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ARTICLE

Insect Pests Control of Okra (*Abelmoschus esculentus*) by Using Plant Aqueous Extracts in Korhogo Area (Northern Côte d'Ivoire, West Africa)

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ABSTRACT

In this study, we monitored for the impact of three aqueous extracts of plants (*Azadirachta indica, Hyptis suaveolens* and *Solanum lycopersicum*) on insect pests abundance in okra (*Abelmoschus esculentus* L.) crop, compared to a synthetic chemical « *SAUVEUR 62 EC* », having as active ingredients, acetamiprid 32g/l and Lambda-cyhalothrin 30g/l. Foliar applications by these extracts were done using manual sprayers. After treatment, the insects were caught using two methods (pitfall traps and colored bowls traps). A total of 6505 insects belonging to nine orders were recorded in four plots. The plot 1 (9 orders) was the most diverse, followed by the plot 3 (8 orders), the plot 2 and 4 (7 orders respectively). Coleoptera, Lepidoptera, Diptera, Orthoptera and Hemiptera were the most frequents. The chemical treatment has impacted significantly the number of orders ($p < 0.05$) but, the insect abundance was impacted significantly by the different biological treatments ($p < 0.05$). This study showed that the aqueous extract of *Solanum lycopercicum* was more effective on the abundance of pests belonging to Hemiptera, while the aqueous extracts of *Azadirachta indica* and *Hyptis suaveolens* were effectives on the abundance of pests belonging to Coleoptera. The chemical treatment was effective on the pests belonging to both orders.

1. Introduction

The economy system in Côte d'Ivoire is highly depending to primary sector. For example, agriculture accounts for around 25% of GDP. It produces almost 2/3 of the jobs and around 40% of the country's export earnings [11]. In recent years, food production has increased considerably alongside export crops. The food balance which stood to around 10 million tonnes in 2012, had enabled the plantation economy to establish its hegemony in the agricultural world in Côte d'Ivoire [11]. In general, agricultural holdings include the cash or industrial crops subsector and the food crops subsector. So, in Côte d'Ivoire, cereals, root and tuber, market gardening and fruit species, are the staple crops essentials for food security [24]. The market gardening includes several crops which are consumed due to their richness in nutrients and their medical virtues. Among these crops, okra, highly ap-

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preciated by Cote d'Ivoire people, take an important place in their food. This plant contains enough nutrients (iron, calcium, vitamin C) [16]. According to Grubben [14], okra ranks third in market gardening after eggplant (*Solanum* spp.) and tomato (*Lycopersicum esculentum*). It represents also an important source of incomes for the populations. Unfortunately, the culture of okra knows serious difficulties due to the attacks of insect pests and diverse diseases which affect considerably its productivity. Thus, the farmers resort to an excessive use of pesticides with as corollary, the biodiversity loss, the soil fertility decline, the resistance of pests as well as the health risks (UNDP, 2015). Therefore, the use of biopesticides seems to be a reliable and effective alternative compared to the chemical pesticides which have shown their limits. Indeed, several plants were used already for their biocidal activities against many bio-aggressors. They were used as plant extracts to protect the leaves [19,20], or in combination with other crops [3,4], or again as essential oils [2]. This study aims to assess the effectiveness of three plant extracts (*Hyptis suaveolens, Azadirachta indica* and *Solanum lycopersicum*) on the pest abundance decrease in okra crops. Specifically, it consists (1) to assess individually each extracts, and (2) to identify the most effective product.

2. Material and Methods

2.1 Study Areas and Study Design

This study was carried out in Korhogo in the Botanical Garden of University, located in the North of Côte d'Ivoire. The climate is a Sudanese type with an alternation of seasons. A wet season characterized by a water surplus for 4 or 5 months (June-September or June-October) and a dry season for 7 or 8 months [22]. During the dry season, there is a persistence of cold and dry wind charged often with fine dust (Harmattan) which blows from December to February [27]. The annual rainfall varies between 1200 mm and 1400 mm. Water is supplied by a hydrographic network made up of two main rivers and their tributaries (Bandama and Comoe). In addition to this hydrographic network, Korhogo benefits of pastoral dams built as part of integrated livestock development projects [23]. The vegetation is a tree savannah composed by trees and shrubs. However, there is the presence of gallery forests along the rivers. The soils are ferralitics and belong to the group of more or less denatured soils, and of constant mineralogical composition [23]. In the fine mineral fraction, Kaolin predominates. These characteristics appear very complex and varied, which suggests good agronomic values. The major of population derives its incomes from the main agricultural crops, perennial, food and market gardening, such as cotton, cashew, mango, rice, corn, millet, peanuts and okra (subject of our study). The experimental sites composed mainly by okra plots, were chosen within the botanical garden of University covering 19.74 ha of superficie. The experimental design was consisted of a block of four elementary plots (3 x 9) m2, separed of 20 m, each. On each plot, six ridges distants of 1.8 m composed by five pockets each, were installed. The distance between two pockets was 0.5 m (Figure 1).

