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Research Article

EFFECT OF BIOPESTICIDES MADE FROM FRESH NEEM LEAVES AND CHILI PEPPERS ON APHIDS AND THE STINK BUG OF COWPEA (*VIGNA UNGUICULATA* L. WALP.)

[1*]HALILOU Hayyo, [2]KARIMOU Issa, [3]KADRI Aboubacar, [3]ISSOUFOU SOUMANA Abdoulaye

[1]University of Agadez, University Institute of Technology, Department of Agriculture in Arid Zones, P.O. Box 199, Agadez, Niger
[2]National Institute of Agricultural Research of Niger, Maradi Regional Agricultural Research Center, Department of Plant Protection, Plant Pathology Laboratory, P.O. Box 429, Niamey, Niger
[3]Abdou Moumouni University of Niamey, Faculty of Agronomy, Department of Crop Production, P.O. Box 10960, Niamey, Niger

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ABSTRACT

Aphids (*Aphis craccivora* Koch) and the stink bug (*Clavigralla tomentosicollis* Stal) are major insect pests of cowpeas in Niger. The objective of this study is to develop an agroecological management method for these insects using neem and chili extracts to increase cowpea yields. A Fischer block design with three replicates and four treatments was used. Data on infestation rates, insect dynamics, and pod and seed yields were collected. Biopesticides based on neem (T3) and chili pepper (T4) resulted in a significant reduction in infestation by these two (02) pests, comparable to that achieved with chemical pesticides. The insect incidence, which was 9.72% for neem and 18.23% for chili pepper after the first application, reached 2.80% and 2.90%, respectively, for neem and chili pepper after the sixth application. A gradual decline in *A. craccivora* colonies was observed during the first two weeks, followed by an increase from the third to the fourth week, then a sharp drop in the fifth week, and the complete disappearance of the colonies by the sixth week following the applications of the biopesticides. It should be noted that the chili-based biopesticide (T4) was more effective than the neem-based biopesticide (T3). For the stink bug *C. tomentosicollis* Stal, the results indicate the presence of this insect only starting from the plant's branching stage (56 days after sowing). A gradual increase in the populations of this insect was observed following the application of the various treatments, with higher levels for the neem-based biopesticide (T3) than for the chili pepper-based biopesticide (T4). The application of biopesticides to manage aphids and stink bugs increased cowpea yield from 478 kg/ha in the control treatment to 1,410 kg/ha and 1,119 kg/ha for the neem- and chili pepper-based treatments, respectively. Farmers can therefore rely on these biopesticides as an alternative to chemical pesticides to increase cowpea yields.

Keywords: Cowpea, aphid, stink bug, neem, chili pepper, Niger.

INTRODUCTION

The cowpea (*Vigna unguiculata* L. Walpers) is a crop of major socioeconomic and nutritional importance in Niger (Stoilova and Pereira, 2013). As the primary food legume and cash crop in Niger, it contributes significantly to meeting household needs and reducing poverty due to its high protein content (Stoilova and Pereira, 2013), its market value, and its central role in food security (Kadri *et al*., 2013). From an agronomic perspective, cowpeas play an essential role in improving soil fertility through their ability to fix atmospheric nitrogen. Their leaves and foliage are also used for human and animal feed. The importance of this crop is confirmed by figures from the 2021-2022 growing season, during which national production reached 2,781,782 metric tons on an area of 5,851,214 hectares,

*Corresponding Author: HALILOU Hayyo, University of Agadez, University Institute of Technology, Department of Agriculture in Arid Zones, P.O. Box 199, Agadez, Niger. Email: hayyohalilou5@gmail.com.

