bicolor*, *R. rapax* are predatory species of *Ootheca mutabilis*. Other work by Tendeng et *al*., [33] on updating the entomofauna of vegetable crops in Casamance (Senegal) identified *C. pictus* as a predatory species of *P. decolorata*. As for *Coranus* sp. it has been listed by Ambrose and Kumar [34] as predator of *E. vitella*, *S. derogata* and *H. armigera*.The relative abundance of *P. decolorata*, *B. tabaci*, *D. voelkeri*, *M. variabilis A. mellifera* and *A. gossypii* showed that the presence of these insects on the plot was a according phenology of okra. Thus, the species *A. mellifera* and *M. variabilis* which were not abundant on the experimental plot at stage before flowering were abundant at flowering. This high abundance at flowering is due to the fact that these insects were attracted large numbers to flowers. The frequency of occurrence has shown that *P. decolorata* was ubiquitous at all phenological stages of okra. This ubiquity could be explained by the fact that this pest attacked several organs plant (leaves, flower buds, flowers and fruits). These results are similar to those of Ossey et *al*., [32] who reported during their work that *O. mutabilis* was present at all phenological stages and attacked several organs of the plant. The pest insects were classified into three groups according to their mode of action on the host plant. Thus, defoliators, biting-sucking and borers were distinguished. The attack rate induced by defoliators at stage before flowering was higher than that caused by biting-sucking. Our results corroborate those of Fomekong et *al*., [35] and Ossey et *al*., [32] who showed during their work that at this stage the leaves are tender and contain water, this is would justify their attraction to defoliators. At the bud flower stage, borers were collected, their presence at this stage of development is due to the appearance of flower buds. At the flowering-fruiting stage, average attack rate of defoliators was higher than that observed in previous stages, this would be due to the fact that the nutritive resources were important at this stage,several insects were therefore attracted. Our study also showed that the larvae of *E. vitella* were drilled shoot, flower buds and fruits of okra. These results are similar to those of Sharma et *al*., [36], who revealed during their study that *E. vitella* is an okra organ borer. All okra organs were attacked by insect pests, but the highest average attack rate induced by defoliators would be explain by important defoliation of the okra leaves by Coleoptera. According to Soro et *al*., [14] *P. decolorata*, was recognized as the voracious pest of okra, which mainly attacks the leaves. Works of Tano et *al*., [37] also showed that *P. decolorata* was caused considerable defoliation of okra leaves at all phenological stages of plant.

5. Conclusion

This study revealed diversity of insects associated with okra crop. These insects were composed of pests and auxiliaries. The pests were defoliators, biting-sucking and borers. The auxiliaries consisted of predators and pollinators. Among the insect pests, *P. decolorata* was major pest of okra pest because, it attacked all organs and induced high average attack rate at all phenological stages. Among the auxiliaries, six species belonging to Reduviidae family were identified as formidable predators of *P. decolorata*. The leaves were the most attacked organs, several perforations on the leaves were occasioned by pests reducing photosynthetic surface. This study therefore revealed *P. decolorata* as major pest of okra and its predators, thus opening up a prospective of biological control as an alternative to chemical control in order to improve the production of okra in Côte d'Ivoire.

Compliance with ethical standards

Acknowledgments

The authors thank all who were contributed to the success of this study.

Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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