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Effect of the aqueous extract of *Carica papaya* L., 1753 on the diversity of the entomofauna and acarofauna of okra (*Abelmoschus esculentus* (L.) Moench 1794) in the peanut basin of Senegal

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Abstract
This study aimed to evaluate the effect of an aqueous extract of *Carica papaya* on the diversity and dynamics of insect and acarid fauna associated with okra cultivation in the peanut basin of Senegal. The experiment was conducted using a randomized complete block design with two treatments: an untreated control (T0) and a treatment with *Carica papaya* extract (T1). A total of 26,320 insects belonging to eight orders were recorded, with a marked dominance of Hemiptera, particularly *Amrasca biguttula* and wingless aphids. No mites were observed. The results show that during the vegetative stage, an increase in certain pests was observed after application of the extract. Conversely, during the flowering-fruiting stage, a significant reduction in the main pest species was recorded. The extract of *Carica papaya* thus showed a variable effect depending on the phenological stage, with interesting regulatory potential on pest populations, while maintaining the overall community structure. No significant effect was observed on yield.

Keywords: Okra, insect fauna, aqueous extract, *Carica papaya*

Introduction
Okra is the only major vegetable crop in the Malvaceae family (Kumar *et al.*, 2013) [1]. This plant is cultivated as a popular vegetable in tropical and subtropical regions worldwide (Saifullah and Rabbani, 2009) [2], in the lower altitudes of Asia, Africa, and the Americas, and has extended to temperate regions of the Mediterranean basin (Charrier, 1983) [3]. It is particularly popular in West Africa, India, the Philippines, Thailand, and Brazil.

In Senegal, okra is among the most widely cultivated crops nationally, representing 34.6% and 29.4% of crops during the off-season (cool and warm seasons), respectively. This plant is exceptional and unique because all its parts are valued for food, medicinal purposes, crafts, and even industrial applications (Abdou *et al.*, 2022) [4].

Despite its importance, okra cultivation faces numerous biotic constraints related to the action of a range of arthropod pests, particularly insects and mites, which can cause significant losses in yield and quality. To control these pests, humans resort to the excessive use of chemical pesticides, leading to detrimental consequences for the environment and public health. Faced with these constraints, the use of environmentally friendly alternative methods is generating increasing interest. Among these, the use of plant extracts represents a promising approach within the framework of integrated crop protection. Many plants are known and used for their biocidal activities (toxicity, repellent, anti-feeding) against a wide range of pests (Yarou *et al.*, 2017) [5]. Papaya leaf extract has been tested by several researchers to control various types of pests, including the fall armyworm *Spodoptera litura* in chili pepper plants (Ningrum *et al.*, 2015) [6], *Spodoptera exigua* (Permadi *et al.*, 2020) [7], aphids on okra, and *Plutella xylostella* on cabbage (Gnago *et al.*, 2010) [8].

In this context, the present study aims to evaluate the effect of aqueous extract of *Carica papaya* on the diversity and abundance of insect and acarid fauna associated with okra (*Abelmoschus esculentus*) cultivation in the peanut basin of Senegal.

Materials and Methods
1. Study Area Overview
The study was conducted in the north-central part of the peanut basin of Senegal, specifically in the village of Sipane (Figure 8), located in the rural commune of Tassette, Thiès Department, at the following geographic coordinates: 14.62755° North latitude and 16.9341° West longitude. Near the hamlets of Sesseck and Palam Tioyane, the village of Sipane has a hot and dry desert climate (BWh) according to the Köppen-Geiger classification. The average annual temperature in Sipane is 24.3°C and the average annual rainfall is 537.7 mm. This site was chosen due to its agroecological representativeness within the peanut basin and the particular interest of okra cultivation, both from an agronomic and ecological perspective.

2. Plant material
The plant material consisted of an okra cultivar, the variety Clemson spineless, belonging to the species *Abelmoschus esculentus* L. Moench, and leaves of a local plant, *Carica papaya*, used for biological control. Clemson spineless is one of the improved and imported varieties that are hybrids, often determinate, and resistant to various diseases (Legba *et al.*, 2018) [9]. The choice of *Carica papaya* for the preparation of aqueous extracts was justified by its previously tested insecticidal effect and its availability in the study area.

3. Experimental Design

The experiment was conducted using a randomized complete block design comprising two treatments (T0 and T1) with three replicates, for a total of six treatments: T0 (control, no treatment) and T1 (treatment with *Carica papaya* aqueous extract). The design was established in a total area of 150 m² (59 m x 3 m) subdivided into three blocks spaced 13 m apart. Each block contained two elementary plots, corresponding to the two treatments, arranged randomly and separated by a distance of 1 m. Each elementary plot measured 9 m² (3 m x 3 m) and consisted of four rows of okra spaced 0.68 m apart. This device made it possible to evaluate the effect of the aqueous extract of *Carica papaya* on the diversity and dynamics of insect and mite populations associated with okra cultivation during the different phenological phases of the crop (vegetative phase and flowering-fruiting phase).