with an average yield of 475 kg/ha (Ludovic *et al*., 2023). Cowpeas thus rank second in terms of production and area planted after millet, first among legumes, and represent the third-largest agricultural contributor to Niger's Gross Domestic Product (GDP) (FAO, 2017; MA, 2012). However, despite its vital role, cowpea production remains severely limited by various biotic and abiotic constraints, including diseases, poor soil quality, and limited access to inputs (Sani and Bagna, 2007). Among these factors, insect pests pose the most devastating threat, potentially causing yield losses ranging from 80 to 100 percent in the absence of control measures (Ahmed *et al*., 2009). Two major pests are of particular concern: the cowpea aphid (*Aphis craccivora* Koch.) and the stink bug (*Clavigralla tomentosicollis* Stal). Historically, pest control in Niger has relied on the widespread use of chemical pesticides, particularly "first-generation" organochlorines (DDT, aldrin, lindane, etc.) since the colonial era (Kolani *et al*., 2003). However, these practices have revealed serious drawbacks: high toxicity, persistence in the environment, low biodegradability, and bioaccumulation in the food chain, leading to severe pathologies and physiological disorders (Fisk *et al*., 2001; Oliva *et al*., 2001; Baldi *et al*., 2003). In light of these findings, agricultural research is shifting toward alternative crop protection methods based on economical, ecological, and less toxic solutions, such as biopesticides (Mukendi *et al*., 2013). In the Sahelian agroecological context, extracts from local plants, particularly neem (*Azadirachta indica*) and chili pepper (*Capsicum annuum*), appear to be promising and sustainable options for controlling cowpea pests (Ba *et al*., 2008; Rabe *et al*., 2017). The overall objective of this study is to develop an agroecological management method for *A. craccivora* and *C. tomentosicollis* on cowpeas, in order to improve the yield of this crop in Niger.

MATERIALS AND METHODS

Experimental Site

The study was conducted at the CERRA research station in Maradi, located at an elevation of 380 m between 13°27′ north latitude and 7°6′ east longitude (Figure 1). The climate is Sahelo-Sudanian, with an eight-month dry season (October through May) and a rainy season from June through mid-October, characterized by annual precipitation ranging from 350 to 670 mm (Hayyo *et al*., 2020).

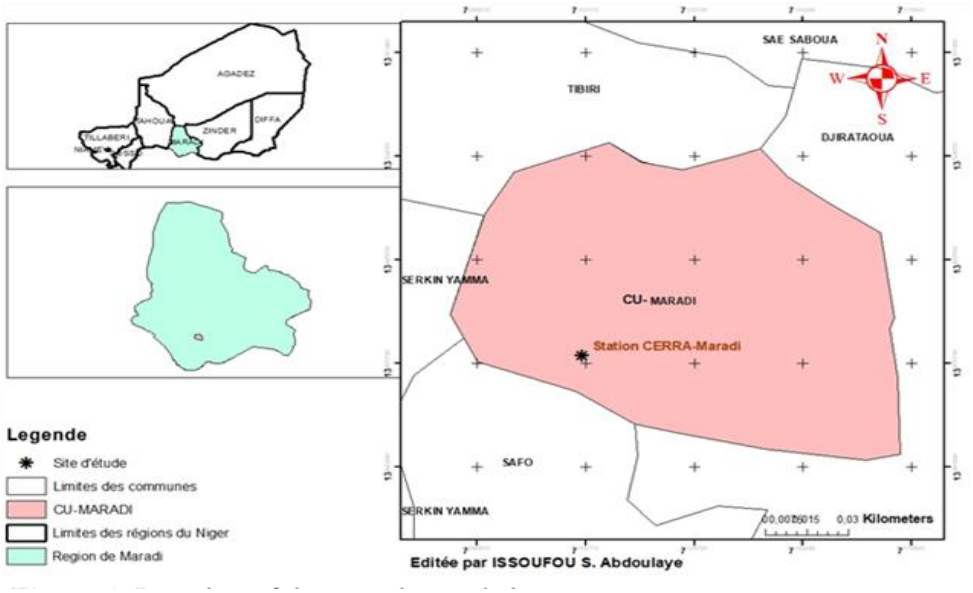

Figure 1. Location of the experimental site.

