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Evaluation of the Efficacy of an *Aloe barbadensis* Based Biological Insecticide against Pests of *Abelmochus esculentus* for Promoting Ecological Agriculture (Far-North, Cameroon)

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Abstract

Chemical insecticides have been considered as a means to combat crop pests. Although their effectiveness is evident, their impact on the environment is increasingly being discussed. The aim of this study is to determine the agro-ecological potential of a biological insecticide ($C_{25}H_{32}O_{12}$) based on *Aloe barbadensis* in a Sahelian context. For this purpose, a completely randomized block experimental design with 3 replications and 4 treatments was set up to experiment with *Aloe barbadensis* as a bioinsecticide against pests of *Abelmoschus esculentus*. However, data were collected using an observation and parameter monitoring grid. This includes the cultivation of *Abelmoschus esculentus*, soil preparation, seeding and watering, plot labeling, preparation of the bioinsecticide (selection and preparation of raw materials, grinding of *Aloe barbadensis* miller and extraction of the crude bioinsecticide, quantification of treatment doses and dilution, and obtaining the formulated bioinsecticide), plant watering, plant treatment, and finally parameter monitoring. The results obtained reveal that the level of damage is significantly high in the control treatment T0 (63%) compared to the other treatments, with 29% for treatment T1, 7% for T2, and 1% for T3, implying a strong action capability of this insecticide against pests of *Abelmoschus esculentus*. Therefore, it can be concluded that for a normal growing season of *Abelmoschus esculentus*, this biological insecticide should be sprayed 12 times. Furthermore, this biological insecticide is unique in that it does not inflict any gastric toxicity on the pests, which gives it the characteristic of being a repellent. It is a biological insecticide whose efficacy period has been tested, with a minimum duration of 21 days. In conclusion, this formulated bioinsecticide based on *Aloe barbadensis* demonstrates significant efficacy against pests of *Abelmoschus esculentus*. In the future, we will consider experimenting with its effectiveness against pests of other plants.

Keywords

Aloe, Biological Insecticide, Pests, Agro-Ecological

1. Introduction

The demographic expansion and economic growth experienced by countries worldwide have driven farmers towards intensive production in order to meet the food needs of the population and eradicate famine prevailing in the regions [1] [2] [3]. However, peri-urban agriculture is of vital importance for food security in Sub-Saharan Africa due to its role in supplying cities with agricultural products and combating unemployment [4] [5] [6]. The use of synthetic pesticides has been the cause of numerous environmental and public health problems, especially since the inherent risks of some of them are poorly assessed [7]. However, the use of biological pesticides (bioinsecticides) varies from one region of the world to another [2] [4] [8] [9] [10]. In Cameroon, the use of biological pesticides is a technology to be promoted as an alternative control against major insect pests and parasitic diseases [5] [7]. Indeed, bioinsecticides contribute to preserving biodiversity and reducing the negative impact of agriculture on water quality [11]. Specifically in the Far North region, we observe health risks and significant destruction of land and biodiversity as a result of the excessive use of synthetic pesticides [12]. Indeed, these intoxications were accompanied by dermatological symptoms (itching, tingling, skin burns, rashes, wounds, complete destruction of the contaminated area), respiratory symptoms (tingling, burning, and itching of the respiratory tract, difficulty breathing, and coughing), ocular symptoms (conjunctival burns, visual disturbances, tingling, and burning in the eyes, loss of vision), gastrointestinal symptoms (abdominal pain, nausea, vomiting), headaches, and dizziness, to the point where some cases led to loss of consciousness in the affected individuals [13]-[17]. Given this situation, it is urgent to turn to organic agriculture with the use of natural inputs, which is why this study is of great importance.

2. Study Area

The study was conducted in the city of Maroua, specifically in the Meskine neighborhood. It is located between 14˚14' and 14˚15' East Longitude, and 10˚32' to 10˚35' North Latitude. **Figure 1** below adequately illustrates the situation.