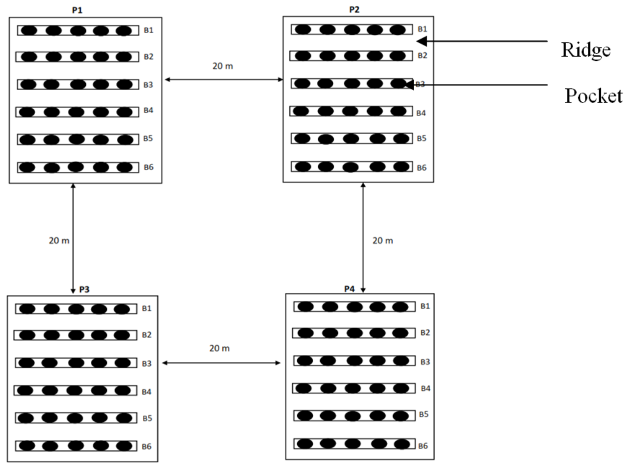

Figure 1. Experimental device

2.2 Data Collection

Mode of plant extraction: The aqueous extracts of three plant species (*Azacdirachta indica, Hyptis suaveolens* and *Solanum lycopersicum*) were obtained by maceration of 1 kg of ground vegetables in five liters of water. The leaves of *Azadirachta indica* and *Hyptis suaveolens* were harvested directly in the field, while those of *Solanum lycopercicum* were obtained from nurseries in order to produce a significant biomass. Indeed, the different types of leaves were pounded in a traditional mortar until obtaining a dough. Then, the dough was induced in a plastic bucket containing five liters of water, and left to macerate for 24 h [26]. The macerate was filtered using various sieves and tissue ''percale''. The final product was packaged and stored in the refrigerator at 4° C.

Implementation of the crop: The cultivation of okra required previously a good preparation of ground consisting in weeding the existing vegetation and preparing the ridges. Organic manure was added in each pocket. Sowing was carried out directly at the rate of four seeds per pocket respecting a spacing of 50 cm between pockets. A total of six rows containing five plants per row were used and the plants were watered every day. The separation process of young plants started two weeks after their emergence. The management and maintenance of plots was done using

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daba and hoe.

Application of treatments: Each plot underwent a single type of treatment according to the recommended dosage, listed in the Table 1. The plot 1 was treated with the aqueous extract of *Solanum lycopercicum*, the plot 2 with a chemical product ‘’SAUVEUR’’, the plot 3 with the aqueous extract of *Azadirachta indica* and the plot 4 with the aqueous extract of *Hyptis suaveolens*. These treatments were carried out using manual sprayers (2 liters). The sprayers were set to spray the leaf area, evenly. Each type of treatment was applied four times, starting the 20th day after sowing, respecting at least ten days between two applications.

Table 1. Recommended dosage for each treatment type

Treatments	Recommended dosage			Relative dosage to the treated area		
	Dose	Water quantity (L)	Area (m^2)	Dose	Water quantity (L)	Treated area(m^2)
Chemical	75ml	15	400	7.5ml	1.5	27
Solanum lycopercicum	1kg	5	250	0.54L	1.5	27
Azadirachta indica	1kg	5	250	0.54L	1.5	27
Hyptis suaveolens	1kg	5	250	0.54L	1.5	27

Insect sampling: Insects were caught using two combined methods (pitfall traps and yellow cup traps). Each type of trap was installed on either side at the bottom of an okra plant. Insects caught were harvested 48 hours after application of the various treatments (chemical and biological), kept in the flasks containing ethanol (70%), labeled and moved to the laboratory for their identification using a binocular magnifier (MOTIC X 4 magnifications) and a key of identification [7].

