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Comparative Study of the Efficacy of Two Biological Insecticides (*Azadirachta indica* and *Bacillus thuringiensis*) and a Chemical insecticide (Diflubenzuron WP) against Fall Armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in Maize Crop, Western Burkina Faso

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aims: This study aimed at comparing the biological efficacy of Diflubenzuron WP, a chemical insecticide, and two biopesticides, one based on neem oil (*Azadirachta indica*) and an entomopathogen (*Bacillus thuringiensis*) against the fall armyworm on maize.

Place and Duration of Study: The work was carried out on the irrigated scheme of Bama, western Burkina Faso during the 2022 and 2023 wet seasons.

Methodology: The experimental design was a Fisher block with 4 treatments: T0: untreated or control; T1: *Bacillus thuringiensis*; T2: neem oil; T3: Diflubenzuron WP, in 4 replications. Entomological observations focused on the score and severity of attacks, as well as the pest's infestations rate.

Results: The results showed that the different insecticides tested over the two wet seasons of 2022 and 2023 induced better control of *S. frugiperda* populations, with larval density being kept lower with the treatment of Diflubenzuron WP (4.25±1.2%), neem oil (14.28±1.6%) and *Bacillus thuringiensis* (24.5±3.2%). The insect damage severity rates and scores of damaged ears were also low for the three treatments respectively (1.09±0.2, 0.9±0.26 and 0.27±0.71) over the two cropping seasons. Diflubenzuron WP insecticide treatment not only reduced pest pressure, but also significantly improved maize yield. No surprisingly the highest yield (5.14 t/ha) was recorded with Diflubenzuron WP, followed by neem oil (4.62kg/ha) and finally *Bacillus thuringiensis* (3.92kg/ha).

Conclusion: Further studies are needed to determine the optimal doses of neem oil and Bt for the control of Fall Armyworm. Neem oil can be considered as a good alternative to a chemical insecticide like Diflubenzuron WP.

Keywords: Spodoptera frugiperda; maize; neem oil; Bacillus thuringiensis; Diflubenzuron; Burkina Faso.

1. INTRODUCTION

Burkina Faso's agriculture is essentially cereal-based. It employs nearly 86% of the working population and contributes nearly 31% to the Gross Domestic Product [1]. Maize remains the most widely grown and consumed cereal, and the second most important agricultural sector in Burkina Faso after cotton [2]. The results of the 2022/2023 agricultural season show that maize is in first place, with a production of 1.853.510 tons, or 39.77% of national cereal production [1]. Although it is grown in significant quantities, maize productivity remains still low for small farmers. Indeed, some growers obtain yields of less than 0.5 t/ha, compared with a potential yield of 3 to 5 t/ha [3]. This relative performance in maize cultivation seems to mask the enormous difficulties experienced by growers. Indeed, the maize sector, like the rest of the agricultural sector, is characterized by low productivity due essentially to agro-climatic conditions, land tenure insecurity, and difficulties in accessing financing, inputs and agricultural equipment [1]. These difficulties are exacerbated by low yields resulting from the combined action of several factors: abiotic and biotic stresses linked not only to diseases, but above all to pests, as a result of climate change, agricultural trade and non-compliance with phytosanitary regulations in the West African sub-region. Insects are the most economically important pests of maize crop. Lepidopteran are those that cause the highest losses to maize crops. Among the insect pests associated with maize, the Fall armyworm (FAW) *Spodoptera frugiperda* emerges as a major threat [4]. It is a fearsome, highly polyphagous pest that attacks over 80 plant species. Apart from maize, its preferred host plant, its caterpillars cause major yield losses on rice, sorghum, millet, groundnuts and cotton [5]. In Burkina Faso, as in all African countries where the pest has appeared, control approaches are limited [6]. Originating in America, FAW was first reported on the African continent in 2016 [7]. Due to its rapid spread and distinctive ability to cause widespread damage to multiple crops, it poses a serious threat to the food and nutritional security and livelihoods of hundreds of millions of farming households in Africa [6]. On average, more than

100,000 ha of crops have been infested by FAW every year in Burkina Faso since 2016 [8]. Yield losses inflicted by *S. frugiperda* attacks have reached 32% in the USA [9] and varied between 45% and 60% in Nicaragua [10]. Recent work in Burkina Faso [11] has shown that *S. frugiperda* can inflict up to 23% yield losses on maize. In the case of severe attacks on young plants, losses are total [12].