4. Extraction of the Biocidal Substance

Carica papaya leaves were harvested in the evening after sunset to preserve their bioactive compounds, near the Technopole road, close to the École Normale and Cheikh Anta Diop University of Dakar. After cleaning, they were dried in the shade for 10 days to retain their active properties. The dried leaves were ground in a mortar and then in a blender to obtain a fine powder. 200 g of this powder was weighed and mixed with 1 L of well water, resulting in a concentration of 200 g/L in a bucket. The solution was sealed tightly with a clean, fine cloth and left to macerate for 7 hours. The mixture was filtered through a sieve and muslin cloth. After filtration, the resulting extract was stored in a bottle at room temperature.

5. Plant Protection Treatment

An aqueous extract of *Carica papaya* was applied on days 36 and 53 after sowing to evaluate its effect on insect and mite populations associated with okra cultivation. Treatments were applied using a hand sprayer, chosen for its ease of use and suitability for applying the plant extract. To ensure even application and effective pest control, the spray jets were directed to cover both the upper and lower surfaces of each plant's leaves.

6. Inventory, Capture, and Identification of Insect and Acar Fauna

To inventory the insect and acar fauna of okra cultivation, observations were conducted the day before and 48 hours after each pesticide treatment. These observations were carried out early in the morning to maximize the detection of insects and mites. Okra planting holes were systematically and rigorously sampled to ensure data representativeness. Each experimental plot consisted of four rows of okra spaced 0.68 m apart. On each row, three okra planting holes were randomly selected for observation, for a total of 12 holes sampled per plot. However, some rows contained fewer than three usable holes. In these cases, all available holes were sampled to obtain 12 holes per plot, for a total of 72 holes observed. The direction of movement was alternated between rows (left-right then right-left) to ensure a smooth and complete passage. This approach-maintained data consistency while taking into account field conditions. Insects and mites were recorded visually and with a magnifying glass on all parts of the okra plant. Capture was done manually or by folding the leaves, and the identification of difficult-to-recognize specimens was completed with a binocular microscope under the assistance of an entomologist.

7. Okra Fruit Harvest

The harvest was carried out on all study plots of the Clemson spineless variety. Two harvests were conducted during this study. The first took place on June 14, 2025, and the second on June 24, 2025. At maturity, the *Abelmoschus esculentus* fruits were harvested manually, placed in bags labeled according to plot type, and then weighed to evaluate and compare yields under each treatment.

8. Parameters Evaluated

Several parameters were evaluated to highlight the presence, composition, and distribution of insects and mites in the environment, as well as their response to the different treatments applied.

Relative abundance: This is the ratio between the total number of individuals of a species, family, or order and the total number of organisms inventoried, expressed as a percentage (Ouali N'goran *et al*., 2019). It is represented by the following formula:

$$AR\% = ni.100 / N$$

AR%: Relative abundance; ni: Number of individuals of species i under consideration;
N: Total number of individuals of all species combined.

Frequency of occurrence or consistency: this is the number of records in which species i (Ni) is found out of the total number of records (N) carried out, expressed as a percentage. It is given by the following formula:

$$Fo\ (\%) = (Ni / N) \times 100$$

Fo%: Frequency of occurrence; Ni: Number of records where the species is found; N: Total number of records carried out.

Diversity:
The study of community diversity was carried out using several indices:
Shannon Diversity Index: This index describes the structure of a community by taking into account both species richness and the proportion of each species relative to all other species. It is represented by the following formula:

$$H' = - \sum ((Ni / N) * \log2\ (Ni / N))$$

Ni : nombre d'individus d'une espèce donnée, i allant de 1 à S (nombre total d'espèces).
N : nombre total d'individus.

Pielou Index: The Shannon index is often accompanied by the Pielou fairness index. It is given by the following formula:

$$J' = H'/H'max \text{ avec } H'max = \log S$$

With (S = total number of species) and H' = Shannon index. The evenness index measures the distribution of individuals within species, independently of species richness. Its value ranges from 0 (dominance of one species) to 1 (equal distribution of individuals across species).

