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Effect of Neem Seed-Based Biopesticides and Hygienized Human Urine (HHU) on the Main Insect Pests of Cowpea [*Vigna unguiculata* (L.) Walp.] on Station and in Rural Environment of Niger

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Abstract

Cowpea, *Vigna unguiculata* (L.) Walp. is an economically important seed legume that helps combat food and nutrition insecurity in the Sahel, particularly Niger. However, its yield remains low due to insect pest attacks. This study was conducted at a station and in seven villages in the Maradi and Tahoua regions. It aimed to test the effectiveness of neem seed biopesticides [*Azadirachta indica* A. Juss] and sanitized human urine for integrated insect pest management. The cowpea variety UAM09 1055-6 was used for the experiments. The experimental trial was a Fisher block design consisting of five treatments: neem oil, neem seed extract (NSE), hygienized human urine (HHU), chemical pesticide, and a control, replicated five times at the station and twice in farmers' environments. The study shows that *Megalurothrips sjostedti* Trybom, *Clavigralla tomentosicollis* Stål and *Maruca vitrata* Fabricius are the main insect pests. Plots treated with synthetic pesticides were the least infested by *C. tomentosicollis*. They were followed by neem seed extract and HHU treatments, which recorded an infestation level of 2.44 and 20.5 times lower than controls at the station and in farming environments. The density of thrips was 1.06 to 32.6 times lower in treated plots compared to controls. The proportion of pods damaged by *M. vitrata* was 1.95, 2.55, and

2.77 times lower in plots treated with HHU, NSE, and synthetic pesticide, respectively, compared to controls. Grain yields were 1.80 and 2.62 times higher in UHH and NSE treatments compared to control plots, both at the station and in farmers' environments. A yield increase of 44.58% and 61.92% was noted for these treatments at the station and in farmers' environments, respectively. These results may promote the dissemination of NSE and HHU biopesticide technologies in rural areas as an alternative method for integrated pest management of cowpeas.

Keywords

Cowpeas, Hyginized Human Urine, Neem, Insect Pests, Niger

1. Introduction

Cowpea, *Vigna unguiculata* (L.) Walpers (Fabaceae), is one of the main food legumes grown globally and in the semi-arid zone of West Africa. In 2022, Africa's total production was 9,475,644 tons, with more than 90% produced by West Africa [1]. This legume plays an important role in poverty reduction and improving food security for the African population due to its nutritional value, its ability to improve soil, and its socio-economic importance [2]-[4].

In Niger, cowpea is the main food legume grown in the country. It plays an important role in dietary diversification by supplementing cereal-based diets with protein. The plant's leaves, green pods, and seeds are used to prepare various traditional dishes [5]. Cowpea production is estimated at 2,149,205 tons, ranking second among rainfed crops after millet [6]. It is grown throughout the southern agricultural strip, either as a pure crop or in association with other crops like millet and sorghum. The intercropping system is generally preferred by farmers [7]. A study conducted in the regions of Maradi and Zinder shows that 47.4% of producers associate cowpea with millet [8].

Despite its food, socioeconomic and agronomic importance, cowpea yield is very low, with the national yield estimated at 391 kg/ha [6]. This low yield is due to biotic and abiotic constraints in cowpea production [9]. Among the biotic constraints, insect pest attacks pose the greatest threat to cowpea cultivation, causing significant economic losses. All growth stages of cowpea are vulnerable to insect pests [10]. The main insect pests of cowpea are aphids (*Aphis craccivora* KOCH), flower bud thrips (*Megalurothrips sjostedti* TRYBOM), pod borers (*Maruca vitrata* FABRICIUS), pod sucking bugs (*Clavigralla tomentosicollis* STAL) and stock bruchids (*Callosobruchus maculatus* F.) [11]. According to [12], 80% to 100% of cowpea production losses are due to insect pest attacks. To improve cowpea production, measures are needed to address this issue. Currently, several methods for controlling these insect pests are being developed. The chemical method is most commonly used by 57.2% of producers in the regions of Maradi and Zinder [13]. This method has rapid effects on insects but poses a risk of environmental pollution. It is also not accessible to small, low-income producers due to its high cost. Therefore, exploring new alternatives for integrated and sustainable pest management to reduce the use of synthetic chemicals and associated risks is necessary.

Several studies have shown that plant extracts are an alternative producers can use. Among these, extracts of *Azadirachta indica* A. Juss, are the most studied and have demonstrated efficiency in combating various insect pests across different crops [14]-[16]. Additionally, studies in many African countries (Republic of Guinea, Côte d'Ivoire, Cameroon, Nigeria, Burkina Faso, Niger, etc.) have highlighted the use of human urine as a fertilizer for several crops, as it contains mostly nitrogen, phosphorus, and potassium [17]-[22]. There are few studies showing the effect of urine as a pesticide; they mostly report its use as an insect attractant, such as in controlling fruit flies [23]. In Sudan, it was used to make a trap for Tephritid fruit flies [24], while in Southeast Asia, it is mixed with spices to control pests [25]. In the Sahel and Niger, there is no report on the use of human urine as a pesticide. The Federation of Producers' Unions of Maradi-Niger (FUMA/GASKIYA) has promoted the use of human urine as fertilizer, and some producers have observed a reduction in crop pests on plants fertilized with sanitized human urine compared to unfertilized plants. This study is conducted to verify farmer perceptions and address the gap in evaluating HHU as a pesticide to reduce the density and damage of cowpea's main insect pests.