Plant Material

The plant material consists of a single variety of cowpea: TN5-78. It is an improved dual-purpose variety listed in Niger's National Catalog of Plant Species and Varieties. It has indeterminate growth and a semi-prostrate habit, with a 50% maturity period of 75 days and a potential yield of 2.5 t/ha. The seeds are brown in color. This variety is susceptible to bacterial canker, aphids, stink bugs, Striga, etc. (MA/CNS, 2021).

Pest Control Materials

The pest control materials consist of fresh neem leaves (*Azadirachta indica*), ripe chili peppers (*Capsicum annuum*), and a chemical pesticide (*Magic Force*) (Figure 3). The criteria for selecting neem and chili peppers are based on their availability in the study area and research findings on their biological activities in other contexts. The Magic Force pesticide is a powerful, broad-spectrum agricultural insecticide formulated with lambda-cyhalothrin and dimethoate, which acts by contact, ingestion, and systemically to eliminate sucking and chewing insects.



Figure 2. Pods and seeds of the TNF-78 variety (MA/CNS, 2021).



Figure 3. Plant protection materials: (A) Fresh neem leaves, (B) Ripe chilli peppers, and (C) Magic Force chemical pesticide.

Experimental Design

The experiment was conducted using a Fischer block design with three replicates, spaced 1.6 m apart. Each block consisted of four (04) subplots spaced 0.8 m apart. The subplots measure 2.4 m long by 2 m wide, for a total area of 4.8 m² each. They comprise three (03) rows, each with 12 holes, for a total of 36 holes per subplot. The spacing between rows is 0.8 m, and the spacing between holes is 0.5 m. Four (04) types of treatments were applied: T1: absolute control (tap water), T2: positive control (chemical pesticide), T3: neem-based biopesticide (fresh leaf juice), T4: chili-based biopesticide (juice from ripe fruits). Seeding was carried out after a beneficial rainfall of 28 mm, at a rate of two to three seeds per hole. Thinning was performed ten (10) days after seeding to maintain two plants per hole. Crop management consisted of two successive weeding operations, supplemented by manual weeding based on the level of weed growth observed in the plots.

Preparation of Biopesticides

The process for preparing biopesticides is the same for neem and chili peppers. The steps in the preparation process are as follows (Figure 4): Grinding and measuring: The amount of raw material (250 g for neem and 12.5 g for chili peppers) was tripled (corresponding to the three replicates) and finely ground using a mortar and pestle. Maceration: The ground mixture was wrapped in a clean cloth, placed in a container, and left to macerate in 1 L of water for 24 hours. Preparation of the adjuvant: Simultaneously, two pinches (equivalent to three (03) fingers' worth) of Marseille soap powder were dissolved in 0.5 L of water to serve as a wetting agent (surfactant). Filtration and mixing: After maceration, the solution (plant extract) was strained, mixed with the 0.5 L of soapy water, then filtered through a fine-mesh cloth and poured into the sprayer. For the chemical pesticide, the mixture was prepared on-site during application for safety reasons, and wearing protective coveralls was mandatory. The treatment volume for each plot was standardized to 500 ml. The required doses were calculated using a rule of three based on the recommended doses (Table 1).

Pest Control Treatments

Figure 5 illustrates some of the steps involved in applying the treatments at the experimental site. A total of seven sprayings were carried out on a weekly basis using a pre-pressurized sprayer with a capacity of 8 liters. The first application took place one month after sowing. The three applications following the first were carried out in the

morning at 7:00 a.m., while the last three were carried out in the evening around 6:00 p.m. to account for the heavy rainfall recorded during that period. As a safety measure and to prevent any cross-contamination, the chemical treatments were systematically applied last during each session.



Figure 4. Process of preparing a neem-based biopesticide.

Table 1. Different Doses Selected for Treatments.

