

Effectiveness of Plant Extracts Against *Podagrica decolorata* and *Amrasca biguttula* in *Abelmoschus esculentus* (L.) Cultivation

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Abstract

Okra cultivation is plagued by pests that affect productivity. Consequently, the use of chemical pesticides causes problems. The present study was conducted to assess the impact of plant extracts of *Azadirachta indica*, *Hyptis suaveolens* and *Solanum lycopersicum* on the abundance of insect pests of the Hiré and Clemson okra varieties. To do this, a factorial block design was set up and foliar applications of these extracts were made, after which the insects were quantified. The extracts significantly reduced the abundance of *Podagrica decolorata* ($p = 0.0009$), *Amrasca biguttula* ($p = 0.01$), *Zonocerus variegatus* ($p = 0.02$) and *Jacobiasca lybica* ($p = 0.009$). Chemical treatment was effective on *Podagrica decolorata* with an average abundance of 40 ± 10.2 , followed by hydroethanolic treatment of *Hyptis suaveolens* (43.3 ± 15.4). On *Amrasca biguttula*, the hydro-anolic extract of the *Azadirachta indica* + *Solanum lycopersicum* combination was effective with an average abundance of 39.7 ± 3.2 . On *Jacobiasca lybica*, the chemical treatment was more effective (18 ± 6.2), followed by the hydroethanolic treatments of *Azadirachta indica* (27 ± 2.1) and *Hyptis suaveolens* (29 ± 6.2). The aqueous extract of *Hyptis suaveolens* considerably reduced the abundance of *Zonocerus variegatus* (3.7 ± 4.6) after the chemical treatment (3.5 ± 5.7). However, no significant difference was observed between these extracts and the chemical control ($p > 0.05$). Yields showed a higher average number of fruits (131.83 ± 45.6) in the chemically treated plot, followed by the plot treated with the hydroethanol extract of *Hyptis suaveolens* and *Solanum lycopersicum* (128.83 ± 15.2).

Keywords: abundance, *Amrasca biguttula*, *Jacobiasca lybica*, okra, plant extracts, *Podagrica decolorata*

1. Introduction

Abelmoschus esculentus, whose fruit is commonly known as okra, is a vegetable plant belonging to the Malvaceae family. It is grown in tropical, subtropical and warm temperate regions in various countries from Africa to Asia, Southern Europe and America (Grazioli et al., 2022). Okra is an important plant for human nutrition due to its richness in nutrients such as vitamins, potassium, calcium, carbohydrates, dietary fibre and unsaturated fatty acids such as linolenic and oleic acids (Durazzo et al., 2019). Its seeds are also rich in α -tocopherol, with high levels of minerals (Dantas, Alonso, & Florentino, 2021), proteins and essential amino acids (Elkhalifa et al., 2021). Its leaves are used to treat dysuria (Siemonsma & Hamon, 2004) and are sometimes used as a base for poultices, as an emollient and as a sudorific (Khomsug et al., 2010). Okra improves kidney function, reduces proteinuria and boosts immunity (Zhao, Jia, & Pei, 2012). It contains compounds with anti-diabetic, anti-cancer, anti-hypertensive and antimicrobial effects when consumed (Agregan et al., 2022). In Ivory Coast, okra is highly prized and cultivated. Annual production is estimated at around 186,112 tonnes in 2022, compared with annual world production of around 11,232,656 tonnes (FAOSTAT, 2023). In the commune of Korhogo, Okra is one of the most widely grown and marketed vegetables. It is a source of income for market gardeners (Yalamoussa, Dago, Yapo, & Kouakou, 2017). In view of the various advantages of okra mentioned

above, it is an important crop in the context of food security and a tool in the fight against poverty in rural, urban and peri-urban areas.

Unfortunately, this crop is subject to several diseases and pests that impact its productivity (Asare-Bediako et al., 2014; Soro et al., 2016). These pests attack all parts of the okra plant from the emergence stage through to fruiting. These pests include *Podagrica decolorata*, *Amrasca biguttula*, *Zonocerus variegatus* and *Jacobiasca lybica*. *Podagrica decolorata* is a defoliating flea beetle that makes holes in the leaves during feeding, thus reducing the photosynthetic surface. This pest is also recognised as a vector of the okra mosaic virus in Nigeria, Kenya, Sierra Leone and Côte d'Ivoire (Ugwoke & Onyishi, 2009). *Amrasca biguttula* and *Jacobiasca lybica* are sucking leafhopper hemipterans. As they feed, these leafhoppers transmit toxins and viruses that cause the leaves of okra plants to curl, reducing the photosynthetic surface and stunting plant growth. *Amrasca biguttula* was found to be the main pest of okra after cotton in Benin (Yarou, Francisco, De Troij, & Aboubakar, 2023) and Côte d'Ivoire (Aboussou et al., 2024). Like *Podagrica decolorata*, the locust *Zonocerus variegatus* is a defiler which, when feeding, gnaws leaves until they are completely consumed (Doumbia & Seif, 2008). The extent of the damage caused by these pests is prompting farmers to use chemical pesticides. However, the massive use of these chemical pesticides creates numerous problems, including loss of biodiversity, reduced soil fertility, pest resistance, health risks (UNDP, 2015) and toxicity to humans (Sougnabe et al., 2009; Son, Somba, Legreve, & Schiffers, 2017).