Simpson's diversity index: This can be interpreted as the probability that two randomly selected individuals belong to different species. It is represented by the following formula:

$$IS = 1 - \sum pi^2$$

With pi = ni / N; ni: population size of species i; N: total population size of the different species in the stand. Maximum diversity is represented by the value 1, and minimum diversity by the value 0.
The okra fruits thus obtained were weighed according to the type of treatment in order to evaluate the yield:
Yield (R) = Total weight of okra fruits / cultivated area

9. Data Analysis

The data collected on the insect and acarid fauna were subjected to statistical analyses to compare the effect of the different treatments applied. The results were analyzed using R software version 4.5.1, and Excel 2013 was used for data entry and processing. These data were subjected to the Shapiro-Wilk normality test with a significance level of 5%. The result of this test allowed us to perform non-parametric Kruskal-Wallis and Wilcoxon tests. The Wilcoxon test was used to test the significance of the mean rank differences between variables for each pair of species. The Kruskal-Wallis test followed by Dunn's test was performed for multiple comparisons of the mean ranks of the corresponding variable.

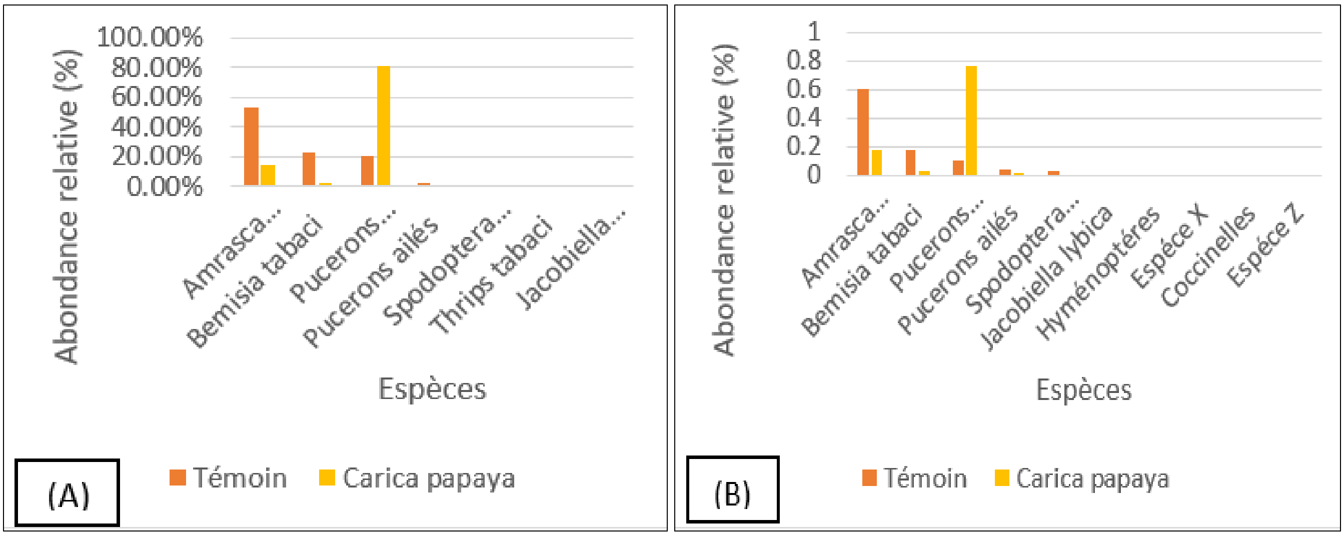
Results

1. Species Inventory

Sampling carried out on the okra crop yielded a total of 26,320 insects, plus 2 spiders. No mites were recorded in the studied plots. Insect identification revealed the presence of eight orders: Lepidoptera, Diptera, Hemiptera, Hymenoptera, Neuroptera, Thysanoptera, Coleoptera, and Orthoptera. The Hemiptera order was largely dominant, with a strong representation of the maggot (*Amrasca biguttula*) and wingless aphids.