2.3 Data Analysis

Insect taxonomic diversity was analyzed regarding their abundance, estimated species richness using Simpson diversity indices and Pielou’s evenness index [17]. Insect orders were pooled taking into account their occurrence frequencies noted Fo according to the formula of Djakou and Thanon [8]: $Fo = (Si / St) \times 100$; Si = number of records where the order ‘’i’’ was present; St = total number of records. The order was considered very frequent if, $80\% < Fo \leq 100\%$, frequent if, $60\% < Fo \leq 80\%$, fairly frequent if, $40\% < Fo \leq 60\%$, accessory if, $20\% < Fo \leq 40\%$ and accidental if, $Fo \leq 20\%$. Non-parametric test of Generalized Linear Model (GLM) was used to compare the abundance of insect orders within the different plots. Following this analysis, Newman-Keuls comparison and classification test was used to compare and classify the abundances. In addition, Generalized Linear Model (GLM) was used to assess the effectiveness of each treatment. Insect orders in the different plots were characterized using the Principal Component Analysis (PCA). All tests in this study were conducted in STATISTICA version 7.1 and PAST version 1.0.

3. Results

3.1 Diversity of Insects

Simpson’s diversity indices corresponding to 0.58 and 0.52 respectively for the plot 1 and the plot 3 were relatively high compared to the plot 2 (0.40) and the plot 4 (0.42). Pielou’s evenness indices between 0.42 and 0.52 revealed a distribution of abundances in relatively balanced within the orders (Table 2). A total of nine orders (Coleoptera, Diptera, Hymenoptera, Orthoptera, Lepidoptera, Mantoptera, Blattoptera, Hemiptera and Isoptera) were recorded during this study. The plot 1 containing nine orders was the most diverse, followed by the plot 3 (8 orders), the plot 2 (7 orders) and the plot 4 (7 orders), respectively (Table 2).

Table 2. Diversity parameters

Plots	Taxonomic richness	Abundance	Index of Simpson (1-D)	Pielou’s evenness index
P 1	9	1808	0.58	0.52
P 2	7	1472	0.40	0.42
P 3	8	1621	0.52	0.52
P 4	7	1604	0.42	0.46

The mean richness of insect orders did not differ significantly among plots after the first, third and fourth application ($P > 0.05$) but, a significant difference was observed at the second application level ($F = 3.46$; $P = 0.03$) (Figure 2). The classification according to the occurrence frequencies revealed the following variations:

(1) In the first plot, three very frequent orders (Coleoptera and Hymenoptera, Fo = 100%; Diptera, Fo = 95.83%), two frequent orders (Hemiptera, Fo = 70.83%; Orthoptera, Fo = 66.67%); one fairly frequent order (Lepidoptera, Fo = 50%) and two accidental orders (Blattoptera and Mantoptera, Fo = 4.16%) were recorded.

(2) In the second plot, two very frequent orders (Diptera, Fo = 100%; Hymenoptera, Fo = 100%), two frequent orders (Coleoptera, Fo = 79.16%; Hemiptera, Fo = 65, 50%), two fairly frequent orders (Orthoptera, Fo = 58.33%); Lepidoptera, Fo = 45.83%) and one accidental order (Blattoptera, Fo = 8, 33%) were recorded.

(3) In the third plot, four very frequent orders (Hymenoptera, Fo = 100%; Diptera, Fo = 95.83%; Orthoptera, Fo = 91.66%; Coleoptera, Fo = 87.50%), one frequent order (Hemiptera, Fo = 66.66%), one fairly frequent order

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(Lepidoptera, Fo = 58.33%) and two accidental orders (Blattoptera, Fo = 8.33%; and Isoptera (Fo = 4.16%) were recorded.

(4) In the fourth plot, three very frequent orders (Hymenoptera, Fo = 100%; Diptera, Fo = 95.83); Coleoptera, Fo = 91.96), one frequent order (Orthoptera, Fo = 62, 50%), one fairly frequent order (Hemiptera, Fo = 58.33), one accessory order (Lepidoptera, Fo = 33.33%) and one accidental order (Blattoptera, Fo = 4.16%) were recorded.