Because of the harmful effects mentioned above, it is necessary to find effective control methods that do not harm human health or the environment. The use of biopesticides seems to be a reliable and effective alternative to chemical pesticides, which have shown their limitations. In fact, the use of biopesticides to control pests is recommended because they have a rapid action, low toxicity against mammals and low persistence after application (Silverio, De Alvarenga, Moreno, & Picano, 2009). Extracts of *Azadirachta indica* and *Hyptis suaveolens* have been shown to be effective against cowpea thrips (Bello et al., 2019) and the cotton pest *Helicoverpa armigera*, which is also a pest of okra (Thiam et al., 2017; Sané, 2021). The aqueous extract of *Azadirachta indica* reduced the density of *Podagrica decolorata* in okra (Yao, 2022). This extract has also been shown to be effective against podagrica beetles (Asare-Bediako et al., 2014). Extracts of *Azadirachta indica* and *Hyptis suaveolens* have been shown to be effective against cowpea thrips (Bello et al., 2019) and the cotton pest *Helicoverpa armigera* (Sané, 2021). Leaf extracts from *Hyptis suaveolens* reduced maize pest numbers by 90.9% (Niang, 2022). Also, on *Sitophilis zeamaïs*, a higher insecticidal efficacy of *Hyptis suaveolens* powder was demonstrated by the work by Sakho et al. (2021). The effectiveness of *Solanum lycopersicum* leaves on the haemipterans encountered in okra cultivation was revealed in work carried out by Gouley (2014), and Koné, Coulibaly, Tuo, and Able (2020). The general objective of this study is to optimise okra production by controlling insect pests using active plant extracts. Specifically, the aim is to quantify the abundance of insect pests on two okra varieties (Hiré and Clemson) after application of extracts and to determine the yield of each variety according to the different treatments.

2. Material and Methods

2.1 Study Site

This study was carried out from December 2022 to September 2023 (involving both seasons) in the town of Korhogo, located in the north of Côte d'Ivoire between 8°26' and 10°18' north latitude and 5°16' and 6°16' west longitude. The climate is Sudanese, with two distinct seasons. The dry season begins in November and ends in March, with little or no rainfall. The rainy season begins in April and ends in October each year. It is marked by abundant and frequent rainfall. Korhogo has an average rainfall of 859 mm per year (Boko-Koiadja, Gueladia, Brama, & Deby, 2016). The city of Korhogo is largely drained by a hydrographic network consisting of two main rivers and their tributaries (Bandama and Comoé). In addition to this hydrographic network, the department benefits from pastoral dams built as part of integrated livestock development projects (Sangaré, Koffi, Akamou, & Fall, 2009). The majority of the population of Korhogo department derives its income from the main agricultural crops, perennial and food crops, as well as market gardening. In addition to agriculture, livestock farming also plays a crucial role in the economy of Korhogo department (MIS, 2023). The study site is located in residential area 1 of the town (Figure 1).