Given the extent of the damage caused by this insect pest, a number of research projects have been carried out to develop appropriate control methods for containing the FAW populations. Ongoing research in Burkina Faso covers a number of areas, including growers' perceptions of the pest [13], varietal resistance [14], biological control, chemical control etc. Chemical control using synthetic insecticides remains the main means of controlling the pest worldwide [15], with the risk of *S. frugiperda* developing resistance to the chemical molecules used. For this reason, research is now focusing on biopesticides, which are more respectful of human and animal health and the environment. These insecticides can be manufactured by growers themselves, thus reducing their production costs. This study aims at exploring an alternative to synthetic chemical control for *S. frugiperda*.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Presentation of the study site

The study was conducted at the Bama irrigated scheme, western Burkina Faso during two consecutive cropping seasons, 2022 and 2023. Bama town is located in the Mouhoun basin, an integral part of the Sudanian-Sudanese domain, about 30 km northwest of Bobo-Dioulasso city on the Bobo-Dioulasso-Faramana axis, on the border with Mali (Fig. 1). The town is located between latitude 10°20'N and longitude 4°20'W, at an altitude of 300 m above sea level. The climate is Sudano-Guinean, with two seasons: a dry season from November to April and a rainy season from May to October. Maximum and minimum temperatures are 37° and 20° respectively. Relative humidity is 20 to 40% in the dry season and 70 to 80% in the rainy season. Air humidity is highest during the rainy season, with a peak in August. Average rainfall is 1070.24 mm. Soils are tropical ferruginous, hydromorphic or acidic and characterized by a silty texture (36.7%). They are sandy loam to silty clay soils marked by active leaching of nutrients, sometimes causing fertility problems. They are subject to toxicity problems [16]. The vegetation is made up of wide forest galleries, within which numerous Guinean species flourish, of the shrub and tree savannah type [17].

2.1.2 Biological material

The maize variety named Espoir was used for the field study. It is a 97-day intermediate-cycle variety, yellow to orange-yellow in color, rich in lysine and tryptophan with a potential yield of 6.5 tons per hectare, adapted to areas with rainfall above 900 mm and to irrigated schemes [18].

The various larval stages of *S. frugiperda* were made up of animal material that was monitored in the field.

2.1.3 Insecticides

Insecticides included Diflubenzuron WP, a product belonging to the benzoylurea chemical family, *Bacillus thuringiensis* (Bt) and neem oil. Diflubenzuron WP is essentially an ingestion larvicide with ovicidal action on contact. It disrupts chitin deposition in the cuticle, causing severe damage to endocuticular tissue. Larvae that are not killed or paralyzed immediately die during the next moult, as the cuticle cannot withstand the muscular tension and turgidity of the moult. Because of its particular mode of action, it has little or no effect on adult insects and auxiliary fauna. Persistence of action is of the order of 3 to 4 weeks. Neem acts on insects like a juvenile hormone: azadirachtin, the main active ingredient, is ingested by the larva, preventing molting. The insect remains in the larval stage and dies. It's an anti-appetent.

2.1.4 Mineral fertilizers

The following operations were carried out:

- Two hand weeding were carried out on the 14th and 40th days after sowing;
- Application of a single dose of NPK at a rate of 200 kg per hectare on the 14th day after sowing;
- Application of the first fraction of urea on the 30th day after sowing at a dose of 100 kg per hectare;
- Application of the second fraction of urea on the 45th day after sowing, at a rate of

50 kg per hectare. The application of this second urea fraction was followed by a ridging on the same day.

2.1.5. Field and laboratory equipment

- An electronic scale to accurately determine the quantities of seed and fertilizer to be used in the experiment;
- Polyester string to delimit plots and mark out plants;
- A 5-ml and a 10-ml syringe to accurately measure the quantities of insecticides to be applied;
- A 15 l pressure-maintained sprayer to apply insecticides in the experimental plots;
- A CANON Ixus digital camera for various shots in the field, laboratory and greenhouse;
- GPS (Global Positioning System) for plot location.