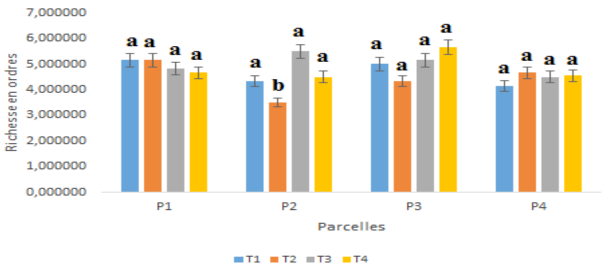

Figure 2. Mean richness of insect regarding the orders (The treatments followed by different letters, differ significantly)

3.2 Effectiveness of Treatments on Insect Abundance

A total of 6,505 insects were caught during the study. Among the orders recorded, Hymenoptera was the most abundant (N = 4459 Ind; 68.54%), followed by Diptera (N = 971 Ind; 14.92%) and Coleoptera (N = 645 Ind; 9.91%). The other orders were weakly recorded (N = 3 - 212 Ind; 0.04% - 3.25%). The largest number of insects was recorded within the plot 1 (N = 1808 ind; 27.79%), the plot 3 (1621 Ind; 24.91%), the plot 4 (N = 1604 Ind; 24.65%) and the plot 2 (N = 1472 Ind; 22.67%), respectively (Table 3).

Table 3. Quantitative inventories of orders by plot

ORDERS	Plot 1	Plot 2	Plot 3	Plot 4	TOTAL
Coleoptera	319 (17.64%)	65 (3.88%)	153(9.43%)	108(6.72%)	645(9.91%)
Diptera	277 (15.32%)	285(17.04%)	228(14.06%)	181(11.27%)	971(14.92%)
Orthoptera	31 (1.71%)	24(1.43%)	51(3.14%)	31(1.99%)	137(2.10%)
Hymenoptera	**1121 (62%)**	**1048(74.64)**	**1094(67.48%)**	**1196(74.51%)**	**4459(68.54%)**
Lepidoptera	19 (1.05%)	19(1.13%)	20(1.23%)	14(0.87%)	72(1.10%)
Hemiptera	37(2.04%)	29(1.73%)	73(4.50%)	73(4.54%)	212(3.25%)
Blattoptera	1(0.05%)	0(0.0%)	1(0.06%)	1(0.06%)	3(0.04%)
Isoptera	2(0.011%)	0(0.0%)	1(0.06%)	0(0.0%)	3(0.04%)
Mantoptera	1(0.05%)	2(0.11%)	0(0.0%)	0(0.0%)	3(0.04%)
Total	**1808 (27.79%)**	**1472 (22.67%)**	**1621 (24.91%)**	**1604 (24.65%)**	6505 (100%)

In overall, the analysis revealed no significant differences of the mean abundance of orders between the plots (F = 0.98; P = 0.40). However, for the first application of treatments, the insect abundance did differ highly significant between the plot 1 and the other plots (F = 11.54; P < 0.001). Newman-Keuls comparison and classification test revealed a weakest effectiveness of treatments with the aqueous extract of *Solanum lycopercicum* within the plot 1. In contrast, strongest effects were recorded within the plot 2, the plot 3, and the plot 4. For the second application, a significant variation of insect abundance was observed between the plot 4 and the other plots (F = 0.68; P = 0.029). Newman-Keuls test revealed a strong effectiveness of treatments within the plot 1, the plot 2 and the plot 3 contrary to the plot 4, treated with the extract of *Hyptis suaveolens*. For the third application, the insect abundance within the plot 1 and the plot 2 is highly significant compared to the plot 3 and the plot 4 (F = 20.64; P < 0.0001). Newman-Keuls test showed a great effectiveness of aqueous extracts of *Azadirachta indica* and *Hyptis suaveolens* on insect abundance compared to the chemical product and the aqueous extract of *Solanum lycopercicum*. For the fourth application, insect abundance within the plot 3 was less significant compared to the plot 1, the plot 2 and the plot 4 (F = 6; P = 0.004). Newman-Keuls test showed a strong effectiveness of treatments within the plot 1, the plot 2 and the plot 4 compared to the plot 3, treated with the aqueous extract of *Azadirachta indica*. The Generalized Linear Model (GLM) revealed that the various treatments affected highly the insect abundance (GLM: ddl = 3; W = 26.9; p < 0.0001) (Figure 3).