2. Materials and Methods

2.1. Presentation of the Study Sites

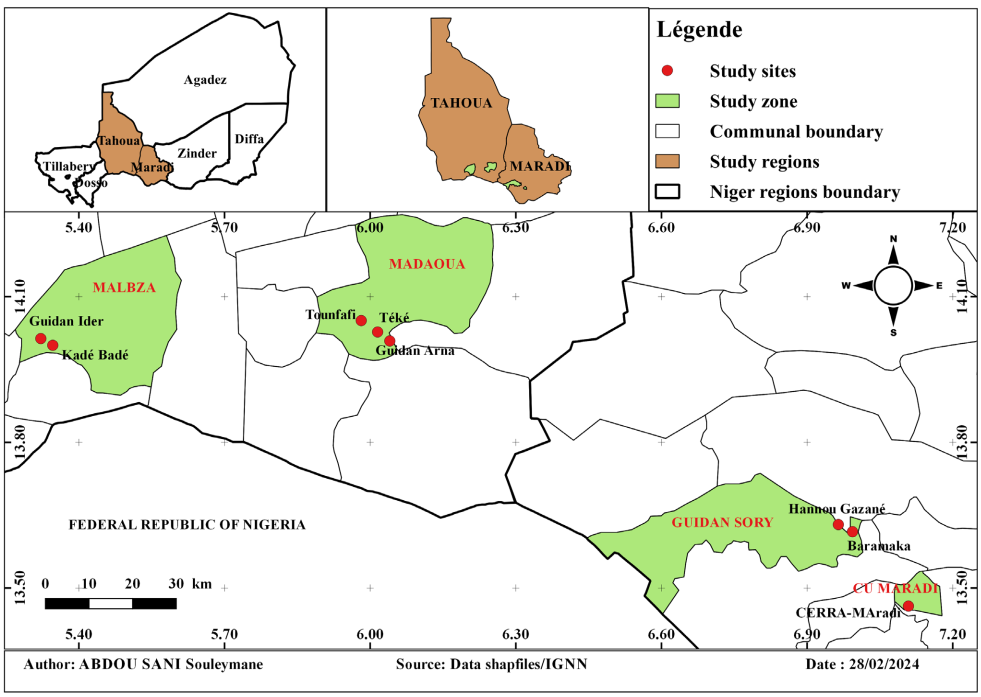

Figure 1. Study sites.

The study was conducted during the 2023 cropping season at the research station of the Institut National de la Recherche Agronomique du Niger (INRAN/Maradi) and in seven villages: two in the Maradi region (Baramaka and Hannou Gazané) and five in the Tahoua region (Guidan Arna, Teké, Tunfafi, Kadé Badé, and Guidan Idder). The villages were selected based on their proximity to private community units for the production and sale of neem-based biopesticides (**Figure 1**).

2.2. Plant Material

The UAM09 1055-6 Dan Hadjia variety was used in the experiments. Its cycle is 50 to 55 days, with a potential yield ranging from 1.5 to 1.9 tons per hectare.

2.3. Application of Biocides

Phytosanitary treatments began as soon as the buds and flowers emerged at both experimental sites. A total of three applications were conducted in the evening between 5 and 6 pm at each site, with a weekly interval between treatments (**Table 1**). In case of strong wind during the treatments, a temporary fence with a plastic sheet was used to prevent interference with other treatments.

Table 1. List of biocides used and applied doses per hectare.

Pesticides	Active ingredients	Dose per hectare	References or Address of the Manufacturer or Distributor/Company
Neem Seed extract	Azadirachtine	12.5 kg (neem almond powder) + 250 liters of water	(Jakai *et al*., 1992)
Neem seed oil	Azadirachtin, salannine, nimbidine, and melandriol	9.06 liters (Peanut Oil) + 1.66 liters (Neem Oil)	Bio phyto Glazoué, Benin, http://www.agrobiobase.com/fr/annuaire/bioproduits/agriculture-sylviculture-viticulture/top-bio
Sanitized humain urine (HHU)	$NH_3 + CO_2$	333.33 liters of HHU	(Inou, 2017)
Synthetic pesticide	Acetamiprid 10 g/l + Lambda Cyhalothrine 15 g/l	1 liter (pesticide) + 300 ml water	Savana: https://www.savana-france.com Distributed by: B.F_PROPHYMO: +22620983940

Neem seed extract: The neem tea bag used for treatment was purchased from private community units that produce and sell neem-based biopesticides in the localities where the trials were conducted. The appropriate amount of neem seed powder was mixed with water and left to macerate for 24 hours. Then, 400 ml of the solution was used to spray each plot of 15 m^2.

Hygienized human urine: The sanitized human urine used in this experiment was provided by private production and sales units located in the FUMA/GASKIA zones. These units were trained in urine collection and sanitization by the extension agent of the farmers' federation. The collected urine undergoes a sanitization process in 25-liter hermetically sealed containers exposed to the sun for one month. Afterwards, each elementary plot was sprayed with 0.5 liters for each treatment.

Neem oil: Produced by a private unit for the production and sale of biopesticides, the solution applied in field trials was prepared by mixing with peanut oil. Each plot was sprayed with 16 ml of the solution for each application.

Synthetic pesticide: The synthetic pesticide solution was prepared by mixing 1 liter of product in 300 liters of water. Each plot was sprayed with 451.5 ml of this solution per application.

2.4. Rainfall Data in the Study Zones

In 2023, the rain started early in May at two locations. The amount of rainfall was almost similar in August at all locations, while the sites in the Maradi region received much rainfall in September. The INRAN station received rainfall only in October and recorded the highest total amount of rain (Figure 2).

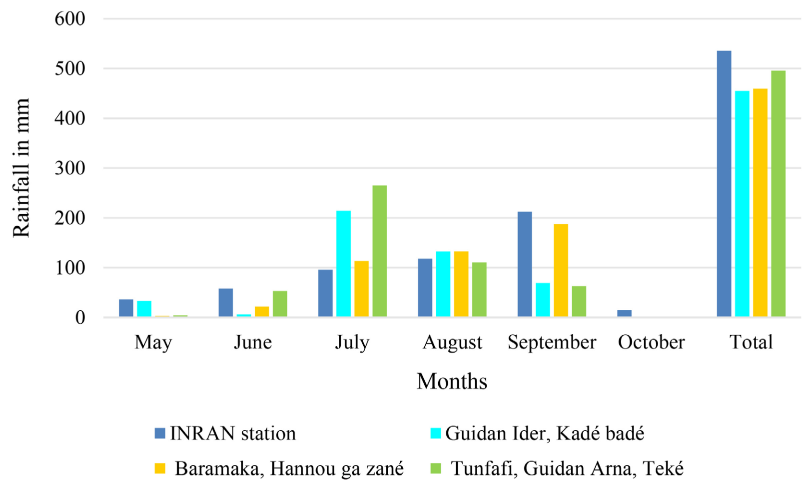

Figure 2. On station experimental trial.

