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Research Article

REPORT ON PHENOLOGICAL STAGES AND INSECT PESTS: THE CASE OF OKRA (*ABELMOSCHUS ESCULENTUS* L.) IN HAUT-SASSANDRA (DALOA, CÔTE D'IVOIRE)

[1*]TAH G.T.T., [2]KADIO Ekien A.A. B. and [1]N'DEPO O.R.

[1]University Jean Lorougnon Guédé of Daloa, Laboratory for Agricultural Improvement and Production, UFR-Agroforestry, Côte d'Ivoire

[2]University Peleforo Gon Coulibaly of Korhogo, Animal Biology Laboratory, Biological Sciences, Côte d'Ivoire

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ABSTRACT

Okra (*Abelmoschus esculentus* L.) is a fruit vegetable with nutritional and medicinal properties. In Côte d'Ivoire, it is consumed by the entire population and is an economic resource. However, it is heavily attacked by insect pests. The objective of this study is to contribute to the control of okra entomofauna with a view to its optimal management. Thus, 10 elementary plots of 15 m² each were set up and planted. On each plot, six traps, three colored and three pit traps, filled two-thirds full with soapy water, were placed according to the diagonal method. The insects were collected according to the three phenological stages, every two days, from 6 a.m. to 12 p.m. At the vegetative stage, 553 insects belonging to 17 families and 32 species were identified. At flowering, 1,052 insects belonging to 14 families and 24 species were recorded. As for the fruiting stage, 2,135 insects, divided into 15 families and 27 species, were counted. Fourteen families and 22 species were common to all three stages. Seven species were present throughout the vegetative and flowering stages, and six were present throughout the fruiting stage. Four omnipresent species (*Camnula pellucida*, *Gastrophysa polygoni*, *Hyalymenus sp.* and *Podagrica decolorata*) and one constant species (*Agrotis ipsilon*) were present throughout the sampling period. *Podagrica decolorata* was abundant (30.56% in the vegetative stage, 65.97% in the flowering stage, and 30.11% in the fruiting stage). This study will enable the development of strategies to control the main pests of okra.

Keywords: *Abelmoschus esculentus*, Phenological stages, Insect pests, Abundance, Côte d'Ivoire.

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is a vegetable plant belonging to the Malvaceae family. It is cultivated in tropical, subtropical, and warm temperate regions around the world (Siddartha *et al*., 2017). Okra is a fruit vegetable that is very rich in nutrients such as proteins, carbohydrates, fiber, vitamins (A and C), and minerals (Agregán *et al*., 2022). These nutrients provide the dietary supplements necessary for the basic nutrition of African populations (Khomsug *et al*., 2010). Its leaves and immature fruits are edible and can be used in soups and sauces (Khomsug *et al*., 2010). In Côte d'Ivoire, okra is one of the most widely consumed vegetables (Fondio *et al*., 2011). Ivorian consumption is approximately 5.5 kg per capita (Fondio & Djidji, 2007). It is a source of income in Côte d'Ivoire, with a price that can reach 1,000 CFA francs/kg (OCPV, 2021). It also has medicinal properties thanks to its polyphenolic and antioxidant composition (Gemede *et al*., 2015). Medically, okra has antidiabetic, anticancer, antihypertensive, and antimicrobial effects (Agregán *et al*., 2022). Its leaves are sometimes used as a base for poultices, emollients, and sudorifics (Khomsug *et al*., 2010). Its economic importance, combined with its nutritional and medicinal properties, makes it an essential crop in the fight against poverty. Unfortunately, okra cultivation is targeted by numerous pests, particularly insects, which reduce its yield (Asare-Bediako *et al*., 2014). The overall objective of this study is to contribute to the control of the entomofauna of *A. esculentus* with a view to its optimal management. The aim is therefore to compile an

*Corresponding Author: TAH G.T.T, University Jean Lorougnon Guédé of Daloa, Laboratory for Agricultural Improvement and Production, UFR-Agroforestry, Côte d'Ivoire. Email: tahgues76@yahoo.fr.

inventory of insect pests according to their different phenological stages, to estimate diversity indices, and to assess the frequency of visits by these insect pests.