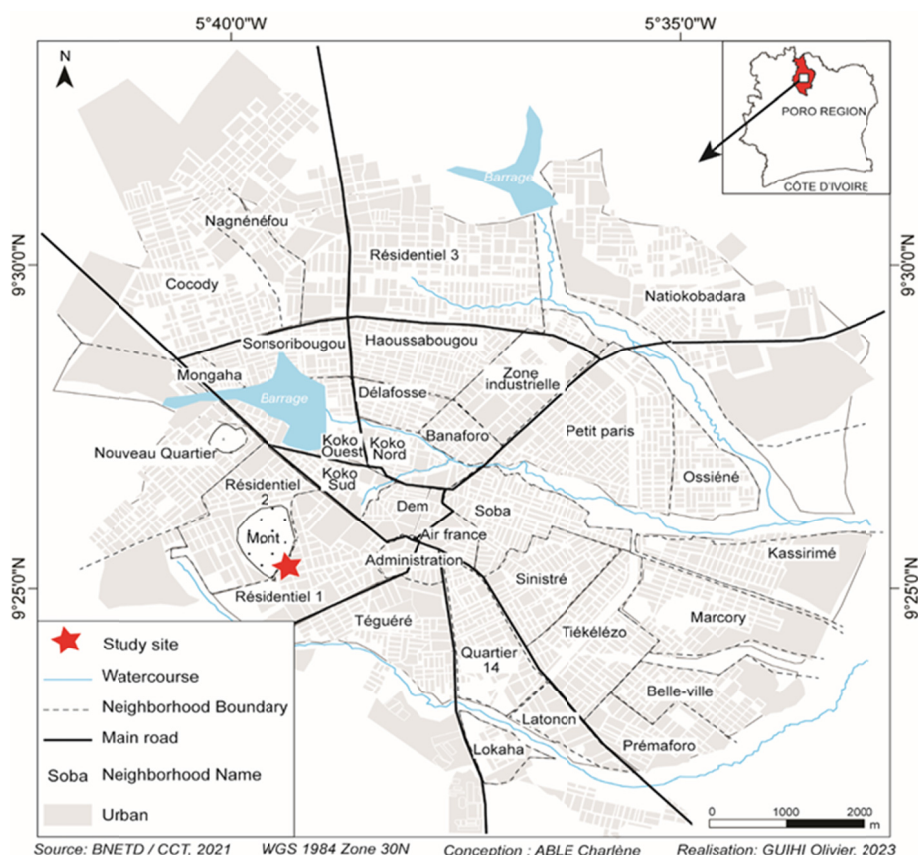


Figure 1. location of the study site

2.2 Experimental Set-Up and Implementation of Treatments

To carry out the experiments, a factorial block design was used with two factors. The first factor was the hiré and clemson varieties and the second was the plant extracts. The design consisted of twenty treatments (10 treatments per variety) with three replicates. The first treatment was a combination of the aqueous extract of *Hyptis suaveolens* and *Solanum lycopersicum*, treatment 2 was a combination of the hydroethanol extract of *Hyptis suaveolens* and *Solanum lycopersicum*, treatment 3 was the aqueous extract of *Hyptis suaveolens*, treatment 4 was the hydroethanol extract of *Hyptis suaveolens*, treatment 5 was the aqueous extract of the mixture of *Azadirachta indica* and *Solanum lycopersicum*, treatment 6 was the hydroethanolic extract of the mixture of *Azadirachta indica* and *Solanum lycopersicum*, treatment 7 was the aqueous extract of *Azadirachta indica*, treatment 8 was the hydroethanolic extract of *Azadirachta indica*, treatment 9 was the chemical control treated with Orthene 75 SP and treatment 10 was the untreated control. The individual plots measured 5 m² (2 × 2.5 m). Consecutive blocks were separated by 2 m. Each block consisted of 20 elementary plots with a distance of 1 m between them in order to limit the influence of one treatment on another (Yao, 2022). On each elementary plot, 3 ridges made up of 5 bunches were created. The okra plants were placed in rows on the ridges, with five plants per row. The distance between plants was 0.5 m to facilitate aeration of the plants by deep rooting (Doumbia & Seif, 2008). Each block was 14 m long and 13 m wide. The entire experimental plot was 14 m long and 43 m wide, giving a total surface area of 602 m². Each elementary plot contained 15 okra plants. Each block therefore contained 300 plants, giving a total of 900 plants for the entire plot.

2.3 Preparation of Extracts and Synthesis Chemical

The plant parts used are the leaves of *Hyptis suaveolens*, *Azadirachta indica* and *Solanum lycopersicum*. The leaves of these 3 plants are harvested in the botanical garden of the Peleforo Gon Coulibaly University in Korhogo. The leaves of these 3 plants were harvested and then dried in the shade in a ventilated room for 3 weeks. After drying, the leaves were ground to a powder in a Nasco® type blender (Singapore). Aqueous extracts were obtained by diluting 100 g of the powder obtained per plant species in 1000 mL of distilled water. Hydroethanolic extracts were obtained by mixing 100 g of powder obtained per species with 1000 mL of 70%

ethanol. To prepare the mixed extracts, 50 g of each powder was combined and then mixed in 1000 mL of solvent (Dansou et al., 2007; Yohanna, Muhammad, & Duna, 2022; Amine, Mohamed, Zoubida, & Jamal, 2017). After maceration for 48 hours, the mixture was homogenised in a blender for 5 minutes. Then filtered first through a sieve, then through a white cloth of the “pergale” type. The filtrate obtained was homogenised again in the blender for 5 minutes and filtered a second time with Wattman paper (3MM), then a third time with cotton wool contained in a funnel. The last filtrate obtained was sprayed in the field (Mondédji, Nyamador, Amevoin, Ketoh, & Glitho, 2014). According to the user guide, 40 g of Orthene 75 SP was diluted in 16 l of water. 1.2 litres of this mixture was applied directly to okra plants (Cécyre, Lambert, Müller, & Sénécal, 2017).

2.4 Application of Treatments

The treatments were applied using two-litre Jardinova manual sprayers. 9 sprayers were used to apply the products. One was used to apply the chemical insecticide, four for the aqueous extracts and the remaining four for the hydroethanol extracts. Treatments began at emergence and the interval between two treatments was 7 days to ensure degradation of the active ingredients in our extracts (Doumbia & Seif, 2008). A total of five foliar applications were made.

2.5 Insect Sampling and Identification

24 hours after each application, the insects present were collected by the direct observation method, capture using coloured traps (yellow plates) and mowing nets. The insects were placed in pillboxes or jars containing 70% alcohol and taken to the Animal biology laboratory of the biological sciences research and training unit at Peleforo Gon Coulibaly University for identification. (Bonneil, Mageleisen, & Bouget, 2009). Identification was carried out using a MOTIC binocular magnifier at $\times 4$ magnification and the identification keys of Delvare and Aberleng (1989), Roth (1974), Appert and Deuse (1988), Scholtz and Holm (1996) up to the family level. It then continued up to the specific level with works such as Chiffaud and Mestre (1990), (Doumbia & Seif, 2008), and Kouadio et al. (2022).

2.6 Performance Evaluation

To assess okra production, the number of fruits per treated plot was recorded. Fruits showing malformations or attacks by insect pests were also counted (Koné, Tuo, Yapo, & Kouakou, 2018).

2.7 Data Analysis

Analyses were performed using R software. After-verifying normality with the Shapiro-Wilk test, ANOVA and Kruskal-Wallis tests at the 5% threshold were performed, depending on whether or not the data followed the normal distribution. Next, Turkey's Post-Hoc test and Dunn's test were performed. These tests enabled us to compare and classify the mean and median number of insect pests and the mean okra yield, in order to identify any significant differences between treatments.