2. Relative Abundance and Frequency of Occurrence

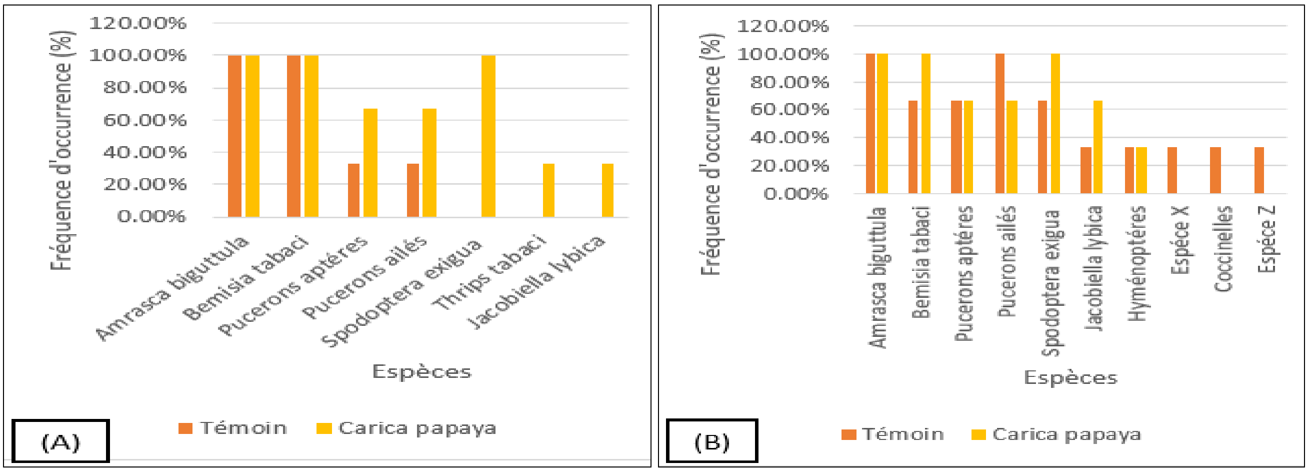
Analysis of the relative abundance (RA%) and frequency of occurrence (FO) of the recorded insect fauna, according to phenological phases and treatments, highlights a population dynamic strongly dominated by a few pests. At the vegetative stage, before treatment (Figure 1A), the insect fauna is dominated by *Amrasca biguttula* and wingless aphids. At T0, *Amrasca biguttula* exhibits a high relative abundance (53.21%) with an occurrence frequency of 100% (Figure 2A), indicating its omnipresence in these plots. In contrast, at T1, wingless aphids become largely dominant (81.00%).



(A): initial state in the vegetative stage (B): final state at the vegetative stage

Fig 1: Relative abundance of species observed in the vegetative stage

After treatment (Figure 1B), a change in population structure is observed. Although *Amrasca biguttula* remains omnipresent (FO = 100%) (Figure 2B), its relative abundance increases slightly in T1 (14.93% to 17.57%), while wingless aphids decrease and remain dominant (77.04%) (Figure 1B).

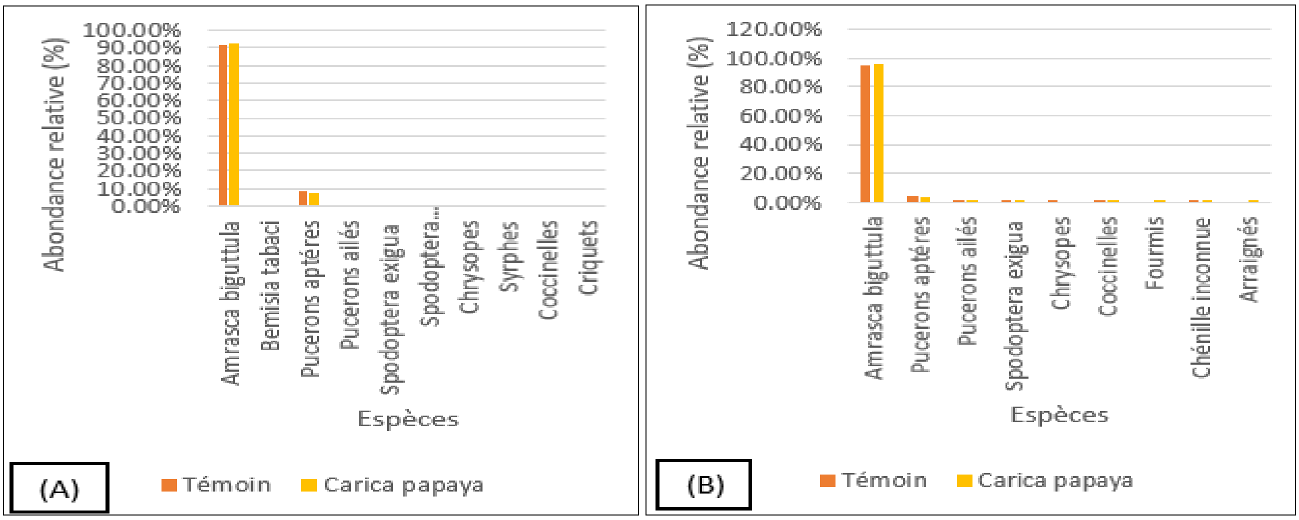


(A): Initial state (under residual effect of Califan); (B) State after application of treatments (*Carica papaya*).

Fig 2: Frequency of occurrence of different species observed in the vegetative stage