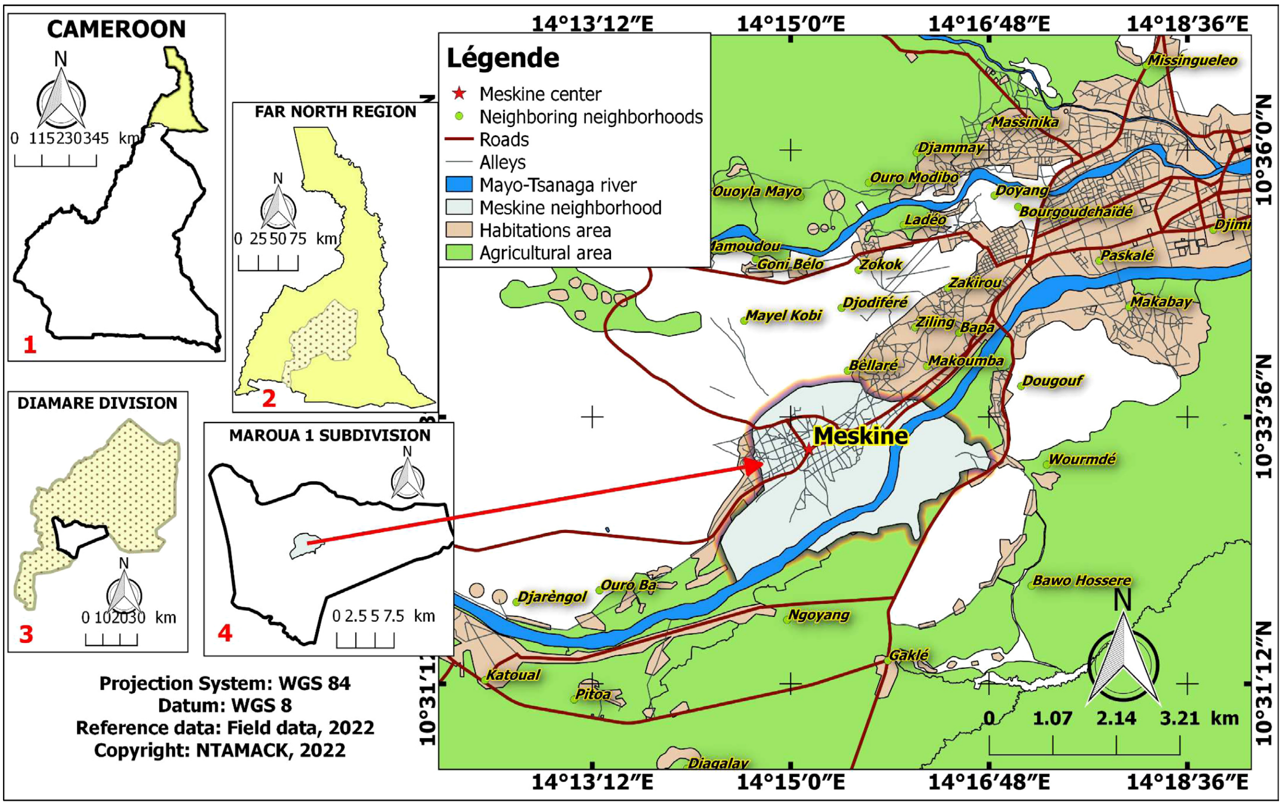

Figure 1. Location map of the study area.

3. Material

- ***Aloe barbadensis Miller***: Also known as Cape aloe, it is the main ingredient of the formulated biological insecticide. It was used in the production of our biological insecticide due to the effectiveness of its gel, the potential action of the active substance on pests, and its availability. Figure 2 below adequately illustrates the situation.
- **The formulated biological insecticide:** The biological insecticide used in this experiment was made from *Aloe barbadensis Miller*, which is a powerful variety of aloe vera due to its numerous virtues, resistance, and effectiveness against pest attacks. It has effectively protected plants from pest attacks, controlled, repelled, limited, and even killed the pest insects of *Abelmoschus esculentus*, thanks to its active ingredient, aloe-emodin gel contained in aloe vera [18]. Aloe-emodin is a bitter-tasting, yellow-brown substance found in the gel of at least 68 species of aloe, with concentrations ranging from 0.1% to 6.6% in dry leaves and 3% to 35% in fresh leaves. It is a stimulating irritant of the digestive tract, with properties such as anti-insecticidal, antifungal, antibacterial, hepatoprotective, antiviral, and anti-tumor effects [11].
- ***Abelmoschus esculentus***, commonly known as okra, is a tropical flowering plant species native to Africa and Asia, closely related to hibiscus. It was used in this experiment as an indicator of the effectiveness of the formulated biological insecticide;

Figure 2. *Aloe barbadensis* miller.

- **A KERN BMX1 digital scale**: used to measure the mass of the raw material (aloe vera) to be used;
- **A BLENDER brand food processor:** used to grind the aloe vera and extract the raw biological insecticide;
- **Three graduated burettes:** used to measure the different doses of the formulated biological insecticide in milliliters.
- **Hoe and machete:** used for ploughing and weeding;
- **GPS and QGIS software:** used to take the geographical coordinates, display and produce the map of the study area;
- **Tape measure:** to measure the dimension of the experimental plot;
- **A 16 L sprayer and an 11 L watering can:** used to spray the biological insecticide on the plants and water them;
- The software Excel and SPSS were used in this study for data processing and analysis.

4. Methods

4.1. Data Collection

- **Cultivation of *Abelmoschus esculentus***

An exploratory visit was conducted on February 29, 2022, in the field (in the Meskine neighborhood) to get a precise idea of the actual conditions before any sampling. This allowed for substantial knowledge about the soil type, previous crops such as maize, dimensions of the experimental plot, and the layout of different compartments. The cultivation of *Abelmoschus esculentus* began after selecting the experimental site and obtaining the plant material (seeds of *Abelmoschus esculentus*) from the market. On March 1, 2022, the dimensions of the experimental plot were measured using a 10-meter tape measure, resulting in a surface area of 56 square meters, with a length of 7 meters and a width of 8 meters. After this step, the site was secured using branches of *Acacia seyal* and mosquito nets. Figure 3 below adequately illustrates the situation.