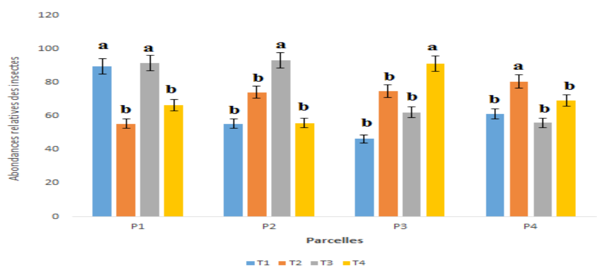

Figure 3. Mean abundances of insects within the different plots (The treatments followed by different letters, differ significantly)

3.3. Principal Component Analysis (PCA)

Insect orders were pooled in two major groups regarding the different treatments using the Principal Component Analysis (PCA).

(1) Axis 1 (99.28% of contribution): on the left, the orders of Hemiptera, Orthoptera, Blattoptera, Mantoptera, Lepidoptera and Isoptera were the least abundant after treatments. In contrast, on the right, the orders of Coleop-

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tera, Diptera and Hymenoptera were the most abundant regardless the treatment.

(2) Axis 2 (0.57% of contribution): the analysis revealed a segregation between the most abundant orders. Thus, insects belonging to Coleoptera were the most abundant after treatment with the aqueous extract of *Solanum lycopercicum* while, Diptera and Hymenoptera were correlated with chemical treatment, the aqueous extract of *Azadirachta indica* and the aqueous extract of *Hyptis suaveolens*, respectively (Figure 4). The Generalized Linear Model (GLM) corroborates these observations showing that the treatments influence significantly the distribution of insect orders abundance (GLM: ddl = 3; W = 21.01; p < 0.001).

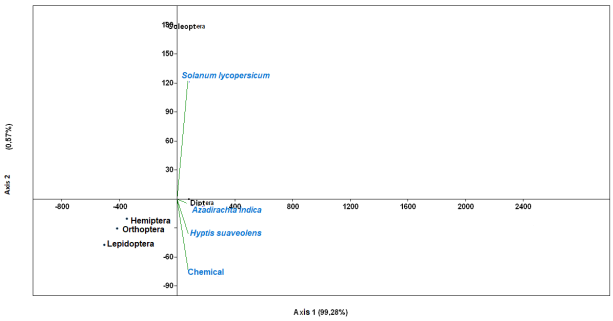

Figure 4. Effectiveness of treatments on insect orders using Principal Component Analysis (PCA)

3.4 Effectiveness of Treatments on the Pest Abundance

Insect pests identified during this study belonged mainly to the orders of Coleoptera, Hemiptera and Lepidoptera. The analysis revealed a significant variation of Coleoptera and Hemiptera abundance (P < 0.05) compared to the Lepidoptera (F = 0.9; P = 0.44). Newman-Keuls test revealed that the chemical treatment, the aqueous extracts of *Azadirachta indica* and *Hyptis suaveolens* were more effectives on Coleoptera abundance. The aqueous extract of *Solanum lycopercicum* was less effective (Figure 5).

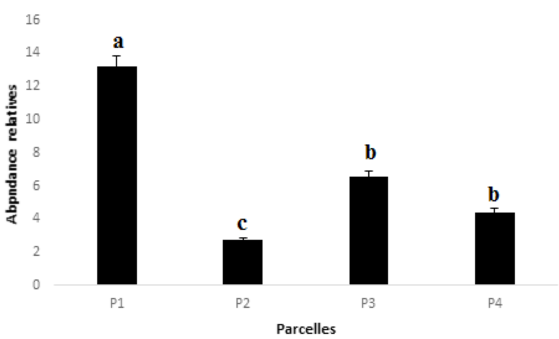

Figure 5. Variation of mean abundance of Coleoptera after treatment

Newman-Keuls comparison and classification test showed that the aqueous extract of *Solanum lycopercicum* and the chemical product were more effectives on Hemiptera abundance compared to the extracts of *Azadirachta indica* and *Hyptis suaveolens* (Figure 6).