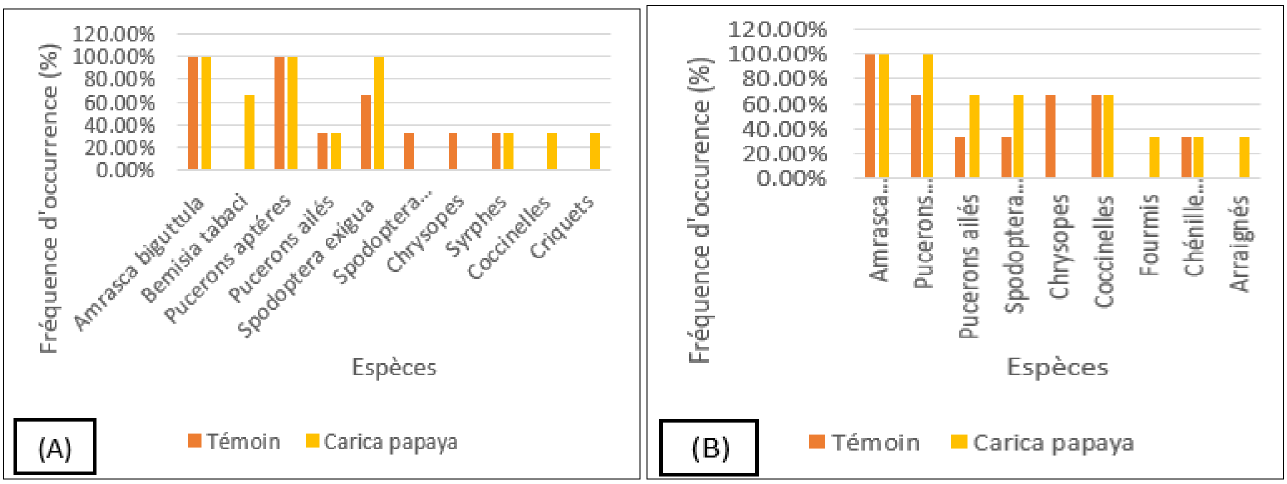
At the flowering-fruiting stage before treatment (Figure 3A), *Amrasca biguttula* became highly dominant in both treatments (over 91%), with an occurrence frequency of 100% (Figure 4A). Wingless aphids remained secondary (8.31% in T0 and 7.45% in T1), while other species were marginal (Figure 3A).

After treatment in T1 (Figure 3B), the dominance of *Amrasca biguttula* increased further (96.07%). Conversely, a significant decrease in wingless aphids was observed (from 7.45% to 3.64% in T1). Beneficial insects (ladybugs, lacewings, and hoverflies) remained poorly represented.



(A): before treatment (B): after treatment

Fig 3: Relative abundance of species observed at the flowering-fruiting stage



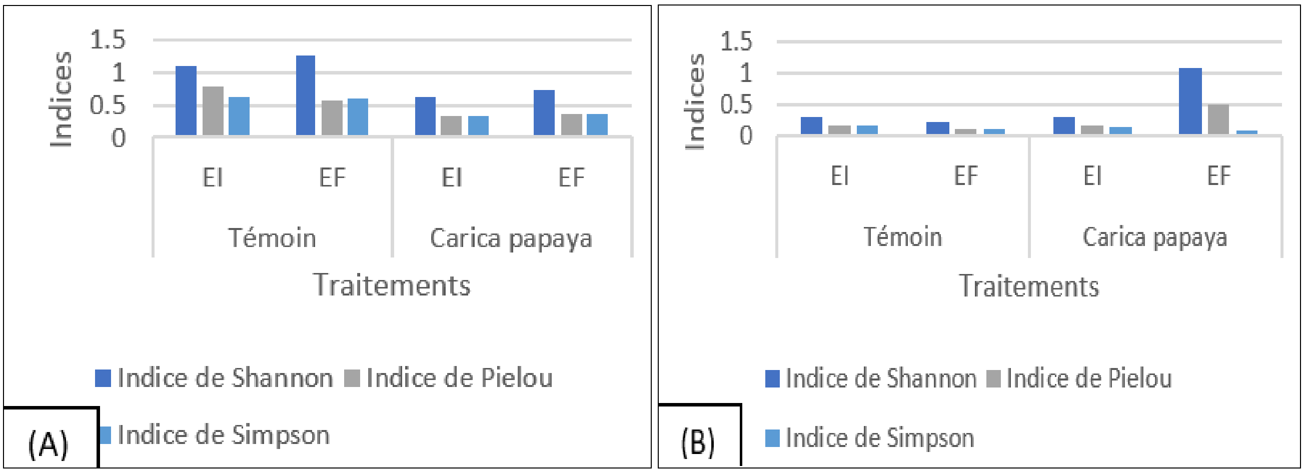
(A): before treatment (B): after treatment

Fig 4: Frequency of occurrence of different species observed at the flowering-fruiting stage

Diversity

During the vegetative phase, the Shannon index increased in both treatments, but remained higher in the control (1.1 to 1.27) than in the treated plot (0.63 to 0.73). The Pielou index decreased in the control (0.79 to 0.58) but increased slightly under the *Carica papaya* treatment (0.33 to 0.37). The Simpson index remained stable in the control and increased under the *Carica papaya* treatment.