MATERIALS AND METHODS

Study site

The trial was conducted at the University Jean Lorougnon Guédé in Daloa. Daloa, located at 6°53 north latitude and 6°27 west longitude, is located in the central-western part of Côte d'Ivoire, in the Haut Sassandra region (Sangaré *et al.*, 2009). The average annual temperature is estimated at 27.5°C and rainfall is between 1000 and 1500 mm. The climate is tropical and the soil is ferralitic (Kouamé *et al.*, 2015).

Experimental set up

The experiment was conducted on a total area of 558 m² (31 m × 18 m). A 300 m² (25 m × 12 m) block of this plot, separated by 3 meters from the edge, was used for planting okra. This block was divided into ten (10) elementary plots of 15 m² (3 m × 5 m) each, separated by 2 meters. Each plot corresponded to one repetition. Sowing was carried out according to the method described by Fondio & Djidji (2007), with 0.50 meters between holes and one meter between rows. Okra seeds were sown at a rate of 3 seeds per hole. Fifteen days (15 d) after sowing, thinning was carried out at a rate of one plant per hole. Each elementary plot consisted of 44 okra plants, for a total of 440 okra plants across the entire experimental plot. To inventory insect pests, six traps, including three colored traps and three pitfall traps, were placed in each elementary plot. This gave a total of 30 colored traps and 30 pitfall traps. The traps were set using the diagonal method.

Sampling rate

Observations were made according to the three (3) phenological stages of okra (vegetative stage, flowering stage, and fruiting stage). Samples were collected regularly every 2 days, from 6 a.m. to 12 p.m., for 3 months.

Catching insects using traps

The insect pests were captured using traps (colored and pit traps) containing soapy salt water filling two-thirds of their volume. The soapy water trapped the insects that fell inside the traps. The salt prevented the trapped insects from deteriorating. The surveys were carried out every two days from 6 a.m. using a mini sieve and entomological forceps. After each collection, the soapy water in the traps was replaced.

Parameters studied

The following ecological diversity parameters were determined:

Specific richness of insects in okra cultivation

Specific richness indicates the total number of species (S) observed in a community (Blondel, 1975). It is calculated using the following formula:

$S = \Sigma$ species

Relative abundance

Relative abundance (Ar) is the ratio of the total number of individuals (ni) in a taxonomic group (order, family, genus, species) to the total number of individuals (nt) in all taxonomic groups in an environment.

$$Ar\ (\%) = \frac{ni}{nt} \times 100$$

Frequency of occurrence

The frequency of occurrence represents the ratio of the number of collections in which the species is found to the total number of collections (Dajoz, 2000). It is calculated using the following formula: C (%) = ni/N x 100 with C: Frequency of occurrence, ni : Number of collections containing the species I and N: Total number of collections. The value of C highlights five (05) categories of species. They are omnipresent species (C = 100 %); species constancy (50% ≤ C < 100%); frequent species (25% ≤ C < 50%); accessory species (5% ≤ C < 25%) and rare species (C < 5%).

Shannon index

The Shannon index (H') reflects the diversity of species present in communities in a given environment (Table 1). It links the number of species to the number of individuals within a given ecosystem or community (Joseph *et al.*, 2012). This index was calculated using the following formula:

H'= −Σpilog2 (pi). With $pi = \frac{ni}{N}$ where n is the number of individuals of pest insect species i and N is the total number of individuals of all pest insect species recorded.

Table 1. Value and interpretation of the Shannon index (Chao & Jost, 2023).