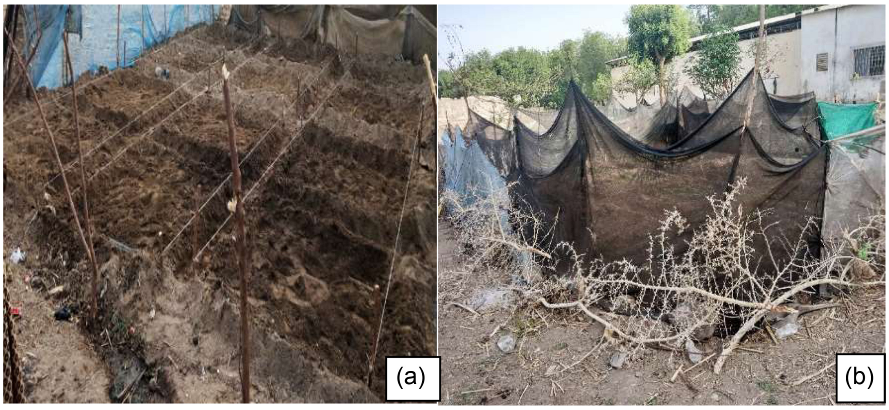

Figure 3. Sizing and arrangement of compartments in the experimental site.

- **Soil preparation, sowing, and watering.**

The fieldwork took place on March 3, 2022, at the experimental site in Meskine. It involved weeding and subdividing the plot into 12 equal-sized compartments, with each compartment measuring 1.5 meters in length and 1.7 meters in width. The alleys between the compartments were 38 cm wide and marked by a string and stakes. The compartments were amended with 100 kg of organic compost, allocated equally to the 12 compartments covering an area of 56 m^2, to fertilize the soil. The plot was weeded using a hoe, and watering was done abundantly every morning using a 15 L watering can to ensure that the microorganisms came into contact with the soil. One week after the soil preparation and protection of the experimental unit, the sowing was carried out by planting 3 seeds of *Abelmoschus esculentus* per hole, with a spacing of 40 cm between the rows and 20 cm between the holes [19].

4.2. Labeling of Lockers

One month after emergence, we created 12 plates to label the percentages of the different doses of the formulated biological insecticide to be applied to the plants [19]. For this purpose, the experimental design adopted for this experiment is a randomized complete block design, with 3 replications and 4 treatments per block (see **Figure 4**).

4.3. Production of the Biological Insecticide

The process of manufacturing the biological insecticide was carried out following seven steps presented below:

- **Step 1: Selection and preparation of the raw material**

This is a step that involves selecting from the existing varieties of Aloe vera the *Aloe Barbadensis Miller*, which is a well-known and widely used variety due to its effectiveness, gel quality, and availability. The seedlings of this variety were purchased from a gardener, planted in a shaded area, and watered until they reached maturity (4 months), and then used for the production of the biological insecticide.

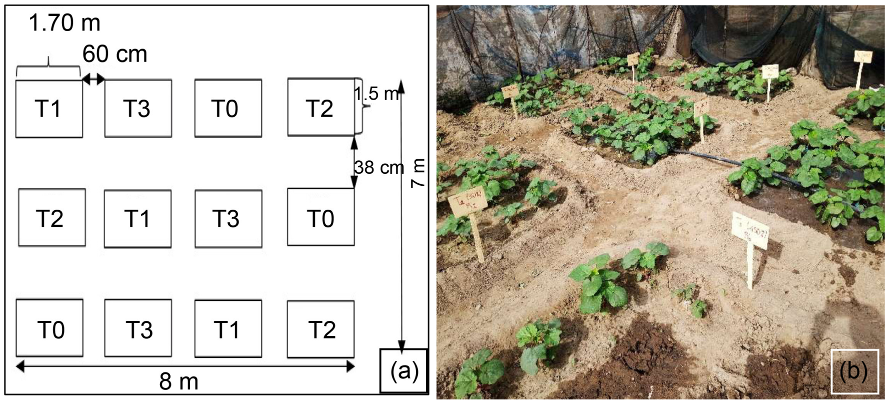

Figure 4. Experimental design of the growing media (a) Labeling of *Abelmoschus esculentus* compartments (b). With: T0: Control; T1: Treatment with 50 ml of *Aloe vera*; T2: Treatment with 100 ml of *Aloe vera*; T3: Treatment with 150 ml of *Aloe vera*.

- **Step 2: Laboratory analysis by grinding of *Aloe barbadensis miller* and extraction of raw biological insecticide**

When the *Aloe barbadensis Miller* plant reaches maturity, 3 leaves from this plant are cut for each treatment, weighed (400 g) on an electronic scale, and then cut into small pieces using a knife. These pieces are then ground for 5 minutes. After grinding, the resulting product is transferred into a container and filtered using a fabric with very small mesh size to extract the liquid. The board below adequately illustrates this step. **Figure 5** below adequately illustrates the situation.

- **Step 3: Quantification of treatment doses**

The laboratory of the Technical School of Agriculture in Maroua (ETAM) assisted us in quantifying the solution of the biological insecticide. Using graduated burettes of 100 ml, 200 ml, and 250 ml, the different treatment was measured at 50 ml of the active substance for the first treatment (T1), 100 ml for the second treatment (T2), and finally 150 ml for the third treatment (T3) (see **Figure 6**).