3. Results

3.1 Effect of Treatments on Insect Pests

Overall, the mean abundance of insect pests varied significantly (Kruskal-Wallis test: $H = 38.037$; $p = 0.005$) according to the different treatments applied. In the course of this work, the most abundant insect pests encountered were *Podagrica decolorata*, *Amrasca biguttula*, *Zonocerus variegatus* and *Jacobiasca lybica*.

3.1.1 Effect of Treatments on *Podagrica decolorata*

Figure 2 shows the effect of the treatments on *Podagrica decolorata*. On the Clemson variety, the population of *P. decolorata* was low with the chemical treatment (40.7 ± 10.2), followed by the hydroethanolic treatment of *Hyptis suaveolens* (49.3 ± 14) and the aqueous treatment of *Hyptis suaveolens* + *Solanum lycopersicum* (54.0 ± 18.1). On the Hiré variety, the lowest average number of *P. decolorata* was recorded with the hydroethanolic treatment of *H. suaveolens* (43.3 ± 15.4), followed by the aqueous treatment of *H. suaveolens* + *S. lycopersicum* (49 ± 12.8), then the chemical treatment (49.3 ± 12.8). The highest average number of pests was recorded in the untreated control plot (96 ± 6.9). Overall, the treatments significantly influenced the *P. decolorata* population (kruskal-Wallis test: $H = 17, 34$; $p = 0.0009$).

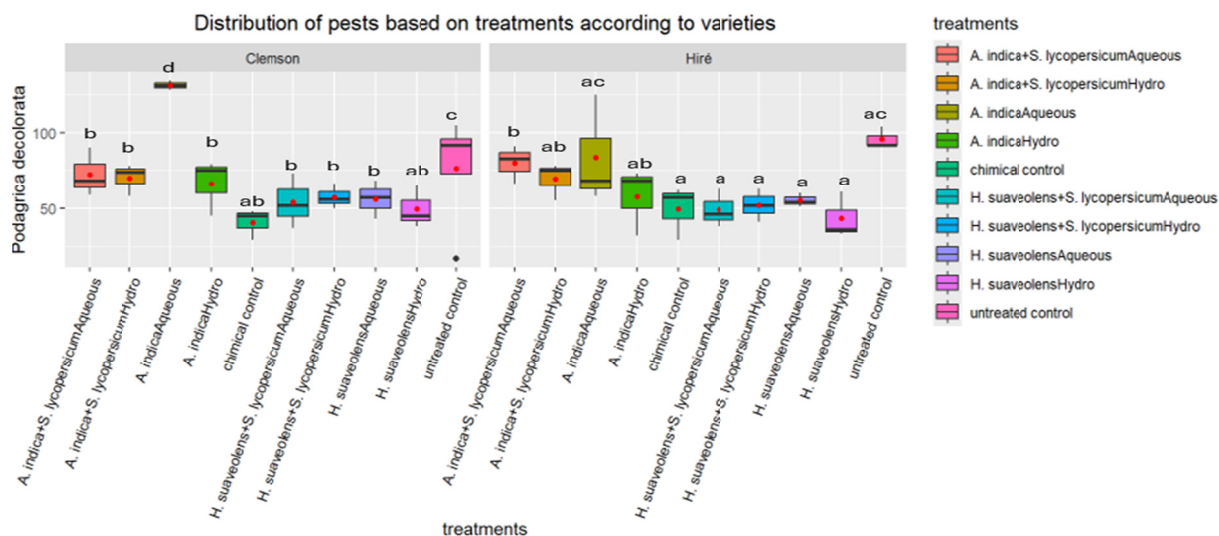


Figure 2. Average number of *Podagrica decolorata* as a function of treatments and by variety

Note. Means followed by the same letter are not significantly different, $\alpha = 0.05$.

3.1.2 Effect of Treatments on *Amrasca biguttula*

The average abundance of the species *Amrasca biguttula* varied significantly between treatments (Kruskal-Wallis test: $H = 9.68$; $p = 0.01$). On the Clemson variety, the chemical control recorded a low average number of the pest (40 ± 2.6). It was followed by the hydroethanol treatment of *H. suaveolens* + *S. lycopersicum* (44 ± 2.6), then the hydroethanol treatment of *H. suaveolens* (44.7 ± 5.8).

The untreated control recorded a very high average number with 66.3 ± 42.2 . On the Hiré variety, the hydroethanolic extract of *A. indica* + *S. lycopersicum* considerably reduced the population of *A. biguttula* (39.7 ± 3.2). This was followed by the hydroethanolic treatment of *Hyptis suaveolens* + *Solanum lycopersicum* (40.7 ± 7) and the chemical treatment (41 ± 7.2). The untreated control plot recorded the highest average number of this pest with 83.7 ± 11.2 individuals (Figure 3).