During the flowering-fruiting phase, diversity decreased in the control (Shannon: 0.31 to 0.21) but increased sharply in the treated plot (0.29 to 1.07). Similarly, the Pielou index decreased in the control (0.16 to 0.11) and increased under the treatment (0.15 to 0.51). The Simpson index decreased in both cases, with a more pronounced decrease under the *Carica papaya* treatment.



(A) Vegetative stage (B) flowering-fruiting stage

Fig 5: Comparative evolution of floristic diversity indices according to treatments

3. Effect of treatments on the insect fauna of okra

In the vegetative stage, before treatment (Figure 6A), the insect fauna is dominated mainly by wingless aphids and *Amrasca biguttula*, while other species are poorly represented. Plots treated with *Carica papaya* extract already show high numbers of wingless aphids.

After treatment (Figure 6B), a more detailed analysis reveals that the main okra pests, including *Amrasca biguttula*, wingless aphids, winged aphids, and *Bemisia tabaci*, saw their populations increase under the influence of *Carica papaya*, with a particularly marked increase in wingless aphids. Conversely, the populations of *Spodoptera exigua* larvae decreased.

At the flowering-fruiting stage, before treatment (Figure 7A), a strong dominance of *Amrasca biguttula* was observed (5060 individuals at T0 and 6212 at T1), followed by wingless aphids (460 individuals at T0 and 502 individuals at T1). Beneficial insects (lacewings, hoverflies, ladybugs) were very poorly represented.

After treatment (Figure 7B), the *Carica papaya* extract had an overall reducing effect on the majority of pests, with notable decreases observed in *Amrasca biguttula*, wingless aphids, winged aphids, *Spodoptera exigua* larvae, and the whitefly *Bemisia tabaci*. A reduction in hoverfly and grasshopper populations was also observed as a result of this treatment. Furthermore, beneficial insects remained scarce despite the treatment, indicating a limited impact on their proliferation.