Treatments	Recommended Doses	Calculated Dose for 500 ml/plot
Neem (T3)	2.5 kg of fresh leaves per 5 L	250 g of crushed leaves
Chili pepper (T4)	250 g of fruit per 10 L	12.5 g of crushed fruit
Pesticide (T2)	40 ml per 15 L	1.33 ml of Magic Force



Figure 5. Spraying of pesticides in the experimental field.

Data Collection

Data on the incidence of insect attacks, the population dynamics of aphids and stink bugs, and crop yields were collected at the plot level. Observations on the incidence of insect attacks were conducted over a 46-day period, at seven-day intervals, and covered all the clumps in each plot. The number of clumps showing signs of attack was recorded, and the incidence was calculated using the following formula:

$$\text{Incidence } (\%) = \frac{\text{Number of infested clusters}}{\text{Number of clusters observed per plot}} \times 100$$

To assess the population dynamics of the aphid *A. craccivora*, observations were made before the first application, then three days after each application, over a total period of 46 days. These observations focused on five (05) randomly selected clusters marked on the center line of each plot. Aphids were counted directly in the field by colony. With regard to the *C. tomentosicollis* bug, observations were conducted every three days following each application, over a 35-day period beginning at the branching stage of the cowpea. They also focused on five (05) randomly selected test plots marked along the center line of each plot. Larvae and adults of the bug were collected and counted. At full maturity, ten (10) central test plots from each plot were harvested. The pods were dried in the shade and then weighed to determine pod yield. After threshing, the seeds were weighed to determine seed yield. Yield was calculated by converting the production obtained from the area of the ten plots comprising the yield square to that of one hectare.

Data Processing and Analysis

The collected data were entered and processed using Microsoft Excel 2016. For variables following a normal distribution-notably the incidence of attacks-an analysis of variance (ANOVA) was performed using Genstat Release 14.1. However, for data related to insect population dynamics, which do not follow a normal distribution, the

nonparametric Kruskal-Walli's test was applied. Graphs were created using Microsoft Excel 2016.

RESULTS AND DISCUSSION

Figure 6 illustrates the incidence of attacks observed after the application of the various treatments. Starting with the first application, the neem-based biopesticide (T3) recorded the lowest incidence of insect attacks, at 9.72%, compared to 21.49% for the control. Analysis of variance revealed a highly significant difference among the treatments ($P < 0.001$). The chemical pesticide (T2) showed the lowest incidence after the second and third applications, at 4.29% and 0%, respectively. It was followed by the chili-based biopesticide, which recorded 4.59% after the second application, and by the neem-based biopesticide, with 14.52% after the third application. In comparison, the control (T1) showed the highest incidence of infestation, reaching 22.71% and 20.02% after the second and third applications, respectively. Analysis of variance revealed a significant difference among the treatments ($P = 0.001$). After the fourth application, the chili-based biopesticide (T4) resulted in the lowest incidence (6.15%), compared to 8.45% for the chemical pesticide (T2). Similarly, at the fifth application, the incidence of infestation was zero (0 %) for both the chili-based biopesticide and the chemical pesticide. The results of the analysis of variance indicate a significant difference between treatments at the 5% level ($P = 0.05$) for the fourth application, and a highly significant difference ($P < 0.001$) for the fifth application. At the sixth application, the incidence ranged from 2.80% for the neem-based biopesticide to 7.22% for the control. At the seventh application, it ranged from 4.28% for the chemical pesticide to 11.22% for the control. A significant difference was observed between the treatments, with $P < 0.001$ at the sixth application and $P = 0.016$ at the seventh.