The concentration of these different treatment doses in (g/L), which will be diluted in 1 L of water, is obtained using the general formula:

$$c = \frac{m(\text{aloe vera solute})}{V(\text{solution})}$$

where:

C: represents the concentration of the raw ground Aloe vera in (g/L)

m: represents the mass of Aloe vera in (g)

V: represents the volume of a treatment (L)

Therefore, the concentration of treatment T1 (50 ml) is: 8 g/L, the concentration of treatment T2 (100 ml) is: 4 g/L, and the concentration of treatment T3 (150 ml) is: 2.6 g/L.

- **Step 4: Dilution and formulation of the biological insecticide**

After formulating the biological insecticide and quantifying the different

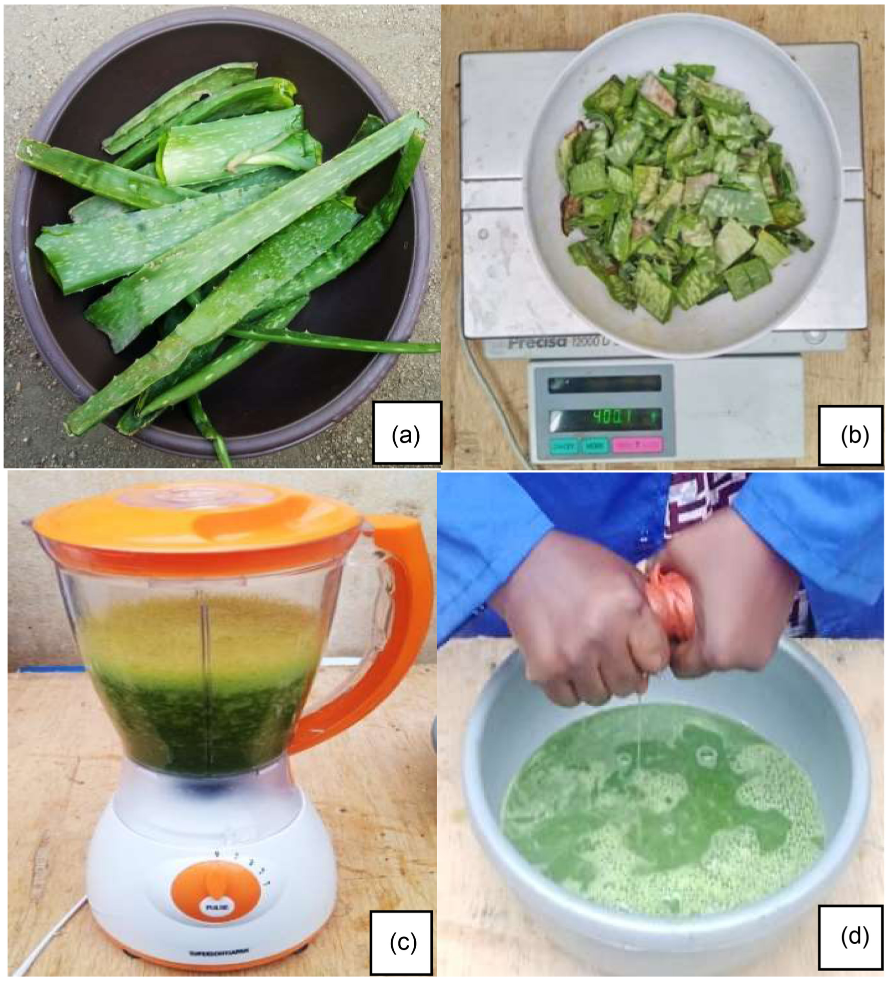

Figure 5. Grinding of *Aloe barbadensis* and extraction of raw biological insecticide.

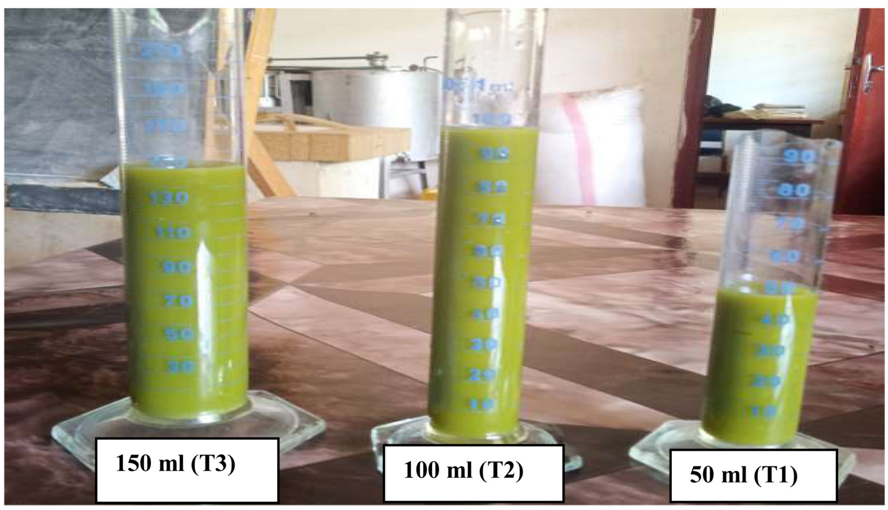

Figure 6. Quantification of treatment doses.

treatment doses in mL, each quantified solution of the biological insecticide is diluted in 1 L of water and applied to the plants using a 1.5 L bottle sprayer for plant treatment (see Figure 7).