2.5. Experimental Trial on Station

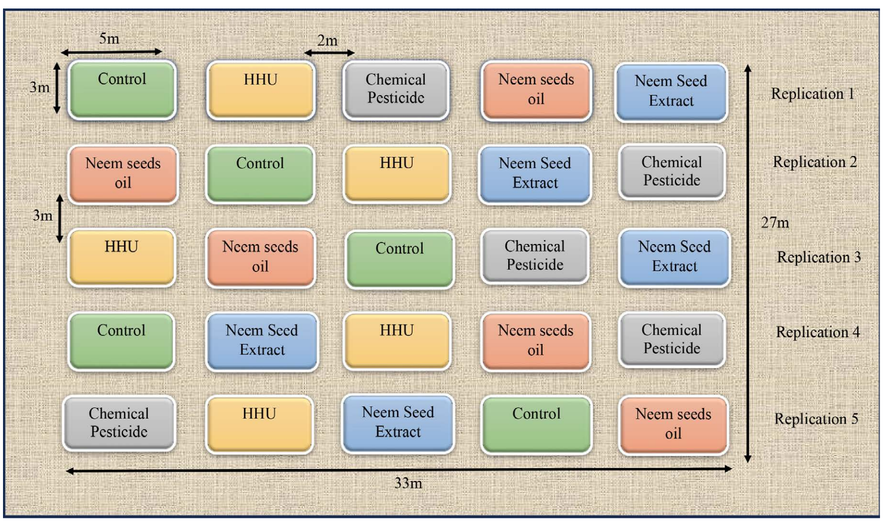

Figure 3. On station experimental trial.

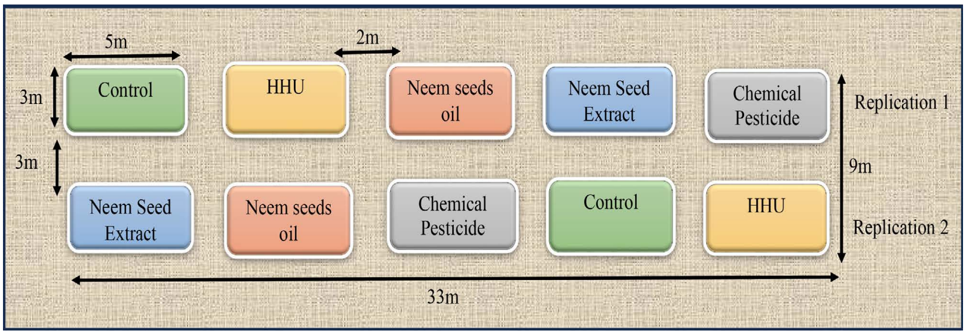

Figure 4. Experimental design in a farming environment.

The experimental trial at the station is a Fisher block comprising five treatments and five replications. The treatments include hygienized human urine (HHU), neem seed extract, neem oil, synthetic pesticide, and a control. Each plot size is 15 m^2, with 3 m spacing between blocks and 2 m between plots. Each plot contains 7 lines of 11 stands, with a sowing density of 0.5 × 0.5 m (**Figure 3**). In the farming environment, the experimental design is a Fisher block with five treatments and two replications. The treatments and plot dimensions are the same as those used at the station (**Figure 4**).

2.6. Cultural Practices

Preparation of the land: A superficial plowing with a tractor was carried out before the installation of the device. On-station sowing was conducted on August 5th, 2023, while it was done on July 20th in the farmers' environment. Sowing involved three seeds per stand, and a week later, re-seeding was done to replace missing plants. Depending on the stage of crop development and weed density, two weedings were performed. At maturity, the harvest was done in a staggered manner; the pods on the two yield lines of each plot were harvested separately, as well as the entire production of each plot. The pods were exposed to the sun for drying.

2.7. Data Collection

For data collection, in each plot of the seven rows, each external row was considered a border row, and the rows adjacent to them were intended for yield. The observation stands were randomly sampled from the remaining three central rows. In each plot, 11 stands were randomly sampled from these three central rows. These stands were distributed as follows: 5 for insect pest dynamics, 3 for flower insect pests, and 3 for damage to cowpea pods.

Sampling of cowpea stands for observation: In each elementary plot, a set of 11 stands was randomly sampled on the three center lines. These stands were distributed as follows: 5 stands for insect pest dynamics, 3 for flower insect pests, and 3 for collecting data on damage to cowpea pods.

The data collection concerned the following parameters: emergence rate; number of insect pests on cowpea stands; number of *M. sjostedti* and *M. vitrata* larvae in 15 flowers; total number of pods per pocket, number of pods attacked by *M.*

vitrata larvae; number of pods attacked by *C. tomentosicollis*; grain yield; weight of 100 seeds; number of healthy seeds; number of seeds attacked by *C. tomentosicollis*; number of seeds attacked by *M. vitrata*; number of seeds attacked by both *M. vitrata* and *C. tomentosicollis*.

2.8. Collecting Data on Cowpea Insect Pests in the Field

The data were collected every three days at the station and weekly in the farming environment.

Infestation of insect pests: The average rate of pods and seeds attacked by pests, including aphid colonies (*Aphis craccivora*), pod bugs (*C. tomentosicollis*), black bugs (*Anoplocnemis curvipes*), locusts (*Oedaleus senegalensis*, *Tettigonia viridissima*), mylabris (*Mylabris senegalensis*), and the number of Amsacta (*Amsacta moloneyi*) were counted and recorded in the field during each observation.

Flower insect pests: during each observation, 15 flowers were collected from the 3 stands of each plot to note the thrips (*M. sjostedti*) and the larvae of the pod borer (*M. vitrata*). These flowers were soaked in bottles containing a 70% ethanol solution. The preserved flowers were then transported to the laboratory and dissected to record the pests' species and densities.

Damage of *M. vitrata* and *C. tomentosicollis* larvae to pods: During each observation, the total number of pods, the number of pods attacked by *M. vitrata* larvae, and the number of pods damaged by *C. tomentosicollis* were counted.

Grain yield

At maturity, the yield was determined from the harvests of the two yield rows. Additionally, the harvested pods were dried and threshed to determine the weight of the seeds. The weighing was done with a Scout Pro electric scale. The yield was calculated by extrapolating the production obtained from the two rows per hectare.

Seed quality

To determine seed quality, three samples of 100 seeds each were counted from each plot. From these samples, the weight of 100 seeds, the number of healthy seeds, the number of seeds attacked by *C. tomentosicollis*, the seeds damaged by *M. vitrata*, and the seeds attacked by both *M. vitrata* and *C. tomentosicollis* were determined (Photo 1).