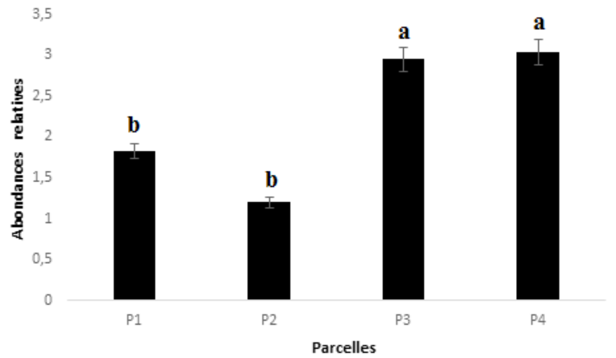

Figure 6. Variation of mean abundance of Hemiptera after treatment

4. Discussion

In the similar studies conducted by Ekra [10] and Alene et *al*., [1] respectively, only three orders were recorded. These authors focused their study only on insect pests. In contrast, our study focused on all groups of insects (pests or not). For this reason, we recorded nine orders. The number of orders recorded within the plots treated with the aqueous extracts of *Solanum lycopersicum* and *Azadirachta indica* was relatively great compared to the two others plots, treated chemically and with the aqueous extract of *Hyptis suaveolens*. Maybe, the aqueous extracts of *Solanum lycopersicum* and *Azadirachta indica* would be more selective. Its action would be specific on certain groups of insects, contrary to the chemical pesticides which benefits a wide spectrum of action [21]. According to Yovo [28], the plant extracts were used as insecticide because they were more selective and present a less drastic action on the insect groups compared to the chemical insecticides. The small number of orders recorded within the plot treated with the extract of *Hyptis suaveolens* revealed its repellent effect [25]. The two orders the most recorded during the study were Hymenoptera and Diptera. The Hymenoptera abundance could be in relation with the abundance of ants (Formicidae) which are ecologically important insects in most terrestrial ecosystems. The great number of fruit trees around the experimental plots could be explain the Diptera abundance. The chemical treatment was very effective on Coleoptera (Chrysomelidae, Coccinelidae and Scarabaeidae) and Hemiptera (Aleurodidae, Reduviidae, Ciccadelidae, Pentatomiidae, Alididae and Correidae). The effectiveness of this product would be

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due to its binary action. It consists of two active ingredients, acetamine 32g/l and lambda-cyhalothrin 30g/l, having a systemic and contact effect. Indeed, it penetrates in the tissues, where it is transported by the vascular system of the plant to organs, to reach its target and act directly to insect contact. It is not specific, so it acts on several insect groups. The aqueous extracts of *Azadirachta indica* and *Hyptis suaveolens* reduced also Coleoptera abundance due to their insecticidal and insect repellent effect. The same results were found by Belanger and Musabyimana [6]. Indeed, their studies revealed that the aqueous extract of *Azadirachta indica* was effective on insects' abundance. The aqueous extracts of *Azadirachta indica* and *Hyptis suaveolens* were very effective on the Coleoptera found in okra fields [9]. Bambara and Tiemboré [5] showed in their study the role of these extracts as good bio insecticides and insect repellents on cowpea pests. The aqueous extract of *Solanum lycopercicum* reduced the populations of Hemiptera. This trend was observed also by Gouley [13].

5. Conclusion

A total of 6505 insects belonging to nine orders (Coleoptera, Diptera, Hymenoptera, Orthoptera, Lepidoptera, Mantoptera, Blattoptera, Hemiptera and Isoptera) were caught. The largest numbers of orders were recorded within the plots 1 (treated with extract of *Solanum lycopersicum*), plot 3 (treated with the extract of *Azadirachta indica*), plot 2 (chemically treated) and plot 4 (treated with the extract of *Hyptis suaveolens*), respectively. Hymenoptera, Diptera, Lepidoptera, Coleoptera and Hemiptera were the most abundant orders and among them, three orders (Coleoptera, Lepidoptera and Hemiptera) belonged to the pest groups. This study revealed the effectiveness of the chemical product on Coleoptera. The extracts of *Azadirachta indica* and *Hyptis suaveolens* were moderately effective while the extract of *Solanum lycopersicum* was the least effective. On the other hand, the extract of *Solanum lycopersicum* and the chemical product were the most effective on Hemiptera compared to the extracts of *Azadirachta indica* and *Hyptis suaveolens*. The results obtained in apply the chemical treatment and the extract of *Solanum lycopersicum* not being statistically different, the extract of *Solanum lycopersicum* could replace the chemical treatment in the fight against the pests of okra, particularly against Hemiptera. That could be less toxic for the environment and reduce the risk of poisoning due to the use of chemical products. In addition, it would be interesting to combine the extracts of *Azadirachta indica* and *Solanum lycopersicum* in order to get a wide spectrum of action on the insect pests of okra.

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