- **Step 5: Parameter tracking**

4.4. Watering the Plants

The frequency of watering the okra plants after sowing was done at an interval of every 5 days with 50 L of water per tray until the appearance of the 4th leaf on the plant because at this stage, the plant needs water in average quantity followed by weeding after every 7 days. After the appearance of flowers, watering was abundant and regular every three (3) days.

4.5. Plant Treatment

After identification of the compartments by plates, the treatment of the plants was done every 3 days thanks to the experimental device in randomized complete block set up for this experiment (see Figure 8). The treatment of the plants was done every 3 days in the morning because just after the plants emerged, the attacks started directly and the pests were much more present on the leaves of each compartment and some on the other parts of the plant.

4.6. Tracking Settings

Parameters for monitoring the behavior of pests as well as the evolution of plant growth, after application of the manufactured bioinsecticide, are recorded using the observation and treatment monitoring grid. This step consisted in labeling six (6) plants per compartment on which we noted the parameters above every seven (7) days. Thus, these parameters are among others: the average length of the plant and that of the leaves, the total number of leaves and the number of attacked leaves, the number of fruits, the level of damage, the number of flower

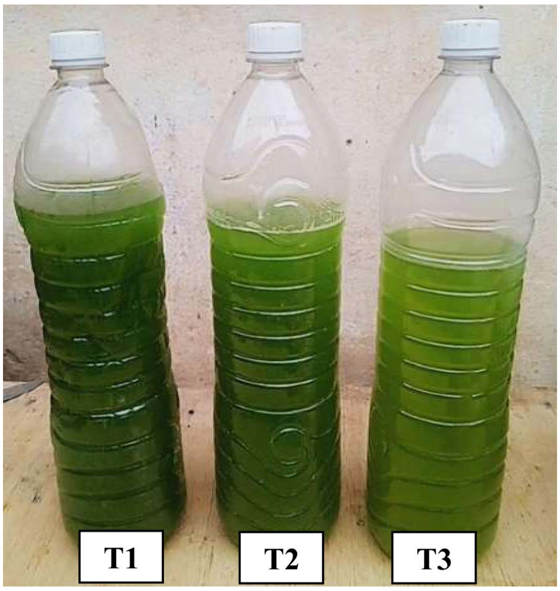

Figure 7. Bioinsecticide ready for use.

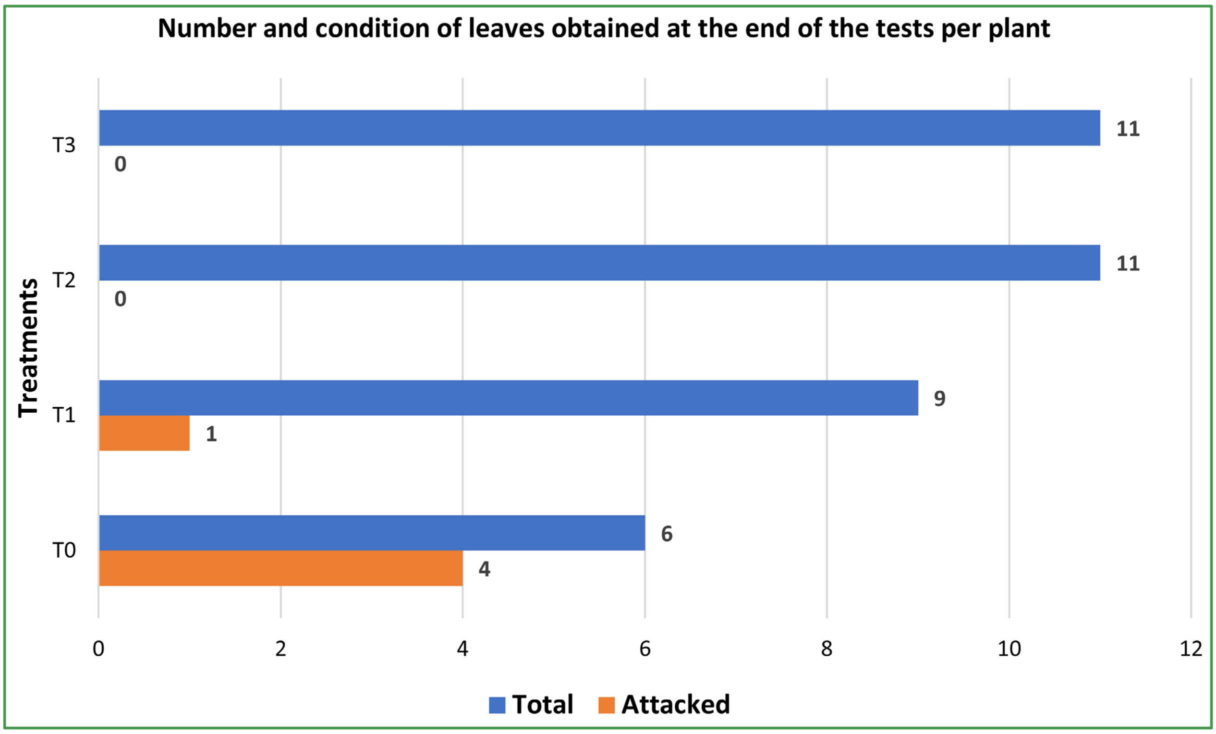

Figure 8. Evolution of the number of leaves based on treatments and weeks.

buds and at the end observation. The compilation of all this information will make it possible to understand the effectiveness of the bioinsecticide formulated with aloe vera.