Index value	Interpretation
Index below 2	Low diversity
Index between 2 and 3	Average diversity
Index between 3 and 4	Moderately high diversity
Index between 4 and 5	High diversity
Index between 5 and 6	Very high diversity
Index above 6	Exceptional diversity

Pielou Fairness Index

The Evenness Index measures the balance within a population. It ranges from 0 to 1. It tends towards 0 when a single species is abundant and tends towards 1 when individuals are evenly distributed among species. The evenness index measures the balance within a population. This index is obtained by the ratio between the Shannon-Weaver diversity index (H') and a fictitious even distribution of these taxa (Moisan & Pelletier, 2011).

Statistical analysis

Insect pest diversity indices were assessed using PAST 4.03 software.

RESULTS AND DISCUSION

Five orders of insect pests (Coleoptera, Diptera, Hemiptera, Lepidoptera, and Orthoptera), comprising 18 families and 34 species, were recorded during our study (Table 2). Fourteen (14) families and twenty-two (22) species were common to all three stages of development (Figure 1). In the vegetative stage, 17 families, including 3 specifics to this stage (Cecidonytidae, Gryllacrididae, Tetrigidae), were recorded, representing 32 species. Six species, *Laccoptera nepalensis*, *Ceutorhynchus pleurostigma*, *Tetrix subulata*, *Gryllacris sp.*, *Boopedon nubilum* and *Cecidomyia sp.*, were specific to the vegetative stage (Figure 1). At the flowering stage, 14 families, divided into 24 species, were recorded. No family or species was specific to this stage of development (Figures 1). As for the fruiting stage, it includes 15 families and 27 species. Only one family, represented by the species *Alaetrinus minimus*, was observed exclusively at this stage. The species *Pentatoma rufipes* was common in the first two stages of development (vegetative and flowering). *Graphocephala* coccinea was observed during the flowering and fruiting stages. *Nezara viridula*, *Brachytrupes sp.*, *Gryllus bimaculata* and *Cyrtotrachous sp.* were pests present during both the vegetative and fruiting stages.

Table 2. List of insect pests according to phenological stages

Order	Families	Species	Vegetative stage	Flowering stage	Fruiting stage
Coleoptera	Chrysomelidae	*Laccoptera nepalensis*	+	-	-
		Podagrica decolorata	+	+	+
		Gastrophysa polygoni	+	+	+
	Curculionidae	*Ceutorhynchus pleurostigma*	+	-	-
		Cyrtotrachelus sp.	+	+	+
	Meloidae	*Lytta auriculata*	+	+	+
	Scarababaeidae	*Melolontha melolontha*	+	+	+
		Plusiotis sp.	+	+	+
	Tenebrionidae	*Alaetrinus minimus*	-	-	+
Diptera	Cecidomytidae	*Cecidomyia sp.*	+	-	-
Hemiptera	Alydidae	*Hyalymenus sp.*	+	+	+
	Cicadellidae	*Amrasca biguttula*	+	+	+
		Graphocephala coccinea	-	+	+
		Ledra aurita	+	+	+
	Coreidae	*Thasus acutangulus*	+	+	+
		Sagotiyus confluens	+	+	+
	Miridae	*Pithanus maerkelii*	+	+	+
	Pentatomidae	*Pentatoma rufipes*	+	+	-
		Nezara viridula	+	-	+
Lepidoptera	Noctuidae	*Agrotis ipsilon*	+	+	+
		Heliothis armigera	+	+	+
		Spodoptera exigua	+	+	+
		Xanthopastis timais	+	+	+
	pyralidae	*Endotricha flammealis*	+	+	+
Orthoptera	Acrididae	*Boopedon nubilum*	+	-	-
		Chorthippus brunneus	+	+	+
		Camnula pellucida	+	+	+
		Brachytrupes sp.	+	-	+
		Gryllus bimaculata	+	-	+
		Acheta domesticus	+	+	+
	Gryllacrididae	*Gryllacris sp.*	+	-	-

	Pyrgomorphidae	*Phymateus viridipes*	+	+	+
	Tetrigidae	*Tetrix subulata*	+	-	-
	Tettigontidae	*Metrioptera brachyptera*	+	+	+