Photo 1. Healthy seeds (A) Seeds damaged by pod bugs (B) Seeds attacked by *M. vitrata* (C).

The average rate of pods and seeds attacked by pests, as well as the yield, were calculated using the following formulas:

$$\text{Pod damaged Rate (\%)} = (\text{Total number of damaged pods}) / (\text{total Number of analyzed pods}) \times 100 \quad (1)$$

$$\text{Yield (Kg/ha)} = \text{Wss x Tns} \quad (2)$$

Wss = Average weight of seeds harvested per cowpea stand on yield rows.

Tns = Total number of cowpea stands per hectare.

2.9. Data Analysis

The KoBo Collect app was used for data collection. Analysis of variance was performed on all variables. The SNK test at the 5% threshold was used to compare the means. Analyses were performed using the Statistical Package for Social Science (SPSS) version 26.

2.10. Data Analysis

The experimental procedure is outlined below (**Figure 5**).

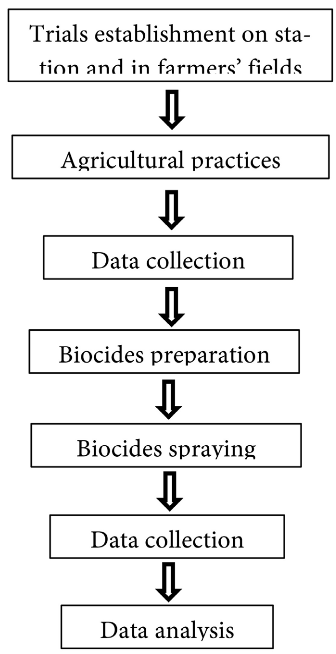

Figure 5. Experimental procedure.

3. Results

3.1. Insect Pest Infestation

Eight species of insect pests were identified during the experiment (**Figure 5**). Among these, *M. sjostedti* was the most significant pest at all sites, with proportions of 46%, 44%, and 39% at stations in the Maradi and Tahoua regions. The proportions of *C. tomentosicollis* were 33% and 19% at the station and sites in the Tahoua region, respectively. In the Maradi region, the second most prevalent pest was *Oedaleus senegalensis*, with a proportion of 30%. Infestations of *Amsacta* *moloneyi*, *Aphis craccivora* and *Mylabris senegalensis* were the lowest at all sites (Figure 6).

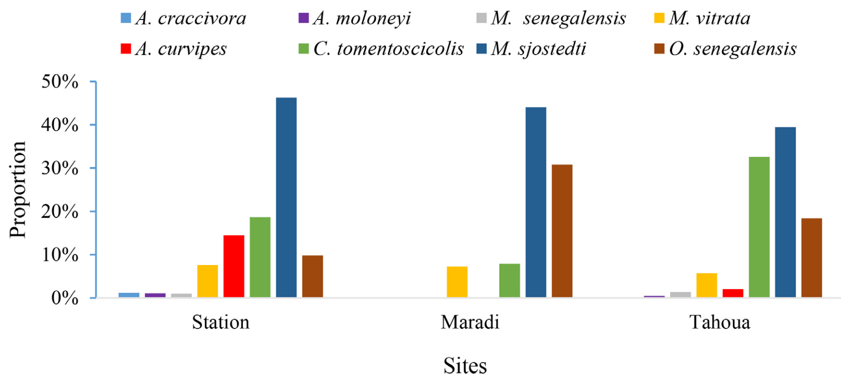

Figure 6. Proportions of the main insect pests identified at the study sites.

3.2. Density of Cowpea Insect Pest Per Treatment and Localities

There is a significant difference between treatments for cowpea infestation by pod bug (*C. tomentosicollis*), black stink bug (*A. curvipes*), aphid (*A. craccivora*), and locusts (*O. senegalensis*) at all sites per treatments (Table 2). Infestations of *M. senegalensis, A. moloneyi, A. craccivora*, and *A. curvipes* have not been observed in farmers' fields in the Maradi region (Table 2).

The infestation of *A. craccivora* was more significant in the station plots treated with neem oil. The infestation was 4 and 2 times lower in plots treated with neem seed extract and HHU, respectively, compared to control plots. In Tahoua, the infestation was 8.85 and 31 times lower in plots treated with neem seed extract and neem oil, respectively, compared to the control (Table 2).

For the infestation of *C. tomentosicollis*, the pest density was 3.16 times higher in the control plots than in the treated plots. The plots treated with synthetic pesticide were the least infested, followed by those treated with neem seed extract and UHH, with 4.75, 4, and 2.62 times less *C. tomentosicollis* respectively, compared to the control plots. In the Maradi region, the infestation was 18.5 to 37 times lower in treated plots compared to untreated plots. The pest density was 21.14 times lower with neem oil treatment compared to the control. In Tahoua, pest densities were 2.27 to 15.67 times lower in treated plots than in untreated ones. The plots treated with synthetic pesticide were the least infested, followed by those treated with neem seed extract (Table 2).

The infestation of *A. curvipes* was 2.07 to 5.27 times lower in the treated plots compared to the control plots. In the HHU treatment, the pest density was 3.05 times lower than in the control treatment. In the Tahoua region, infestation was more significant in the control plots and those treated with UHH. Plots treated with neem seed extract were 29.66 times less infested compared to the control plots (Table 2).

Concerning *O. senegalensis*, this pest was observed more frequently in control plots than in treated plots. The density was 1.75 and 1.5 times lower in plots treated with neem seed extract and HHU, respectively, compared to control plots. In Maradi, infestation by *O. senegalensis* was 4.5 and 4.75 times lower with HHU and neem seed extract, respectively, compared to control plots. In Tahoua, the pest population was higher in untreated plots than in treated plots. Plots treated with HHU and neem seed extract were 1.4 and 2.16 times less infested, respectively, compared to control plots (Table 2).

Table 2. Average number of cowpea insect pest species per treatment at the study sites.