5. Statistic Analysis

The quantitative and qualitative data from the observation and treatment monitoring grid were analyzed and sorted, then processed and analyzed with software such as: Microsoft Excel for data interpretation and diagram construction; SPSS for statistical tests of correlation, correspondence and hypothesis.

6. Results and Discussion

6.1. Presentation of the Obtained Biological Insecticide

The obtained product has properties relatively similar to those of AloeGuard, with a chemical formula of $C_{25}H_{32}O_{12}$. In this regard, 4 treatments (T0 (0 ml), T1 (50 ml), T2 (100 ml), and T3 (150 ml)) of the *Aloe barbadensis*-based biological insecticide were highlighted on the pests of *Abelmoschus esculentus*, resulting in a specific outcome according to the analysis of well-defined parameters. Furthermore, this biological insecticide is unique in that it does not inflict any gastric toxicity on the pests, which gives it the characteristic of being a repellent.

6.2. Effect of Biological Insecticide Treatments on the Leaves

Figure 8 below, presenting the number of leaves, illustrates that treatments T1

(50 ml), T2 (100 ml), and T3 (150 ml) are not significantly attacked compared to the control treatment T0 (0 ml). Furthermore, T3 and T2 are significantly different from treatments T0 and T1 in terms of the total number of leaves. While treatment T0 had 4 out of 6 leaves attacked, T1 had 1 out of 9, while T2 and T3 recorded 0 attacked leaves each. It is possible that treatments T2 and T3 did not record any attacked leaves due to certain parameters such as heat (unfavorable for the flourishing of pests in the environment) and constant watering, which evidently helped capitalize on the potential of the active ingredient in this function against pests. **Figure 8** below adequately illustrates the situation.

However, it is evident that in the months of March, April, and May, the heat is much stronger, and therefore watering is frequently done, which leads pests to migrate towards untreated okra plants, resulting in more damage in the T0 treatment. Therefore, it can be concluded that for a normal growing season of *Abelmoschus esculentus*, this biological insecticide should be sprayed 12 times. **Figure 9** below adequately illustrates the situation.

6.3. Effect of the Biological Insecticide on the Number of Flowers and Fruits

Through **Figure 10**, it can be observed that: only in week 4 did flowering occur in treatments T2 (7 flowers) and T3 (12 flowers). This justifies the absence of the biological insecticide in T0 and a low dose in the T1 treatment. However, in the 5th week, flowering continues in treatments T2 (17 flowers) and T3 (20 flowers), T0 (2 flowers), and T1 (6 flowers). **Figure 10** below adequately illustrates the situation.

In addition, **Figure 11** shows that in week 5, fruit formation occurs. On average, 1/3 fruit is observed at T1, 2/3 fruit at T2 and T3. The major observation is that, at T0 there are no flowers that have become fruit except around the 5th week, when we see 02 flowers. This result makes sense because the control treatment was not treated with the biological insecticide. Therefore, insect attack had a significant impact on the T0 control treatment.

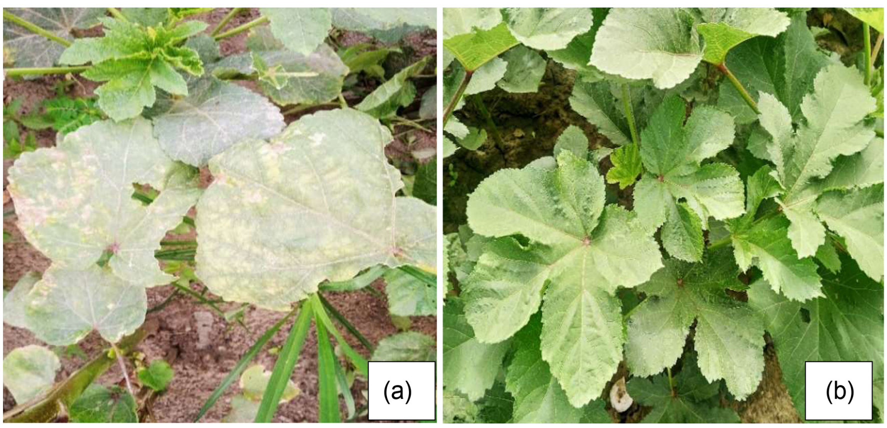

Figure 9. Untreated leaves (a) and leaves treated with the biological insecticide (b).