+: Presence; -: Absence

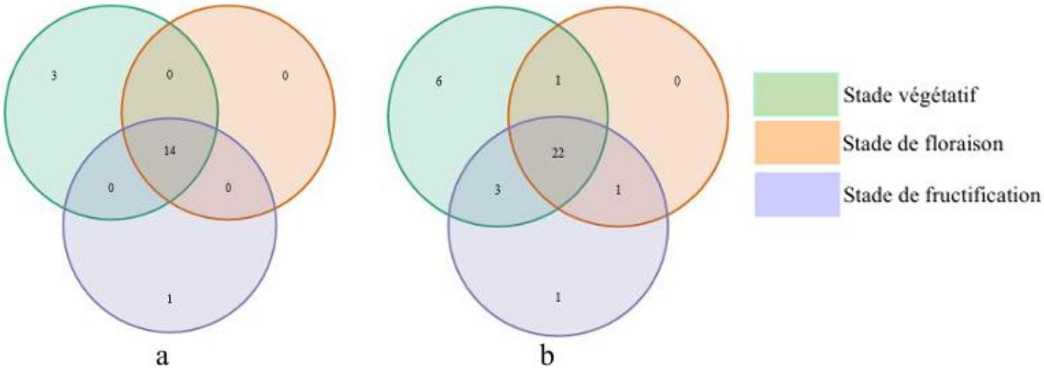

Figure 1. Appearance of insect according to phenological stages a: insect pest families; b: insect pest species.

During the vegetative stage, fewer insects were captured, with a total of 553 insects. During the flowering stage, the insect fauna consisted of 1,052 insects, while 2,135 were recorded during the fruiting stage (Table 3). During the vegetative and flowering stages, the most abundant species was *Podagrica decolorata* (Table 3), with relative abundances of 30.56 % and 65.97 %, respectively. In contrast, two species were abundant at the fruiting stage, namely *Amrasca biguttula* (34.56 %) and *Podagrica decolorata* (30.11 %). *Podagrica decolorata* was abundant throughout the okra production cycle. The identified insect pests were divided into four groups using ascending hierarchical classification. The first group consists of incidental species, the second of frequent species, the third of constant species, and the fourth of ubiquitous species (Figure 2). The group of accessory species consists of nine (9), six (6), and three (3) species respectively in the vegetative, flowering, and fruiting stages. The accessory species common to all three phenological stages is *Lytta auriculata.*

Table 3. Relative abundances and frequency of occurrence of insect pests according to phenological stages.

Species	Vegetative stage			Flowering stage			Fruiting stage		
	ni	Ar (%)	C (%)	ni	Ar (%)	C (%)	ni	Ar (%)	C (%)
Acheta domesticus	28	5,06	100	23	2,19	100	114	5,34	100
Agrotis ipsilon	6	1,10	66,6	10	0,95	80	23	1,08	75
Alaetrinus minimus	0	0	0	0	0	0	4	0,19	37,5
Amrasca biguttula	61	11,03	83,3	34	3,23	80	738	34,56	100
Boopedon nubilum	2	0,36	33,3	0	0	0	0	0	0
Brachytrupes sp.	2	0,36	16,6	0	0	0	2	0,09	62,5
Camnula pellucida	50	9,04	100	127	12,07	100	218	10,21	100
Cecidomyia sp.	2	0,36	16,6	0	0	0	0	0	0
Ceutorhynchus pleurostigma	1	0,18	16,6	0	0	0	0	0	0
Chorthippus brunneus	1	0,18	16,6	2	0,19	40	13	0,61	75
Cyrtotrachelus sp.	23	4,16	83,3	13	1,24	100	7	0,33	37,5
Endotricha flammealis	18	3,25	66,6	1	0,09	20	9	0,42	75
Gastrophysa polygoni	16	2,90	100	26	2,47	100	134	6,28	100
Graphoge phalacoccinia	0	0	0	3	0,29	20	3	0,14	25
Gryllacris sp.	1	0,18	16,6	0	0	0	0	0	0
Gryllus bimaculata	11	2,00	33,3	0	0	0	3	0,14	25
Heliothis armigera	20	3,62	100	10	0,95	100	17	0,80	50
Hyalymenus sp.	19	3,44	100	52	4,94	100	104	4,87	100
Laccoptera nepalensis	1	0,18	16,6	0	0	0	0	0	0
Ledra aurita	2	0,36	33,3	12	1,14	60	26	1,22	100
Lytta auriculata	1	0,18	16,6	2	0,19	2	1	0,05	12,5