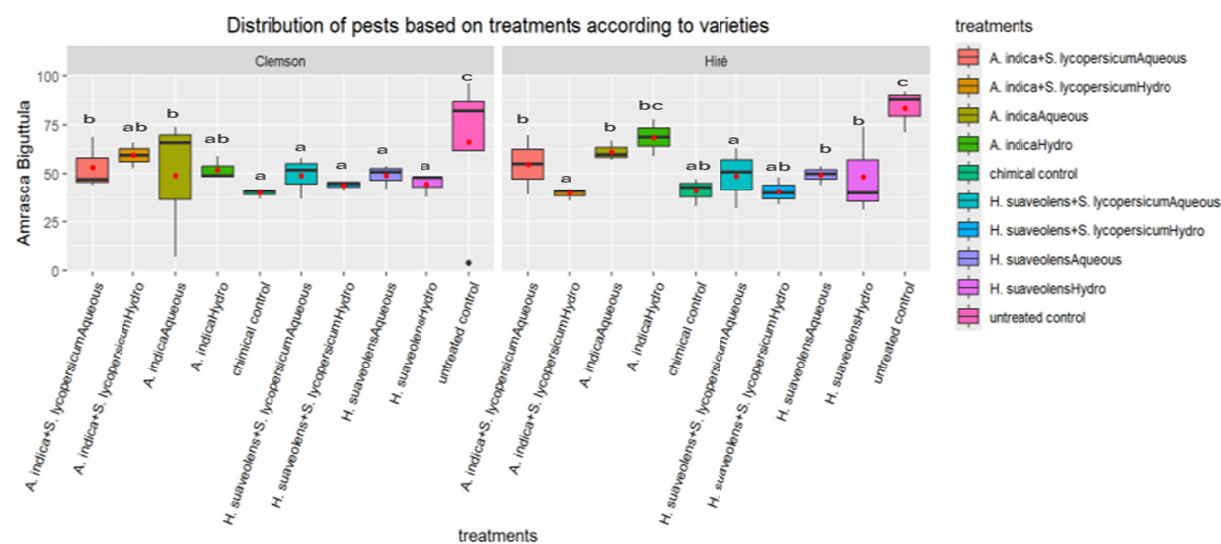


Figure 3. Average number of *Amrasca biguttula* as a function of treatments and by variety

Note. Means followed by the same letter are not significantly different, $\alpha = 0.05$.

3.1.3 Effect of Treatments on *Jacobiasca lybica*

Whatever the variety used, the chemical treatment reduced the population of *J. lybica* with an average number of 19.3 ± 8.5 for the Clemson variety and 18 ± 6.2 for the Hiré variety. After the chemical treatment, the hydroethanolic treatment of *Azadirachta indica* and the hydroethanolic treatment of *Hyptis suaveolens* had a considerable effect on the average abundance of this pest for the Clemson variety (27 ± 21.1 and 29 ± 6.2 respectively). For the Hiré variety, the hydroethanolic treatment of *Azadirachta indica* + *Solanum lycopersicum* recorded an average number of 26.3 ± 10.5 after the chemical treatment. This was followed by the hydroethanolic treatment of *Azadirachta indica* (27.3 ± 19.1). Compared with the untreated control, the aqueous extract of *Azadirachta indica* was not effective against this pest species (Figure 4). Finally, the treatments carried out had a significant impact on the number of *J. lybica* (kruskal-Wallis test: $H = 21.27$; $p = 0.009$) (Figure 4).

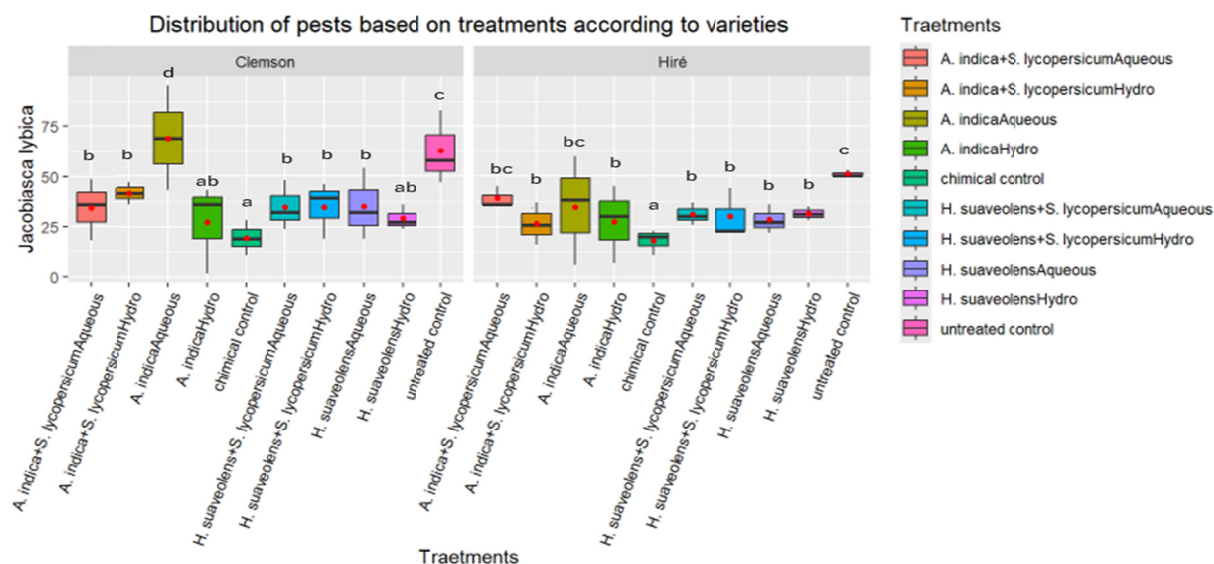


Figure 4. Average number of *Jacobiasca lybica* as a function of treatments and by variety

Note. Means followed by the same letter are not significantly different, $\alpha = 0.05$.