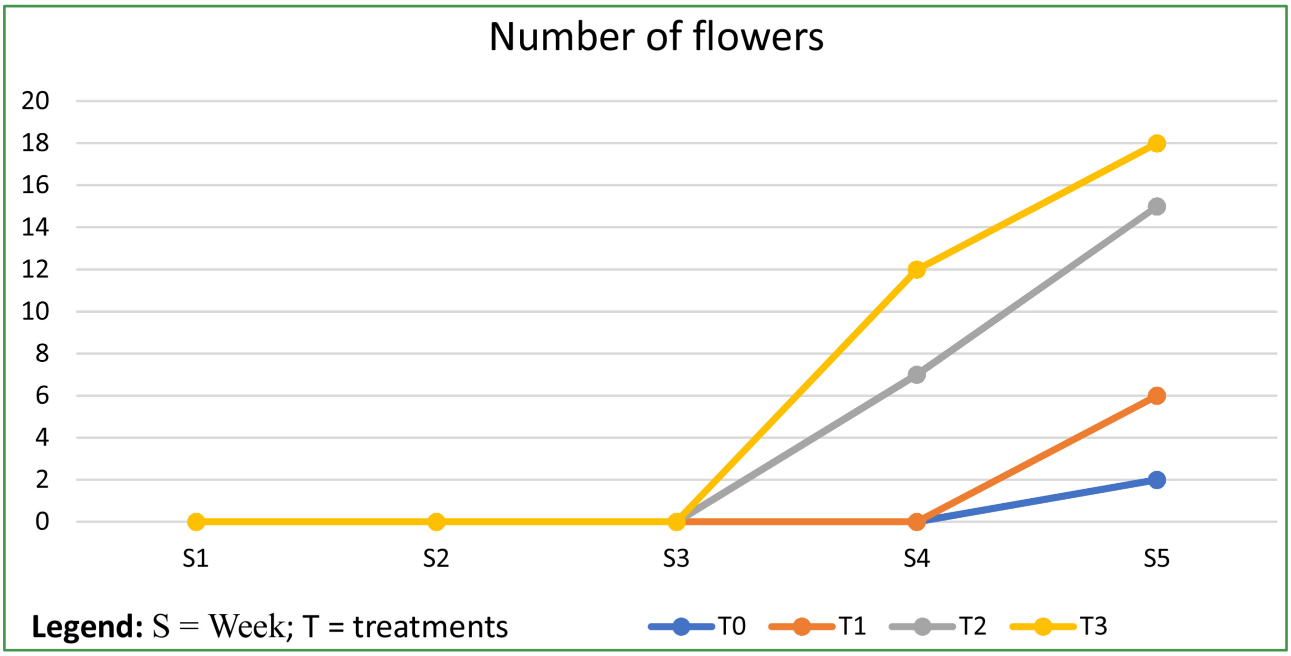

Figure 10. Representation of the evolution of the number of flowers based on weeks and applied treatments.

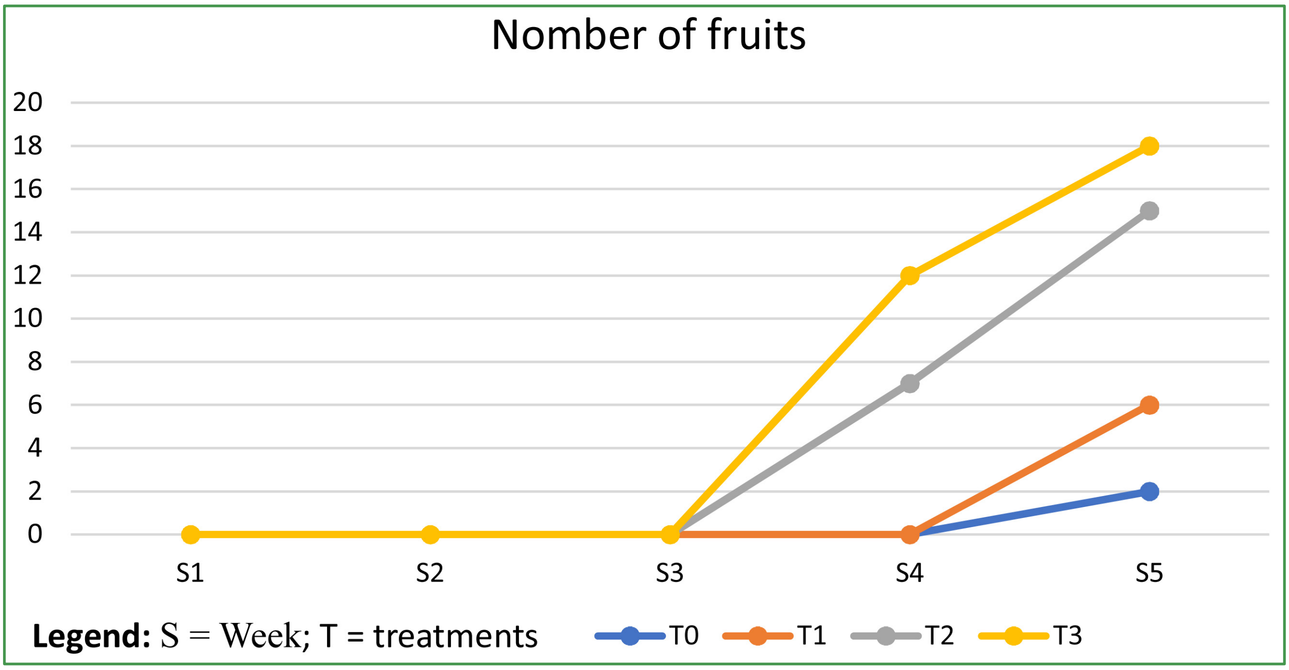

Figure 11. Representation of the evolution of the number of fruits according to the weeks and the treatments carried out.