Region	Treatments	Number of *M. senegalensis*/ stand	Number of *A. moloneyi*/ stand	Number of *A. craccivora*/ /stand	Number of *C. tomentoscicollis*/ stand	Number of *A. curvipes*/ stand	Number of *O. Senegalensis*/ stand
Station	Synthetic pesticide	0.01 ± 0.007	0.04 ± 0.025	0.01 ± 0.007 a	0.16 ± 0.034 a	0.11 ± 0.030 a	0.08 ± 0.015 a
	Neem seed extract	0.03 ± 0.009	00.0 ± 0.003	0.01 ± 0.07 a	0.19 ± 0.04 a	0.15 ± 0.038 ab	0.16 ± 0.024 b
	Neem oil	0.01 ± 0.007	0.02 ± 0.024	0.07 ± 0.02 b	0.34 ± 0.05 a	0.28 ± 0.042 b	0.2 ± 0.02 bc
	HHU	0.02 ± 0.009	0.00 ± 0.003	0.02 ± 0.01 a	0.29 ± 0.045 a	0.19 ± 0.03a b	0.18 ± 0.024 b
	Control	0.01 ± 0.006	0.05 ± 0.025	0.04 ± 0.013 ab	0.76 ± 0.109 b	0.58 ± 0.08 c	0.28 ± 0.041 c
	Anova	F = 0.775; P = 0.542	F = 1.096; P = 0.357	F = 4.780; P = 0.001	F = 15.831; P < 0.001	F = 15.903; P < 0.001	F = 6.339; P < 0.001
Maradi	Synthetic pesticide	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00 a	0.00 ± 0.00	0.07 ± 0.05 a
	Neem seed extract	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.03 a	0.00 ± 0.00	0.36 ± 0.11 a
	Neem oil	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.07 ± 0.05 a	0.00 ± 0.00	0.40 ± 0.11 a
	HHU	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.08 ± 0.05 a	0.00 ± 0.00	0.38 ± 0.11 a
	Control	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.48 ± 0.26 b	0.00 ± 0.00	1.71 ± 0.28 b
	Anova				F = 28.75; P < 0.001		F = 17.74; P < 0.001
Tahoua	Synthetic pesticide	0.00 ± 0.00	0.03 ± 0.02	0.08 ± 0.04 a	0.40 ± 0.14 a	0.17 ± 0.09 a	0.48 ± 0.09 a
	Neem seed extract	0.00 ± 0.00	0.01 ± 0.01	0.02 ± 0.02 a	1.26 ± 0.40 a	0.03 ± 0.02 a	0.84 ± 0.19 ab
	Neem oil	0.00 ± 0.00	0.01 ± 0.01	0.07 ± 0.05 a	1.37 ± 0.44 a	0.18 ± 0.08 a	0.82 ± 0.15 ab
	HHU	0.01 ± 0.01	0.06 ± 0.03	0.90 ± 0.31 b	2.76 ± 0.61 a	0.91 ± 0.28 b	1.30 ± 0.21 b
	Control	0.00 ± 0.00	0.06 ± 0.03	0.62 ± 0.25 ab	6.27 ± 01.65 b	0.89 ± 0.28 b	1.82 ± 0.20 c
	Anova	F = 1.00; P = 0.40	F = 0.97; P = 0.42	F = 4.73; P = 0.001	F = 7.74; P < 0.001	F = 5.12; P < 0.001	F = 8.72; P < 0.001

3.3. Infestation of Cowpea Flowers by *M. sjostedti* and *M. vitrata*

Flower infestations by *M. sjostedti* varied between treatments both on station and in farmers' fields in the two study regions. For *M. vitrata*, infestation varied between treatments only in a farming environment (Table 3).

The density of *M. sjostedti* infestation was 1.06 to 2.15 times lower in treated plots than in control plots. The lowest infestation was observed with the synthetic pesticide treatment, followed by the neem seed extract treatment. In plots treated with HHU and neem oil, infestation levels were comparable to those in control plots. In the Maradi region, pest density was 1.96 to 32.6 times lower in treated plots compared to untreated plots. Specifically, this density was 3.88 and 10.19 times lower in plots treated with neem oil and neem seed extract, respectively. In the Tahoua region, infestation was 1.7 to 6.98 times higher in untreated plots than in treated plots. Infestation was 1.74 times higher in untreated plots compared to those treated with neem seed extract (Table 3).

The *M. vitrata* infestation in Maradi was relatively low at all study sites, with fewer than 2 individuals seen in control plots. However, the pest density was 4 to 13.6 times lower in treated plots compared to untreated plots. For neem biopesticides, the insect density was 4.25 and 6.18 times lower with neem seed extract and neem oil treatments, respectively. In the Tahoua region, the density of *M. vitrata* was 2.26 and 4.9 times higher in plots treated with HHU and neem seed extract, respectively, compared to the control treatment (Table 3).

Table 3. Average densities of *M. sjostedti* and *M. vitrata* in 15 flowers per treatments.

Treatments	Station		Maradi		Tahoua	
	Number of thrips (*M.* sjostedti)	Number of *M. vitrata larvae*	Number of thrips (*M. sjostedti*)	Number of *M. vitrata larvae*	Number of thrips (*M. sjostedti*) plants	Number of *M. vitrata larvae*
Synthetic pesticide	3.47 ± 0.61 a	0.72 ± 0.15	0.05 ± 0.05 a	0.05 ± 0.05 a	0.57 ± 0.130 a	0.14 ± 0.058 a
Neem seed extract	4.70 ± 0.66ab	0.78 ± 0.21	0.16 ± 0.09 a	0.16 ± 0.09 a	2.29 ± 0.542 ab	0.22 ± 0.073 a
Neem oil	6.86 ± 0.87 b	0.90 ± 0.18	0.42 ± 0.18 a	0.11 ± 0.07 a	2.13 ± 0.515 ab	0.31 ± 0.095 a
HHU	7.02 ± 0.99 b	0.94 ± 0.20	0.83 ± 0.31ab	0.17 ± 0.09 a	2.33 ± 0.628 ab	0.41 ± 0.133 a
Control	7.45 ± 1.13 b	1.50 ± 0.26	1.63 ± 0.56 b	0.68 ± 0.29 b	3.98 ± 1 546b	1.08 ± 0.282 b
Anova	F = 3.729; P = 0.005	F = 2.319; P = 0.058	F = 4.53; P = 0.002	F = 2.92; P = 0.025	F = 2.20; P = 0.007	F = 6.18; P < 0.001

3.4. Density of Cowpea Pods Damaged by *M. vitrata* and *C. tomentosicollis*

In the Tahoua region, there is a significant difference between treatments for all parameters. However, on the station and in the Maradi region, the difference between treatments was only for the average number of pods damaged by *M. vitrata* and the total number of pods per stand (Table 4).