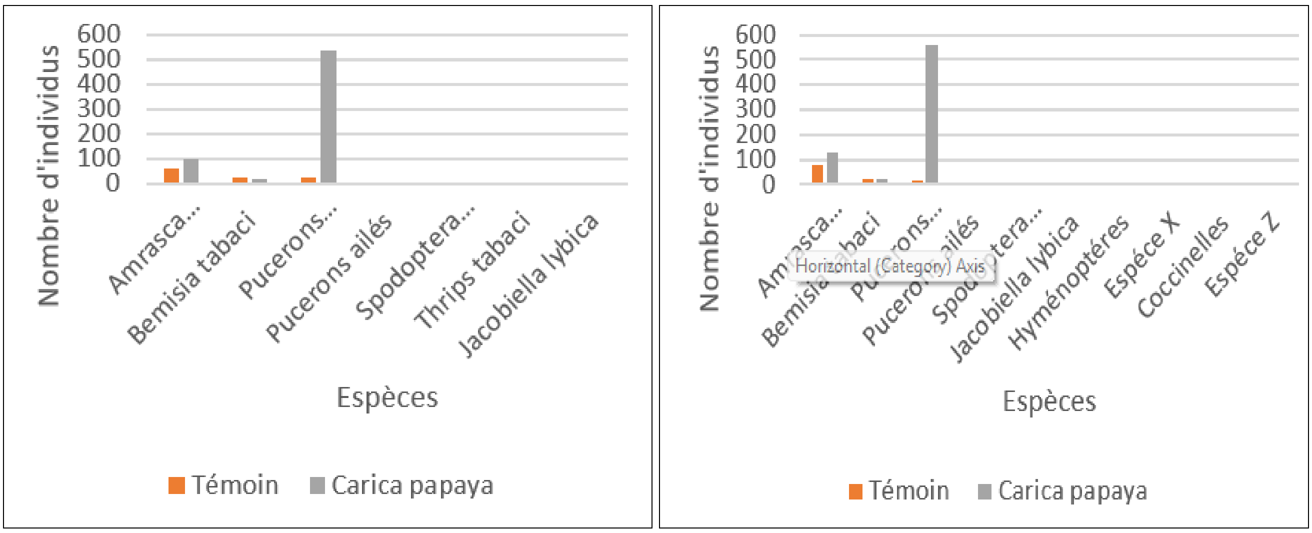


Fig 6: Effect of treatments on the insect fauna in the vegetative stage

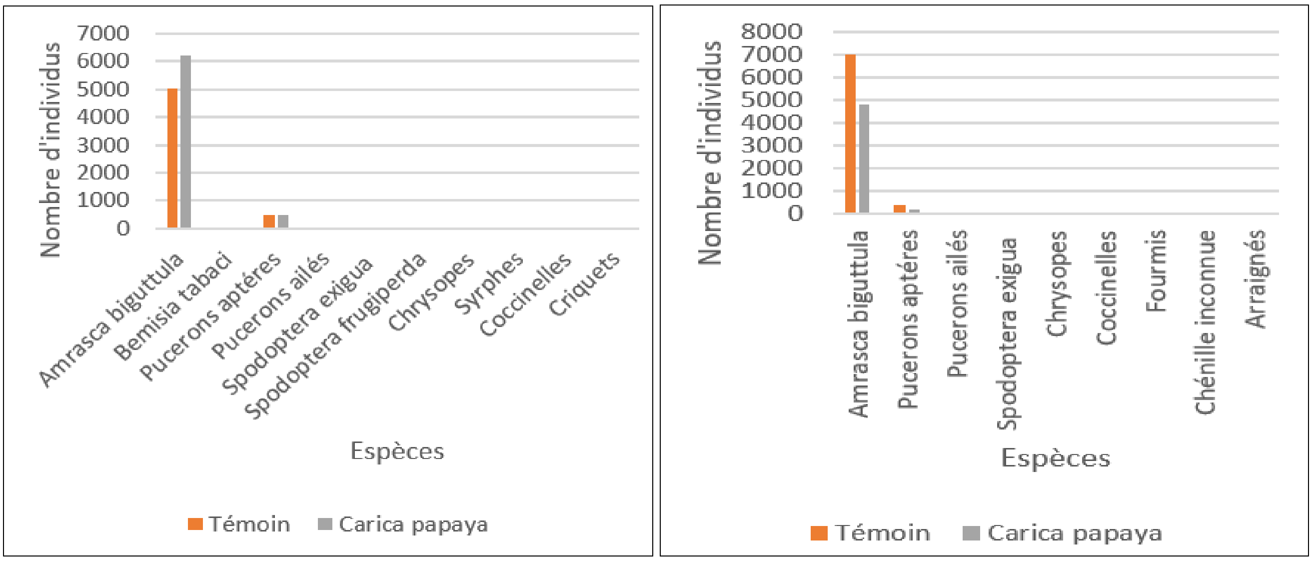


Fig 7: Effect of treatments on the insect fauna at the flowering-fruiting stage

4. Effect of treatments on net yield of okra crop

As shown in Figure 8, the net yields obtained for each treatment (T0, T1) were similar (0.02 kg/m²) for okra. However, statistical analysis using a normality test is not possible due to the similarity of the net yields.

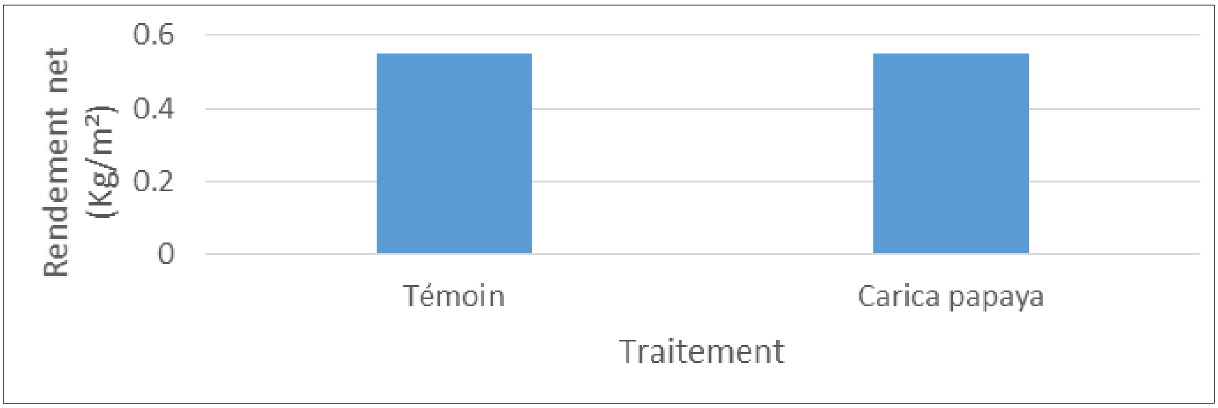


Fig 8: Net yield of okra (kg/m²) according to treatments

Discussion

The order Hemiptera was the most abundant during this study. These results confirm those of Ka (2020) [11], who also highlighted a dominance of Hemiptera throughout the okra development cycle in Senegal, despite the significant variations in climatic conditions observed between the two sites.

At the vegetative stage, the dominance of wingless aphids in plots T1 could be explained by the sap richness of the young plants, which is conducive to their development. Indeed, according to Ryckewaert and Rhino (2017) [12], young shoots, rich in nutrients, constitute a particularly favorable environment for the attraction and multiplication of aphids by parthenogenesis. Furthermore, the application of the *Carica papaya*-based biopesticide induced a significant change in the community structure. Although wingless aphids remained dominant, their relative abundance decreased slightly compared to the initial state, while that of *Amrasca biguttula* increased slightly. This dynamic reflects a differentiated effect of the extract depending on the species, affecting aphids more than leafhoppers.