3.1.4 Effect of Treatments on *Zonocerus variegatus*

Analysis of variance revealed a significant difference (ANOVA: $F = 3.25$; $p = 0.02$) between treatments on the *Z. variegatus* population. On the Clemson variety, the average number of *Z. variegatus* obtained with the chemical treatment was 3.5 ± 3.5 . This is followed by the hydroethanolic treatment of *Hyptis suaveolens* + *Solanum lycopersicum* (7 ± 5.7). These average numbers are lower than those obtained with the other treatments. However, the highest number was observed on the untreated plot (32.5 ± 7.8). For the Hiré variety, the aqueous treatment with *Hyptis suaveolens* greatly reduced the number of *Z. variegatus* (3.7 ± 4.6). This was followed by treatment with hydroethanol extract of *Hyptis suaveolens* (6.3 ± 2.3), aqueous treatment with *Hyptis suaveolens* + *Solanum lycopersicum* (6 ± 5) and hydroethanol treatment with *Azadirachta indica* (8.3 ± 3.8). For the untreated control, a high average number of *Z. variegatus* (35 ± 14.5) was collected (Figure 5).

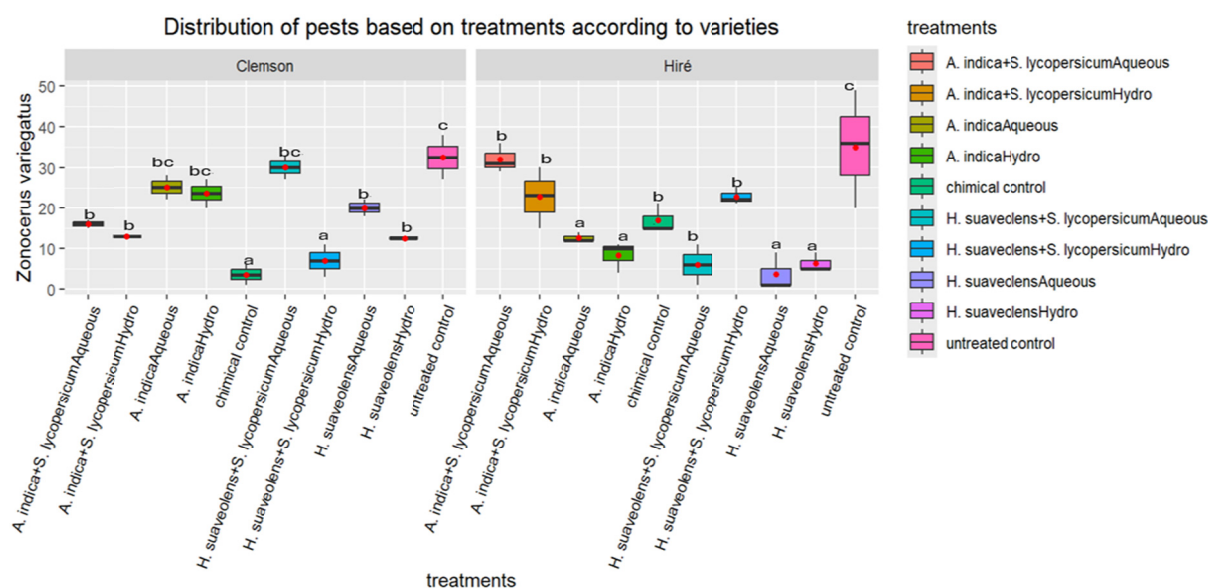


Figure 5. Average number of *Zonocerus variegatus* as a function of treatments and by variety

Note. Averages followed by the same letter are not significantly different; $\alpha = 0.05$.

3.2 Effect of Treatments on Okra Production

A total of 6098 fruits were harvested, including 3113 fruits of the Clemson variety (51.04%) and 2985 fruits for the Hiré variety (48.95%) (Figure 6).

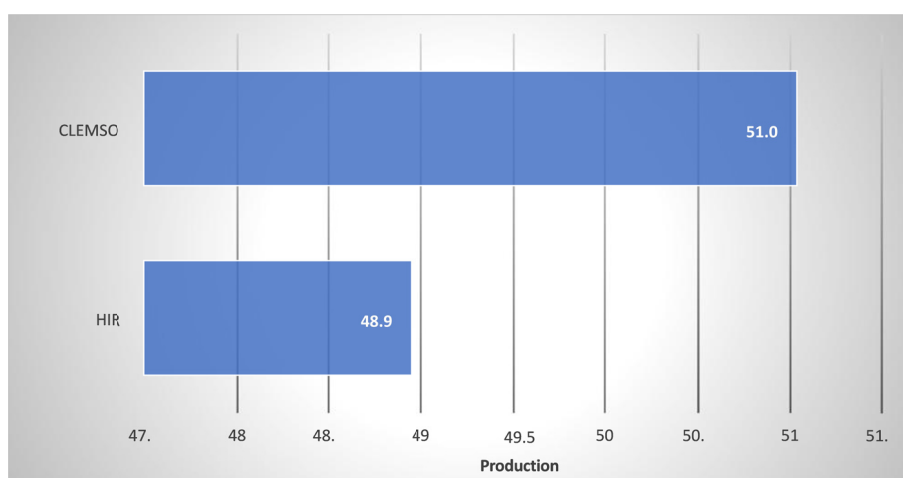


Figure 6. Rate of fruit harvested by variety (%)