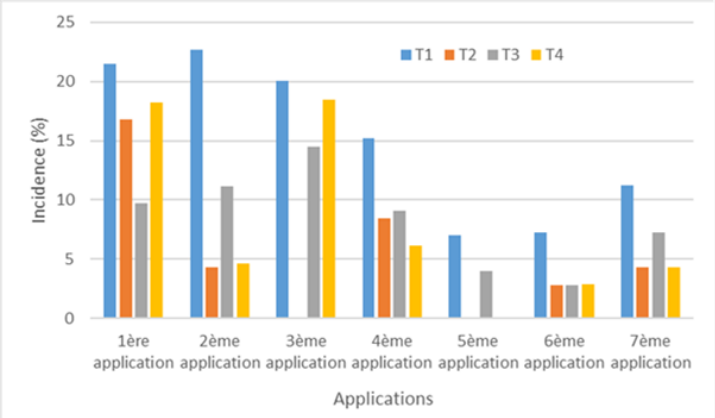

Figure 6. Incidence of insect attacks following the application of various treatments.

Figure 7 illustrates the population trends of *A. craccivora* based on observation dates. The control (T1) showed a significantly higher number of colonies than the other treatments at all application times, with the exception of the third application, where a gradual decline was observed. The chemical pesticide (T2), on the other hand, recorded the lowest number of colonies throughout the entire application period. The biopesticides showed a gradual decline in *A. craccivora* colonies over the first two weeks, dropping from 2 for neem and 1 for chili pepper in the first week to zero by the end of the second week. However, an increase was observed during the third and fourth weeks, followed by a sharp drop in the fifth week and a complete disappearance of the colonies by the sixth week. It should be noted that, over the entire period, the chili-based biopesticide (T4) was more effective at reducing *A. craccivora* colonies than the neem-based biopesticide (T3). Analysis of variance revealed a significant difference between the treatments ($P = 0.016$).

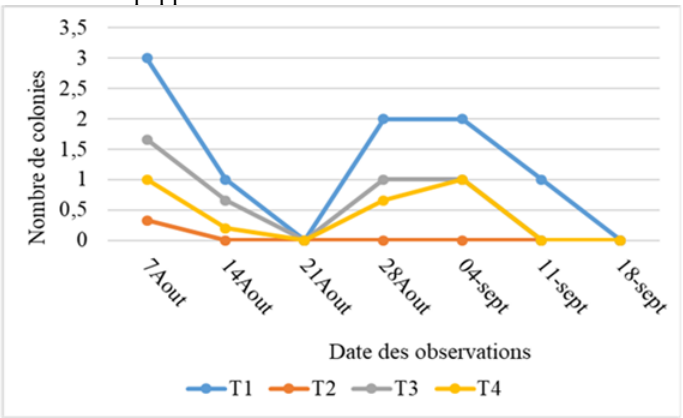

Figure 7. Effect of treatments on the population dynamics of *A. craccivora*.

Figure 8 shows the population trends of *C. tomentosicollis* under the different treatments. The results indicate that this insect was not observed until the plant's branching stage (56th JAS), which is after the second application of the treatments. Analysis of variance revealed a significant difference among the treatments ($P < 0.016$). The highest number of *C. tomentosicollis* was recorded in the control (T1), with a significant increase over time. In contrast, the chemical pesticide (T2) maintained the lowest population levels throughout the application period. Regarding the biopesticides, a gradual change in population levels was observed following the applications, with higher levels for the neem-based biopesticide (T3) than for the chili-based biopesticide (T4).