In the Maradi region, plots treated with synthetic pesticides yielded an average of 2.76 times more pods than control plots. Pod production with HHU treatment and neem seed extract was 1.63 and 1.70 times higher, respectively, compared to untreated plots. In the Tahoua region, the average number of pods per stand was 1.03 to 2.36 times higher in treated plots compared to untreated plots. Plots treated with synthetic pesticides yielded the highest number of pods, followed by neem oil and neem seed extract treatments (Table 4).

For damage caused by the pod borer (*M. vitrata*), the number of attacked pods was 1.95, 2.55, and 2.77 times lower in plots treated with HHU, neem seed extract, and synthetic chemical pesticide, respectively. In Tahoua, the proportion of damaged pods in treated plots ranged from 0.82% to 4.84%, while control plots recorded a damage rate of 7.40%. Plots treated with neem seed extract had a damage rate of 2.04%.

The *C. tomentosicollis* pods damage was significant only in the Tahoua region. The rate of pod attack by this pest in this region varied between 1.13% and 20.56% in the treated plots, compared to 26.94% in untreated plots. The plots treated with neem seed extract and HHU recorded damage rates of 4.95% and 20.56%, respectively (Table 4).

Table 4. Average number of pods produced per stand and pod proportion with *M. vitrata* and *C. tomentosicollis* damage.

Regions	Treatments	Total pods/cowpea stand	Pods damaged by *M. vitrata*	Pods damaged by *C. tomentosicollis*
Station	Synthetic pesticide	14.60 ± 1.59	0.13 ± 0.03 a	2.85 ± 0.27
	Neem seed extract	13.40 ± 1.70	0.11 ± 0.03 a	2.50 ± 0.25
	Neem oil	15.24 ± 1.06	0.30 ± 0.06 b	3.04 ± 0.26
	HHU	15.44 ± 1.20	0.18 ± 0.04 a	2.59 ± 0.22
	Control	11.88 ± 0.86	0.27 ± 0.09 b	3.24 ± 0.26
	Anova	F = 1.916; P = 0.106	F = 2.508; P = 0.041	F = 1.483; P = 0.205
Maradi	Synthetic pesticide	17.20 ± 1.18 a	0.06 ± 0.04	0.03 ± 0.028
	Neem seed extract	10.66 ± 1.18 ab	0.06 ± 0.06	0.06 ± 0.04
	Neem oil	10.56 ± 0.95 ab	0.08 ± 0.06	0.11 ± 0.07
	HHU	10.22 ± 0.63 ab	0.08 ± 0.08	0.11 ± 0.08
	Control	6.28 ± 0.54 b	0.06 ± 0.04	0.31 ± 0.20
	Anova	F = 3.509; P = 0.009	F = 0.111; P = 0.979	F = 1.164; P = 0.328
Tahoua	Synthetic pesticide	19.50 ± 1.31 a	0.16 ± 0.04 a	0.22 ± 0.05 a
	Neem seed extract	13.72 ± 1.04 ab	0.28 ± 0.06 a	0.68 ± 0.11 a
	Neem oil	14.04 ± 1.05 ab	0.30 ± 0.07 a	0.88 ± 0.13 a
	HHU	8.46 ± 0.71 b	0.41 ± 0.08 ab	1.74 ± 0.33 b
	Control	8.24 ± 0.68 b	0.61 ± 0.18 b	2.22 ± 0.43 b
	Anova	F = 5.16; P < 0.001	F = 4.78; P < 0.001	F = 10.24; P < 0.001

3.5. Grain Yield by Treatment and Site

The cowpea grain yield varied between treatments at all study sites (Figure 7). The yield of the on-station trial ranged from 451.55 ± 74.72 to 865.06 ± 89.27 kg/ha depending on the treatments. The highest yield was obtained with the synthetic pesticide, which was 1.92 times higher than that observed in control plots.

Neem oil, HHU, and neem seed extract treatments yielded 1.34, 1.35, and 1.58 times higher yields, respectively, compared to control treatments.

In the Maradi region, the yields of plots treated with neem and HHU were comparable. However, they were 3.04 to 4.22 times higher than the yields of untreated plots. The plots treated with synthetic pesticides yielded 5.45 times higher than control plots.

In the Tahoua region, the yield was 1.84 to 5.97 times higher in treated plots compared to control plots. The highest yield was obtained with the synthetic chemical pesticide treatment, followed by the neem seed extract treatment. The plots treated with neem oil and HHU had yields 1.84 and 1.85 times higher, respectively, compared to the control plots.

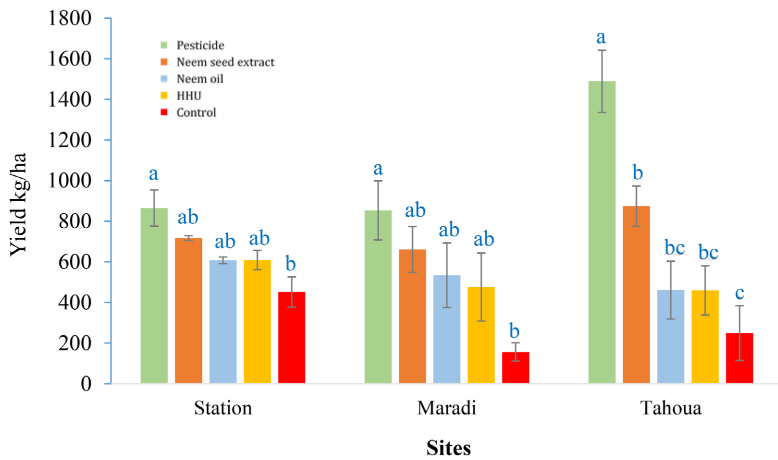

Figure 7. Cowpea yield per treatment at the study sites.

3.6. Damage of the Main Insect Pests on Cowpea Seeds

For the 100-seed weight, it was 1.07 to 1.11 times higher in the treated plots compared to the control plots at the station. The average number of healthy seeds was 1.14 to 1.24 times higher in the treated plots compared to the control plots. However, this parameter remained comparable between HHU and neem seed extract treatments. In the Maradi region, the 100-seed weight differed between all treatments. It was 1.06 to 1.08 times higher in neem seed extract and HHU treatments compared to the control treatment.