On the Hiré variety, an average of 132.67 ± 11.67 fruits were harvested from the plot treated with the hydroethanol extract of *Hyptis suaveolens* + *Solanum lycopersicum*. Next came the plots treated with the hydroethanol extract of *Azadirachta indica* (132 ± 37.07), the chemical control (128.67 ± 27.35), the aqueous extract of *Hyptis suaveolens* (125.33 ± 6.13) and the aqueous extract of *Azadirachta indica* + *Solanum lycopersicum* (122 ± 8.83). The untreated control plot produced a low average number of fruits (56 ± 15.77). This analysis shows a significant difference between the average number of fruit harvested per treatment on the Hiré variety ($F = 7.9377$; $p = 0.0038$) (Table 1).

For the Clemson variety, the control plot treated with chemical insecticide produced an average number of fruits of 135.00 ± 58.29 . It was followed by those treated with aqueous extract of *Hyptis suaveolens* + *Solanum lycopersicum* (133 ± 18.99), aqueous extract of *Hyptis suaveolens* (129.33 ± 26.04), the hydroethanol extract of

Hyptis suaveolens + *Solanum lycopersicum* (125±17.20), the hydroethanol extract of *Azadirachta indica* + *Solanum lycopersicum* (120.67±7.41) and the hydroethanol extract of *Azadirachta indica* (119±20.46). Compared to the treatments carried out, the untreated control plot harvested a lower average number of fruits (59.67±14.20) than the plot treated with the aqueous extract of *Azadirachta indica* (56.67±15.41).

A significant difference was also observed between the average number of fruit harvested according to treatment on the Clemson variety (ANOVA: $F = 4.5013$; $p = 0.02$) (Table 1).

Table 1. Average number of fruits per treatment according to variety

Treatments	Varieties		Total
	Hiré	Clemson	
<i>Hyptis suaveolens</i> + <i>Solanum lycopersicum</i> Aqueous	100.67±19.34 ab	133.00±18.99 a	116.83±25.1 a
<i>Hyptis suaveolens</i> + <i>Solanum lycopersicum</i> Hydroethanol	132.67±11.61 a	125.00±17.20 a	128.83±15.2 a
<i>Hyptis suaveolens</i> Aqueous	125.33±6.13 a	129.33±26.04 a	127.33±19.0 a
<i>Hyptis suaveolens</i> Hydroethanol	66.00±20.40 ab	77.00±30.47 ab	71.50±26.5 bc
<i>Azadirachta indica</i> + <i>Solanum lycopersicum</i> Aqueous	46.7±8.83 a	92.00±5.89 ab	107.00±16.8 ab
<i>Azadirachta indica</i> + <i>Solanum lycopersicum</i> Hydroethanol	80.67±25.62 ab	120.67±7.41 a	100.67±27.5 ab
<i>Azadirachta indica</i> Aqueous	50.33±11.09 b	56.67±15.41 b	53.50±13.8 c
<i>Azadirachta indica</i> Hydroethanol	132.00±37.07 a	119.00±20.46 a	125.50±30.6 a
Chemical control	128.67±27.35 a	135.00±58.29 a	131.83±45.6 a
Untreated control	56.00±15.77 b	59.67±14.20 ab	57.83±15.1 c
P	0.003	0.02	0.00001

Note. Means followed by the same letter are not significantly different, $\alpha = 0.05$.

4. Discussion

The various treatments using plant extracts were effective against pests of okra. Compared with the untreated control, the treatments reduced the populations of insect pests encountered during the study. The chemical (ORTHENE 75 S.P) was effective on all pests in general, but more specifically on *Podagrica decolorata*, *Amrasca biguttula*, *Zonocerus variegatus* and *Jacobiasca lybica*. The effectiveness of 'orthene 75 S.P.' is due in part to its chemical composition. This product circulates in the plant. Through its contact and ingestion action, it blocks the insect's nervous system when it touches and/or absorbs it. The insect stops feeding; immobile and inactive, it quickly dies. Its active ingredient is acephate, a member of the organophosphate family. Acephate has a broad spectrum of action when applied to foliage, acting on a large number of insects including aphids, leafhoppers, bugs, jassids and whiteflies. As a cholinesterase inhibitor, it causes damage to muscles and nerve cells. In addition, this insecticide gives off a very strong odour which, in addition to its insecticidal effect, may act as an insect repellent (Cécyre et al., 2017).