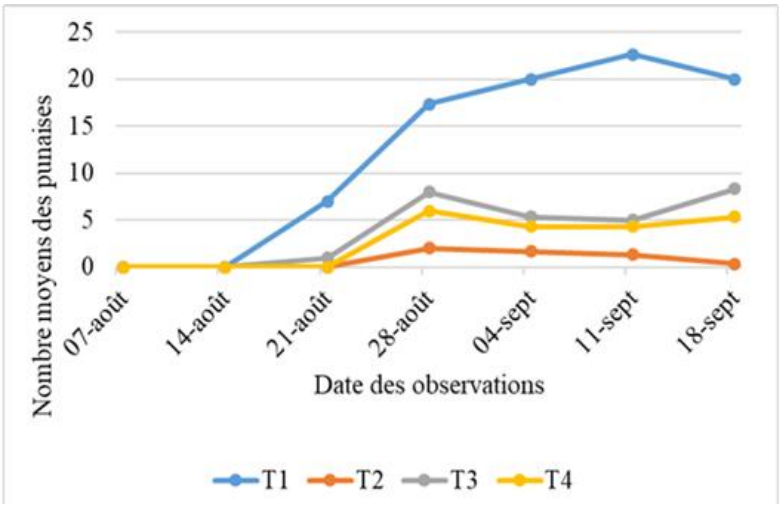

Figure 8. Effect of treatments on the population dynamics of *Clavigralla tomentosicollis*.

The effect of treatments on cowpea yield is illustrated in Figure 9. The highest pod yields were obtained with the biopesticides: 1,870 kg/ha for the neem-based biopesticide (T3) and 1,518 kg/ha for the chili-based biopesticide (T4). In comparison, the chemical pesticide (T2), although it showed greater effectiveness in reducing pest attacks, recorded a lower pod yield of 964 kg/ha. Regarding seed yields, the neem-based biopesticide (T3) produced the highest yield at 1,410 kg/ha, followed by the chili-based biopesticide (T4) at 1,119 kg/ha.

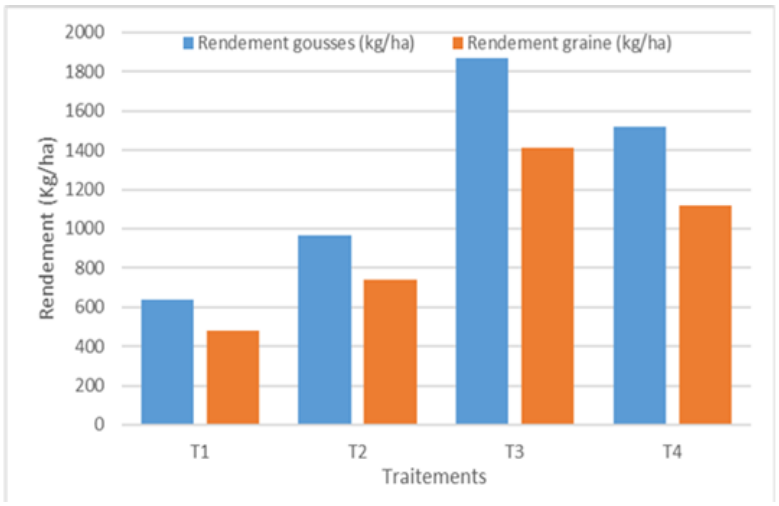

Figure 9. Average yield of cowpea in terms of pods and seeds by treatment.

The objective of this study was to evaluate the impact of biopesticides on the infestation levels of the aphid *A. craccivora* and the brown stink bug *C. tomentosicollis* Stal, two major pests of cowpea (Rabe *et al*., 2017). The results obtained highlight significant variability in infestation rates depending on the treatments applied. A statistically significant difference was observed among the treatments tested. Treatments based on neem leaves (T3) and ripe chili peppers (T4) showed efficacy comparable to that of the chemical treatment (T2), which recorded the lowest level of infestation. Conversely, the untreated plots (T1) exhibited the highest incidence rates. These results underscore the significant effect of biopesticides in reducing damage caused by insect pests, confirming the conclusions of

Zakari *et al*. (2025) in Zinder, who also reported a decrease in infestations and population density through the use of biopesticides. The analysis of relative efficacy nevertheless confirms the superiority of the synthetic chemical pesticide (T2), which proved to be the most effective treatment, with the lowest level of infestation across all applications. These observations reaffirm the recognized effectiveness of synthetic products in pest management, as documented by several authors (Naseri *et al*., 2009).