Melolontha melolontha	15	2,71	100	9	0,86	80	8	0,37	62,5
Metrioptera brachyptera	23	4,16	50	1	0,09	20	16	0,75	75
Nezara viridula	1	0,18	16,6	0	0	0	3	0,14	25
Pentatoma rufipes	1	0,18	16,6	4	0,38	20	0	0	0
Phymateus viridipes	54	9,76	83,3	11	1,04	80	28	1,31	87,5
Pithanus maerkeli	2	0,36	33,3	1	0,09	20	3	0,14	25
Plusiotis sp.	4	0,72	50	3	0,29	40	1	0,05	12,5
Podagrica decolorata	169	30,56	100	694	65,97	100	643	30,11	100
Sagotilus confluens	2	0,36	33,3	2	0,19	40	3	0,14	37,5
Spodoptera exigua	3	0,54	33,3	7	0,67	60	6	0,28	50
Tetrix subulata	2	0,36	33,3	0	0	0	0	0	0
Thasus acutangulus	9	1,63	83,3	2	0,19	40	7	0,33	37,5
Xanthopestis timais	3	0,54	50	3	0,29	40	1	0,05	12,5
	553	100		1052	100		2135	100	

ni : Total number of individuals of the species I, Ar : Relative abundance, C: Frequency of occurrence, %: Percentage