We can also come up with the idea of formulating the biological insecticide at different doses; because it had a positive effect on insect pests, thus promoting a strong repulsion of them, at T2 and T3 treatments. Therefore, it appears that the more the treatment was applied, the more insects migrated to the untreated traps, which increased the damage in these T0 traps. However, in the T2 and T3 treatment boxes, the fruit obtained was of good quality (see **Figure 12**). It is a biological insecticide whose efficacy period has been tested, with a minimum duration of 21 days.

It is evident that the quality of the *Abelmochus esculentus* obtained is of very good appearance. This is clearly due to the effectiveness of the biological insecticide applied.

6.4. Effects of Biological Insecticide on Pest Damage Level

Figure 13 below shows the different levels of damage observed per treatment. It appears that the T0 treatment (which is the control) was the most vulnerable to pest damage (63% damage). However, the T1 treatment, having received a low dose of the experimental biological insecticide, was unable to cope with the attacks of the pests (29% damage). On the other hand, at the level of T2 treatments (07% damage) and T3 (1% damage), the level of damage is rather negligible following the significant action of the biological insecticide tested. The figure below adequately illustrates the situation.

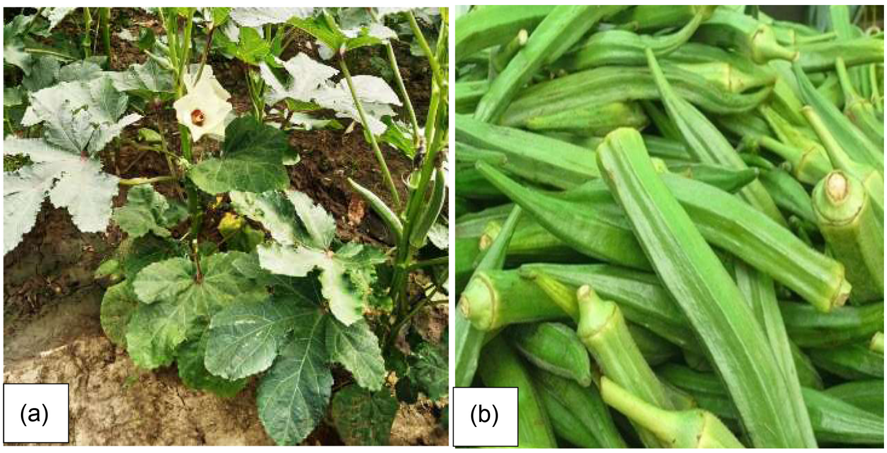

Figure 12. Good quality flowers (a) and fruit (b) in treated bins.

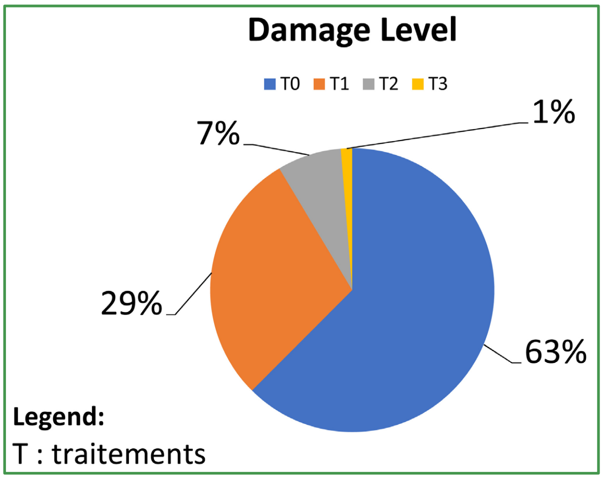

Figure 13. Evolution of the level of damage by week and according to treatments.

This result corroborates the work of [11], showing an acceptable significance rate of a biological insecticide. It is therefore advisable to maintain the T3 treatment at the dose of 150 ml, as being adequate for optimal treatment of okra culture.

7. Conclusion

At the end of this research work on the evaluation of the effectiveness of a biological insecticide based on Aloe Vera (*Aloe barbadensis Miller*) against okra pests (*Abelmochus esculentus*), the aim was to show that with a natural insecticide, pests can be effectively controlled. To this end, it appears that the phytosanitary product obtained and which was the subject of our study turns out to be an insect repellent (because it promotes the conservation of biodiversity by simply repelling pests without killing them). It is an insect repellent whose active ingredient is very effective at a dose of 150 ml concentration. Despite its relatively average content and slowness, this product is advisable for healthy and sustainable agriculture. In perspective, it is possible to set the expiry period or duration of this product. In the future, we will consider experimenting with its effectiveness against pests of other plants.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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