Among the biopesticides tested, the neem leaf-based treatment (T3) showed notable efficacy, significantly reducing the infestation rate compared to the negative control (T1). The negative control recorded the highest infestation rates, confirming the protective effect of neem. Neem's efficacy is attributable to its active compounds, notably azadirachtin and nimbidin, which give the plant a broad spectrum of actions: anti-feeding effects, growth inhibition, disruption of molting, and ovicidal action (Srivastava *et al*., 2007; Mouffok *et al*., 2008). The anti-appetite effect, which often occurs rapidly, may explain the early reduction in infestations observed (Ba *et al*., 2008; Egho, 2012; Abdourahamane *et al*., 2019). The chili pepper-based treatment (T4) showed efficacy similar to that of neem (T3), with an average reduction in infestations of 7.18%. This equivalence can be explained by the fact that the maximum insecticidal activity of neem is generally concentrated in seed extracts rather than in the leaves, allowing chili pepper to compete with neem leaf extract. Collectively, the neem and chili pepper extracts performed similarly to the synthetic chemical (T2), with an average reduction in infestation of 7.18% compared to 9.75% for the chemical treatment. These results are encouraging for the development of environmentally friendly alternatives to synthetic pesticides.

The beneficial effect of biopesticides on yield is also significant. Treatments T3 and T4 produced yields significantly higher than those of the negative control T1, confirming the devastating impact of pests in the absence of control, which can lead to losses of 60 to 100% (Ahmed *et al*., 2009). Remarkably, the biopesticides outperformed the chemical treatment (T2) in terms of pod and seed yield, with 1,870 kg/ha and 1,410 kg/ha, respectively, for neem, and 1,518 kg/ha and 1,119 kg/ha for chili pepper, compared to 964 kg/ha and 741 kg/ha for the chemical. These results corroborate those of Badii *et al*. (2009) in Ghana, who obtained a yield of 1,647 kg/ha following a neem-based treatment. Two main factors may explain this performance: (i) the early efficacy of biopesticides, which allowed the plants to pass through the stage of maximum vulnerability with minimal damage, thereby optimizing their yield potential (Emmanuel *et al*., 2020); (ii) the biostimulant effects of biopesticides, particularly neem, which stimulates soil microbial activity, improves nutrient uptake, and promotes better root development. Neem is also more selective, less toxic to beneficial insects, and contributes to better overall plant health (Emmanuel *et al*., 2019). Chili peppers, on the other hand, have a more aggressive effect on pests, but can cause burns and disrupt the plant's physiology-particularly photosynthesis-triggering a stress response. However, the absence of chronic phytotoxicity in natural extracts promotes the overall health of the crop, unlike certain chemical insecticides that can have growth-inhibiting effects, such as the gradual loss of flowers observed in plots treated with synthetic products (Egho, 2011). Thus, this study confirms the potential of neem- and chili-based biopesticides as effective and sustainable alternatives to synthetic chemical pesticides. They not only reduce infestations but also improve plant development and overall health, leading to a significant increase in cowpea yield.

CONCLUSION

This study confirms the effectiveness of neem- and chili-based biopesticides in reducing infestations of aphids (*A. craccivora*) and brown stink bugs (*C. tomentosicollis*) on cowpea crops. The results show that chemical pesticides remain the most effective treatment for direct pest control, but that they are not the most favorable for increasing yield. Biopesticides, particularly the treatment based on fresh neem leaves (T3), proved to be promising alternatives, combining notable agronomic efficacy with a significant improvement in pod and seed yields. These results suggest the potential for integrating biopesticides into production systems, particularly in organic farming and in low-input production contexts. The use of these natural, environmentally sound extracts thus appears to be a sustainable approach to managing cowpea insect pests. Promoting their use in real-world settings among low-income farmers is a relevant strategy for reducing dependence on chemical pesticides, improving crop health, and strengthening food security.

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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 declare 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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