The proportion of seeds showing signs of *C. tomentosicollis* damage varied from 4.85% to 7.92% in the treated plots, compared to 15.53% in control plots. The plots treated with synthetic pesticides recorded the lowest proportion of seeds attacked by the pod bug (4.85%), followed by neem seed extract (6.45%), HHU (6.48%), and neem oil (7.92%). At Maradi sites, the proportion of seeds with *C. tomentosicollis* attacks ranged from 6.08% to 8.13% in treated plots, compared to 18.5% in control plots. For the HHU treatment, 6.52% of the seeds showed damage. In Tahoua, the proportion of seeds showing signs of pod bug attacks in treated plots varied from 8.37% to 15.66%, compared to 31.39% in control plots. Neem seed extract and HHU treatments recorded 1.93 and 2.13 times fewer seeds damaged by *C. tomentosicollis*, respectively, compared to the control plots.

The damage to seeds attacked by both *M. vitrata* and *C. tomentosicollis* was 1.25 to 4.01 times less in treated plots compared to control plots. Plots treated with neem seed extract and HHU had 1.99 and 2.73 times fewer damaged seeds, respectively, compared to untreated plots. In Maradi, the proportion of seeds attacked ranged from 0.1% to 0.21% in treated plots, compared to 0.93% in control plots. In plots treated with neem seed extract, neem oil, and HHU, the number of seeds attacked was 7.25, 3.41, and 7.25 times lower, respectively, compared to control plots.

Regarding the proportion of seeds attacked by *M. vitrata*, it remained comparable between the treatments at the station and in farmers' fields in the Maradi and Tahoua regions (**Table 5**).

Table 5. Average weight of seeds and number of seeds damaged by the main pests in the study sites.

Regions	Treatments	Weight of 100 seeds	Healthy seeds	Seeds attacked by *C. tomentosicollis*	Seeds attacked by *M. vitrata*	Seeds attacked by *C. tomentosicollis* and *M. vitrata*
Station	Synthetic pesticide	19.09 ± 0.15 a	82.47 ± 1.80 a	4.00 ± 0.45 a	2.80 ± 0.42	0.73 ± 0.18 a
	Neem seed extract	19.37 ± 0.19 a	80.53 ± 1.13 ab	5.20 ± 0.64 a	2.07 ± 0.21	1.47 ± 0.34 from
	Neem oil	19.14 ± 0.28 a	75.73 ± 2.08 b	6.00 ± 0.83 a	3.27 ± 0.64	2.33 ± 0.73 av. J.-C.
	HHU	18.87 ± 0.11 a	77.07 ± 1.66 ab	5.00 ± 0.47 a	2.40 ± 0.27	1.07 ± 0.28 from
	Control	17.65 ± 0.25 b	66.13 ± 1.67 c	10.27 ± 0.89 b	3.40 ± 0.35	2.93 ± 0.3 7 C
	Anova	F = 10.837; P < 0.001	F = 13.974; P < 0.001	F = 12.873; P < 0.001	F = 1.929; P = 0.115	F = 4.579; P = 0.002
Maradi	Synthetic pesticide	19.72 ± 0.37 a	77.83 ± 2.01 a	6.33 ± 0.67 a	1.33 ± 0.28	0.08 ± 0.28 a
	Neem seed extract	19.70 ± 0.25 a	80.83 ± 1.24 a	4.92 ± 0.62 a	1.00 ± 0.30	0.08 ± 0.08 a
	Neem oil	19.49 ± 0.21 a	78.75 ± 1.75 a	4.92 ± 0.56 a	1.58 ± 0.38	0.17 ± 0.11 a
	HHU	19.40 ± 0.25 a	74.92 ± 2.93 a	4.83 ± 0.84 a	1.42 ± 0.34	0.08 ± 0.08 a
	Control	18.22 ± 0.25 b	62.17 ± 4.59 b	11.5 ± 1.36 b	1.67 ± 0.40	0.58 ± 0.23 b
	Anova	F = 6.702; P < 0.001	F = 7.219; P < 0.001	F = 11.070; P < 0.001	F=0.576; P = 0.681	F = 3.105; P = 0.037
Tahoua	Synthetic pesticide	17.24 ± 0.35	68.21 ± 4.34	5.71 ± 0.67 a	2.13 ± 0.25	0.67 ± 0.21
	Neem seed extract	16.40 ± 0.49	53.25 ± 6.06	8.13 ± 1.08 a	2.04 ± 0.18	1.25 ± 0.35
	Neem oil	16.39 ± 0.61	59.29 ± 6.04	9.29 ± 1.79 a	1.79 ± 0.25	0.79 ± 0.31
	HHU	16.51 ± 0.44	54.58 ± 5.93	7.33 ± 0.99 a	2.08 ± 0.25	0.5 ± 0.15
	Control	15.37 ± 0.8	49.92 ± 5.2	15.67 ± 2.76 b	2.63 ± 0.21	1.17 ± 0.34
	Anova	F = 1.431; P = 0.228	F = 1.628; P = 0.172	F = 5.474; P < 0 001	F = 1.171; P = 0.152	F = 1.277; P = 0.283

4. Discussion

The results of the present study show that the cowpea crop is attacked by several insect species during its development, particularly during vegetative growth and reproductive stages. This finding is consistent with those of [26] in West Africa, [14] [27] in Niger, and [28] in Côte d'Ivoire, who reported that cowpeas are infested by many insect pests.

The insect pests identified in the study sites were mainly *C. tomentosicollis, M. sjostedti, A. curvipes and M. vitrata*, as reported by [14] in on-station trials, by [29] in farmers' environments in the Maradi and Zinder regions, and by [30] in the Diffa region.

The lowest infestation of *C. tomentosicollis, M. vitrata, and M. sjostedti* was recorded with synthetic chemical pesticide treatment, demonstrating the effectiveness of synthetic pesticides, as reported by [31]. This effectiveness could be explained by the effect of acetamiprid and lambda-cyhalothrin molecules, which likely affected the majority of insect pests.