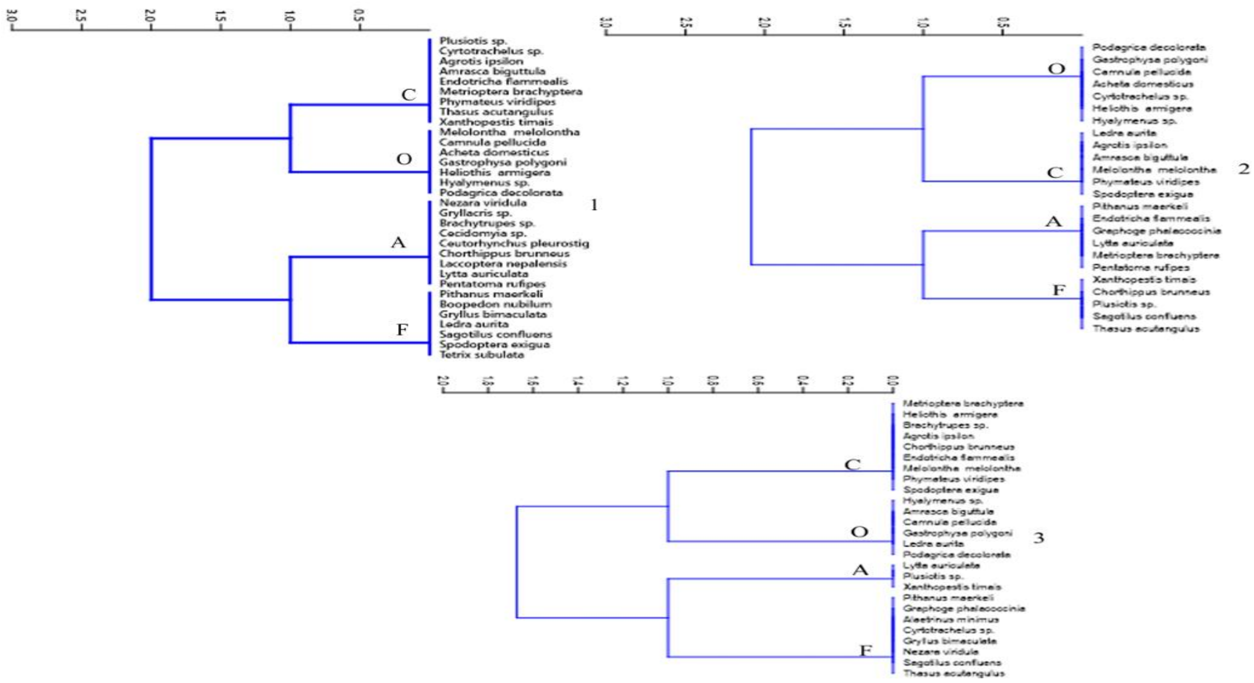

Figure 2. Hierarchical structure of insect pest species affecting okra crops according to phenological stages.
1: Vegetative stage, 2: Flowering stage, 3: Fruiting stage, A: Accessory species, C: Constant species, F: Frequent species, O: Omnipresent species

As for the group of common species, the vegetative, flowering, and fruiting stages consist of seven (7), five (5), and eight (8) species, respectively. *Sagotilus confluens* is common to all three stages of development. *Thasus acutangulus* was sampled in the last two stages of development, namely the flowering and fruiting stages. The group of constant species comprises nine (9) species in the vegetative stage, six (6) in the flowering stage and nine (9) in the fruiting stage. *Agrotis ipsilon* was observed throughout the sampling period. *Amrasca Biguttula* was specific to the vegetative and and flowering stages. The species *Melolontha melolontha*, *Phymateus viridipes* and *Spodoptera exigua* were identified in the flowering and fruiting stages. The population of ubiquitous species consists of seven (7) species in the vegetative and flowering stages and six (6) in the fruiting stage. *Camnula pellucida*, *Gastrophysa polygoni*, *Hyalymenus sp.* and *Podagrica decolorata* were identified throughout the sampling period. *Acheta domesticus* and *Heliothis armigera* were identified in the vegetative and flowering stages. Diversity index of okra pest insects according to phenological stages: The Shannon indices and Piélou's Equitability index vary according to phenological stages. The Shannon index has higher values during the vegetative period (2.68) and fruiting period (2.15) than during the flowering period (1.78). As for the Piélou Equitability Index (E), values were also higher during the vegetative and fruiting stages, at 0.73 and 0.62, respectively Table (4).

Table 4. Ecological diversity indices.

	Vegetative stage	Flowering stage	Stage of fructification
Shannon index (H')	2,55	1,43	1,88
Equitability (J)	0,72	0,44	0,56

In this study, two collection techniques were used, enabling us to record a total of 3740 insects belonging to 34 species divided into 18 families and 5 orders. The diversity of the species collected could be related to the absence of human activity in the study area. In fact, this okra crop was the only garden on the site during the experiment. This greenery may have attracted insects to the okra plot. However, our results differ from those of Yao (2022). This author obtained 11602 individuals. This difference may be related to the number of collection techniques used to capture the insects. Yao (2022) used four capture techniques. Unlike this author, our samples were collected using two techniques. Also, the lower number of insects collected in okra cultivation could be explained by the period of the experiment. The experiment took place during the rainy season. The heavy rainfall may have diluted the trapping solutions (soapy water) contained in the pit and colored traps, causing the trapped insects to escape. Our results also differ from those of Ablé *et al.* (2024), who identified 21 species belonging to 18 families grouped into 6 orders. This difference could be linked to abiotic factors in the study areas, particularly temperature and relative humidity. Indeed, the studies conducted by these authors took place in northern Côte d'Ivoire, in the city of Korhogo. This locality and Daloa are two different geographical areas, one in a savanna zone (Korhogo) and the other in a forest zone (Daloa). The values of the Shannon index and those of the Equitability index at the vegetative stage (H' = 2.55; J = 0.72) and fruiting stage (H' = 1.88; J = 0.56) showed that the two phenological stages are diverse.