At the flowering-fruiting stage, the dominance of *Amrasca biguttula* becomes particularly pronounced. These results are consistent with those of Srinivas and Kumar (2024) [13], who indicate that the progression of the okra growth cycle is accompanied by an increase in populations of this species, which are more abundant at the reproductive stage. After treatment, *Amrasca biguttula* further accentuates its dominance, as no treatment with *Carica papaya* significantly reduced its frequency of occurrence. This situation could be explained by a certain tolerance or resistance of the species, as well as by the limited efficacy of the applied treatment. The decrease in the relative abundance of wingless aphids observed in the T1 plots could be explained by the reducing effect of *Carica papaya* applied to these populations.

The results show that the *Carica papaya* extract influences the diversity of the insect fauna in a variable manner depending on the crop growth stage. At the beginning of the growth cycle, the lower diversity and higher dominance in the treated plot suggest an initial disruptive effect, likely related to the biocidal action of the extract. Conversely, during the flowering-fruiting phase, the increase in diversity and evenness, associated with a decrease in dominance, indicates an improvement in community structure. This could be explained by a reduction in dominant species, particularly certain pests, thus promoting a better ecological balance. Therefore, the *Carica papaya* extract appears to have an initial negative effect followed by a beneficial regulatory effect on the biodiversity of the agroecosystem.

During the vegetative phase, the paradoxical increase in major pests, particularly the jasper louse (*Amrasca biguttula*) and wingless and winged aphids, observed after treatment with *Carica papaya* extract, could be explained by the residual effect of previous chemical pesticide applications. These likely reduced natural enemy populations, thus promoting pest proliferation in the absence of effective biological control. Indeed, according to Janssen and van Rijn (2021) [14], the reduction in natural enemies induced by pesticides can lead to pests becoming unresponsive to their biological control, resulting in higher population levels. Despite this unfavorable context, *Carica papaya* extract demonstrated targeted efficacy against Spodoptera exigua larvae, consistent with the work of Ngom *et al*. (2020) [15] and Siregar *et al.* (2024) [16], which highlights the action of papaya bioactive compounds disrupting the feeding and development of this pest. At the flowering-fruiting stage, prior to treatment, a strong dominance of *Amrasca biguttula* was observed, followed by wingless aphids, indicating significant pest pressure. The decrease in populations of sap-sucking insects (*Amrasca biguttula*, wingless and winged aphids, *Bemisia tabaci*) as well as caterpillars (*Spodoptera exigua*) after the application of *Carica papaya* underscores the importance of the phenological stage in the efficacy of treatments. Indeed, the reproductive phase is accompanied by significant metabolic changes, notably an increase in secondary metabolites. These compounds could act synergistically with the active principles of *Carica papaya*, thus enhancing their toxicity or repellent effect on pests. Contrary to the results of Gnago *et al.* (2010) [8], which attributed the efficacy of papaya extract solely to aphids, our study highlights a reduction in *Spodoptera exigua*, *Bemisia tabaci*, and *Amrasca biguttula*. This divergence could be linked to agroecological conditions and differences in the composition of the extracts used.

The results show that the net okra yield was identical between the control (T0) and the plots treated with *Carica papaya* extract (T2), with a value of 0.02 kg/m² for both treatments. This indicates that the application of the extract did not lead to any yield improvement compared to the control. This lack of difference could be explained by similar initial conditions between the plots or by relatively moderate pest pressure during the study period. Furthermore, the limited number of harvests does not allow for the detection of any potential cumulative effect of the treatments over the entire growing cycle.

Conclusion and Perspectives

This study evaluated the effect of the plant extract (*Carica papaya*) on the diversity of insect and acarid fauna in an okra agroecosystem in the peanut basin of Senegal. The main results revealed a dominant insect fauna (99.99% of the collected individuals), characterized by the predominance of Hemiptera, with the leafhopper *Amrasca biguttula* as the key pest. Acarids were absent. The *Carica papaya* extract showed a reducing effect against *Spodoptera exigua* larvae at all phenological stages and controlled other major pests (*Amrasca biguttula*, wingless and winged aphids, *Bemisia tabaci*) during the flowering-fruiting stage. Despite the differences observed in the composition and dynamics of the arthropods, the yields observed between treatments were similar. To further this work, it would be important to:

- Test the effect of *Carica papaya* extract on a larger scale in larger plots,
- Study the seasonal dynamics of insect and mite populations to better understand natural fluctuations related to climatic conditions,
- Investigate the effect of plant extracts on the developmental stages of pests (eggs, larvae, adults) to determine the most effective timing for applications and optimize pest control,
- Experiment with different concentrations and formulations of *Carica papaya* extract, as well as various types of synthetic insecticides.

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