Products based on neem and HHU have reduced the population density of *M. sjostedti* by 5.77% to 36.91% at stations, 40.07% to 42.46% in Maradi, and 41.45% to 90.18% in Tahoua. For the same biocides, a reduction in the density of *M. vitrata* in flowers was noted, ranging from 37.33% to 48% at stations, 75% to 83.38% in Maradi, and 62.03% to 79.62% in Tahoua. The density of *C. tomentosicollis* was reduced by 55.26% to 78.94% at stations, 94.59% to 97% in Maradi, and 55.98% to 79.90% in Tahoua. This confirms the results of [11] [32] [33], who reported that neem derivatives are broad-spectrum insecticides. They affect the metabolic processes of insects, including feeding and egg-laying, inhibit metamorphosis and growth, alter protein synthesis and sexual communication, and affect chitin synthesis. Neem also has a repellent effect on insects. These results are similar to those of [14], who reported a reduction rate of 16.56% to 87.74% for *M. sjostedti*, 30.08% to 82.69% for *M. vitrata*, and 36.84% to 92.29% for *C. tomentosicollis* following the application of neem seed extracts. However, they are not comparable to those of [34], who reported a 96% to 98% reduction in the density of *M. sjostedti*, 98% to 99% for *C. tomentosicollis,* and 93% to 96% for *M. vitrata* in a farmer's environment in Maradi. It is well known that damage and yields are linked to pest density [14] [15], and the efficiency of biopesticides depends on chemical composition and climatic conditions. The difference may be due to the frequency and high amount of rainfall received during the spraying period, as biopesticides are sensitive to rain and solar radiation.

Pod damage of 4.95% and 20.56% by *C. tomentosicollis* in plots treated with neem seed extract and HHU in the farmers' environment of Tahoua is lower than the 18.65% to 19.94% obtained with the same treatments on station, compared to 27.27% in control plots. This damage also did not reach the rate of 69.53% of pods attacked by the pod bug reported in control plots by [14] on station or the 85% damaged pods rate reported by [29] in untreated plots in farmers' environments.

The lower proportion of pods attacked by *C. tomentosicollis* in plots treated with chemical pesticides suggests its effective action on targets, reducing pest incidence on cowpea pods.

The higher yields recorded in plots with synthetic pesticides can be attributed to the pesticide's lethality to a wide range of pests and its knockdown effect, which reduces the number of insect pests and their impact on yields, as reported by several authors [4] [35].

The yield losses of 47.80%, 81.66%, and 83.27% were recorded in control treatments at the station, Maradi, and Tahoua, respectively. These results are comparable to the 71.1% and 91.0% production loss rates reported by [14]. Similarly, they are close to the yield loss rates of 60.16% and 63.50% for the varieties UAM09 1055-6 and IT90K-372-1-2 in the control plots reported by [34]. A higher yield loss of 93.45% was reported by [30] in farmers' fields in the Diffa region, demonstrating the sensitivity of cowpea cultivation to insect pest attacks.

The yield increase of neem seed extract and neem oil treatments, ranging from 25.68% to 36.99% and 45.92% to 76.30% respectively, in both station and farming environments, demonstrates the capacity of biopesticides to reduce pest infestation and increase cowpea yield.

This performance can be explained by the insecticidal effect of azadirachtin and other active ingredients in seeds and plant material. These results are similar to those reported by [15] [16] in Burkina Faso, who demonstrated that neem-based biopesticides, particularly neem oil and neem leaf-based aqueous extract, can reduce cowpea insect pest infestations and increase crop yields. Additionally, the insecticidal effect of neem-based biopesticides has been demonstrated in Niger by several authors [14] [29] [30] [35].

The yield variation between neem seed extract and neem oil ranges from 15.21% to 47.31%, depending on the site. This could be explained by the difference in azadirachtin content between neem seed extract and neem oil, as demonstrated by [36]. The reduction in azadirachtin is probably due to the neem oil extraction process. However, [16] showed that cold-extracted neem oil contains a higher quantity of active ingredients than hot-extracted neem oil.

On the other hand, the lower efficiency of neem biopesticide treatments compared to synthetic chemical pesticides can be explained by their different modes of action. Neem products are known for their repellent and anti-palatability properties, and pest mortality occurs slowly due to reduced feeding from blocked mouthpart activities [37] [38].

The yield from plots treated with HHU is often lower than those treated with neem-based biopesticides. However, this yield was 15.05%, 27.91%, and 47.5% lower in the station, Maradi, and Tahoua, respectively, compared to plots treated with neem seed extract. This difference in yield could be due to HHU's repellent effect against insect pests, which seems to last only a few hours after application. The plots treated with HHU showed a yield increase of 25.82% to 67.13%, depending on whether it was on the station or in a farmer's environment. These results corroborate those reported in Rwanda by [39], who noted a 37.5% yield increase in *Phaseolus vulgaris* after application with 10% diluted urine. Thus, regardless of the site, the yield from plots treated with HHU was higher than the national yield [40].

The quality of cowpea seeds is crucial for achieving good market value. Various treatments have resulted in seeds with fewer alterations from insect pest attacks compared to those from the control treatment. The level of seed damage is almost proportional to insect densities depending on the treatment. However, the proportion of seed damage is lower than 68% by *C. tomentosicollis* and 24% by *M. vitrata*, as reported in [29]. This variation could be explained by differences in insect pest infestation levels and climate conditions compared to previous studies.

The proportion of seeds attacked by *C. tomentosicollis*, ranging from 6.31% to 15.47% with neem-based biopesticides and HHU treatments, is also lower than the rates of 64% to 66% reported by [14].

Biopesticides derived from neem and hygienized human urine (HHU) can be promoted as alternatives to synthetic chemicals for managing cowpea insect pests. Despite the effectiveness of neem biopesticides [13], their adoption by farmers is low due to the tedious fabrication process and limited market availability in the country. To increase adoption, cottage industries should be established in production zones, and efficiency should be improved. The effect of HHU can be enhanced by mixing it with other neem-based biopesticides and organic soap.

5. Conclusions

This study compares the efficacy of neem seed biopesticides and hygienized human urine (HHU) for managing cowpea pests. The *C. tomentosicollis, M. sjostedti* (flower thrips), and *M. vitrata* (pod borer) were identified as the main field pests of cowpea.

The results showed that the synthetic chemical pesticide was the most effective treatment, despite its environmental risks. Its performance was the highest at all study sites. However, treatments based on neem and HHU also reduced infestations and pest damage, yielding an acceptable output. Neem seed extract and HHU, based on locally available resources, should be promoted as alternative methods against the main insect pests of cowpea. This study is one of the first to test HHU as an insecticide in the Sahel. Further studies are needed to understand how neem and HHU affect insects, and a chemical analysis of these biopesticides is necessary to determine the active ingredients affecting insects.

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Conflicts of Interest

The authors state that there are no competing interests in this article.

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