This high diversity of species at the vegetative stage is thought to be due to their attraction to the greenery on the okra plot. Indeed, this okra crop was the only garden on the site during the experiment. As for the fruiting stage, its species richness is thought to be linked to the diversity of food resources, namely flowers and fruits in addition to leaves. Table III reveals a significant variation in insect numbers depending on the phenological stage of the plant. Indeed, the insect population is significantly lower at the vegetative state (553 insects) compared to the flowering (1052 insects) and fruiting (2135 insects) stages. These differences are consistent with the work of Zongo *et al.* (2018), who observed a gradual increase in insect abundance as the crop development cycle progressed. Similarly, the work of Obodji *et al.* (2016), Assi *et al.* (2018), and Ouali-N'Goran *et al.* (2019) revealed an abundance of insects during the fruiting period on eggplant in Azaguié and cucumber in Dabou and Bonoua, respectively.

The low presence of insects during the vegetative state could be explained by the reduced availability of attractive resources at this stage. Indeed, young plants offer few nutrients or attractive shelters for most phytophagous insects. This is consistent with the findings of Koulibaly *et al.* (2020). Conversely, flowering is generally accompanied by increased emissions of volatile compounds and nectar, two factors known to attract a variety of insect pests. The peak reached during the fruiting stage can be explained by the abundance of fruit, which is a direct source of nutrition for several insect species. This finding is similar to that of Ouattara *et al.* (2021). Furthermore, they pointed out that some pests have a reproductive cycle that is synchronized with the fruit ripening period. This experiment revealed that certain insect pests were specific to a particular stage of development, with six species targeting the vegetative stage and one targeting the fruiting stage. This specificity can be explained by the fact that certain insect pests have a reproductive cycle that is synchronized with a specific period of development.

The results revealed that *Podagrica decolorata* is the most abundant and ubiquitous species. The increase in its population during the flowering stage (30.56 % during the vegetative stage and 65.97 % during the flowering stage) appears to be linked to an abundance of food sources, which is believed to be a determining factor in its proliferation. This strong presence could also be due to *P. decolorata* being attracted by the kairomones produced by okra and by the yellow color of its flowers. Bright colors, especially yellow, attract insects. Our results corroborate the work of Fondio (2022), who showed that the color and smell of flowers play a role in attracting insect pests of Cucurbitaceae. The reduction in the population of *P. decolorata* (30.11 %) during the fruiting period is thought to be linked to competition for food with other insect pest species, in this case *Amrasca biguttula* (34.56 %). Furthermore, its ubiquitous status is thought to be due to the fact that *P. decolorata* is the main insect pest affecting okra crops.

CONCLUSION

This study shows a significant variation in insects depending on the plant's stage of development. During the vegetative stage, 553 insects belonging to 17 families and 32 species were identified. During the flowering stage, 1052 insects belonging to 14 families and 24 species were recorded. As for the fruiting stage, 2135 insects, divided into 15 families and 27 species, were counted. Fourteen (14) families and twenty-two (22) species were common to all three stages of development. Seven (7) species were omnipresent during the vegetative and flowering stages, and six (6) during the fruiting stage. During the sampling period: four species were omnipresent (*Camnula pellucida*, *Gastrophysa polygoni*, *Hyalymenus sp.*, and *Podagrica* *decolorata*) and one species was constantly present (*Agrotis ipsilon*). *Podagrica decolorata* was the most abundant species, accounting for 30.56 % in the vegetative stage, 65.97 % in the flowering stage, and 30.11 % in the fruiting stage. These results show that the diversity and distribution of insect pests depend on the stages of crop development. Identifying abundant and persistent species makes it possible to identify priority targets for okra protection. It is therefore necessary to develop targeted integrated pest management strategies adapted to the dynamics of each pest species and the sensitive phenological stages of the plant.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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