The use of insecticidal or insect repellent plant extracts has a dual advantage, including respect for the environment and effectiveness in controlling crop pests (Mkenda et al., 2015). Apart from the leaves of *Solanum lycopersicum*, *Hyptis suaveolens* and *Azadirachta indica*, are not cultivated. The results show that after the chemical, the hydroethanolic and aqueous extracts of *H. suaveolens* + *S. lycopersicum* and *H. suaveolens* were effective on the pests encountered and more specifically on *Podagrica decolorata*, *Amrasca biguttula* and *Zonocerus variegatus*. Research has shown that the proximity of *H. suaveolens* plants to certain plots seems to have a repellent effect on these pests. This repellent action due to the volatile substances emitted by the plant has been proven by numerous authors (Belder Den et al., 1998). Phytochemical analysis of *H. suaveolens* carried out by gas chromatography-mass spectrometry, enabled the main volatile compounds contained in the leaves of this plant to be detected. These are: β caryophyllene, bergamotene, terpinolene, humulene, sabinene and limonene (Jaenson et al., 2006; Peerzada, 1997). Most of these compounds have been reported as insect repellents and insecticides. β -caryophyllene, which is classified as an insect repellent and parasiticide, is, in percentage terms, the most important volatile compound identified in *H. suaveolens* (Jaenson et al., 2006). In addition, Kossouh et al. (2010) showed that the essential oil extracted from *H. suaveolens* leaves harvested in Benin contains 42.3% β -caryophyllene. The efficacy of *H. suaveolens* leaves has also been demonstrated by several authors on several groups of insect pests. This plant is said to have an insecticidal and insect repellent effect on crop pests (Biao et al., 2018; Sakho et al., 2021), which could explain the reduction in the number of insect pests.

H. suaveolens is a highly aromatic plant. Its minty aroma and chemical composition, including the presence of alkaloids, give it an insecticidal and insect repellent effect (Kumar et al., 2015). Alkaloids, terpenoids, phenolic compounds or flavonoids are photosynthates of plants that affect the life or development cycle of crop pests in different ways (Boeke et al., 2004). The odour of biopesticides acts as an insect repellent (N'gom et al., 2020). This would justify the efficacy of *H. suaveolens* leaves. Sané (2021) showed that the hydroethanol extract of *H. suaveolens* was effective against *Helicoverpa armigera*. The efficacy of *S. lycopersicum* leaves is justified by the presence of certain alkaloids such as dehydrotomatine and α -tomatine (Friedman, 2002). Most alkaloids act as insecticides. They regulate growth by antagonistically disrupting insect hormones (Banken et al., 1997). The efficacy of the *Hyptis suaveolens* + *Solanum lycopersicum* mixture in aqueous or hydroethanolic preparations would therefore be due to the presence of certain chemical compounds such as alkaloids, terpenoids, phenolic compounds or flavonoids in the leaves. Similar studies have shown satisfactory results for the aqueous extract of *Solanum lycopersicum* leaves on hemipteran insect pests of okra (Koné et al., 2020). Compared with the hydroethanolic and aqueous extracts of *Hyptis suaveolens* + *Solanum lycopersicum* and *Hyptis suaveolens*, the extracts of *Azadirachta indica* and *Azadirachta indica* + *Solanum lycopersicum* in hydroethanolic preparation were moderately effective on the pests observed, except for *Amrasca biguttula* and *Jacobiasca lybica*. This could be explained by the fact that Neem (*Azadirachta indica*) leaves are less concentrated in *Azadirachta indica* (Tobi, 2006). However, the presence of *Azadirachta indica* the leaves would explain the efficacy of hydroethanolic extracts of *Azadirachta indica* and *Azadirachta indica* + *Solanum lycopersicum* on *Amrasca biguttula* and *Jacobiasca lybica*. This trend has been observed by Boyombe et al. (2022), who state that *Azadirachta indica*, the active principle of neem, is found in all parts of the plant and that the use of any part could control pests in natural or controlled environments. Hydroethanol extracts of *Hyptis suaveolens* + *Solanum lycopersicum*, *Azadirachta indica* and *Hyptis suaveolens* were not significantly different from the chemical on *Podagrica decolorata*, *Amrasca biguttula* and *Zonocerus variegatus*. They could therefore be used as a substitute for the chemical to control insect pests of okra. The effectiveness of hydroethanol extracts is thought to be due to ethanol's high capacity to extract large quantities of chemical constituents (Ballo, 2013; Tidiane et al., 2021). The high average number of fruits in treated plots compared to untreated plots, could be explained by the effect of the treatments carried out on insect pests affecting production. Similar studies carried out by Koné et al. (2018) revealed that treatments carried out on cabbage plots favoured a high fruit harvest due to the effect of treatments on insects affecting production.

5. Conclusion

This study showed that aqueous and hydroethanol extracts of *Hyptis suaveolens*, *Azadirachta indica* and *Solanum lycopersicum* can be recommended for the control of insect pests of okra. In fact, all the extracts had an impact on insect pest populations. The chemical product (ORTHENE 75 S.P), the aqueous and hydroethanolic extracts of *Hyptis suaveolens* + *Solanum lycopersicum* and *Hyptis suaveolens* proved equally effective on the pest species observed (*Podagrica decolorata*, *Amrasca biguttula*, *Zonocerus variegatus* and *Jacobiasca lybica*). Unlike the above extracts, hydroethanol extracts of *Azadirachta indica* and *Azadirachta indica* + *Solanum lycopersicum* were moderately effective. The hydroethanol extracts of the mixtures were not significantly different from the chemical product. They could therefore be used as a substitute for the chemical in the control of insect pests of okra. The study also showed that plots treated to reduce pests had good harvests. These extracts can be recommended for use against insect pests of okra.

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