2.2 Methodology

2.2.1 Setting up the experiment

The experimental plot was ploughed to a depth of 20-25 cm. The maize was sown as soon as the rains began, after delimiting and labelling the various elementary plots. Each elementary plot (EP) consisted of 8 lines of maize, including 2 border lines. The length of each line was 4 m. Spacing was 0.40 m between bunches on the row and 0.80 m between rows. Each line consisted of 10 bunches, i.e. 80 bunches per PE. Fourteen days after sowing, the number of plants per pot was maintained at 2 after removing the extra plants. The seed rate used was 20 kg/ha.

2.2.2 Experimental design

The experimental design used was a Fisher block with 4 treatments, 04 replicates, i.e. a total of 20 elementary plots (EP). The EP was 6 m long and 4 m wide. A distance of 2 m separated the replicates and elementary plots. The area of an EP was 6 m x 4 m = 24 m² and the total area of the experiment: [(6m x 5) + (2m x 4)] x [(4m x 4) + (2m x 3)] = 836 m2. The treatments including the following: an untreated control (T0), Diflubenzuron WP (T3) applied at a dose of 1l/ha; *Bacillus thuringiensis* (Bt) (T1) applied at 1.5kg/ha and neem oil (T2), *Azadirachta indica* (1l/ha) were applied in 3 different doses. Applications were made with a pressure-maintained backpack sprayer. Three insecticide applications were made at 14-day intervals, the first treatment being carried out as soon as the first *S. frugiperda* larvae appeared.

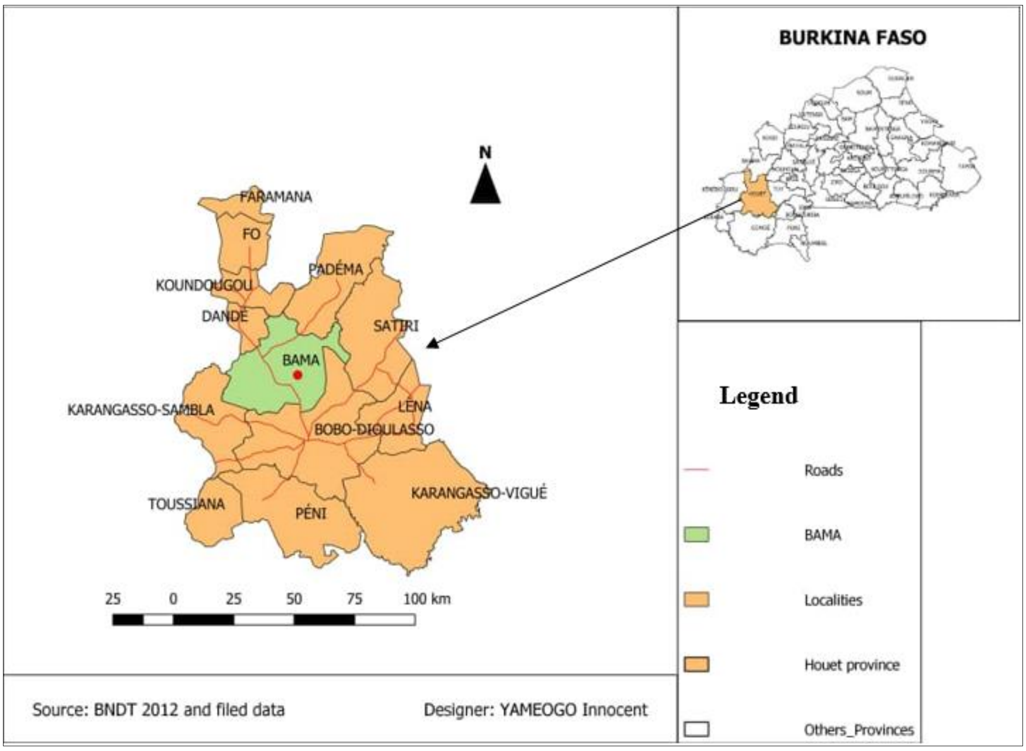

Fig. 1. Map of the study area

2.2.3 Data collection

Data were collected to assess the following parameters: number of plants attacked, number of larvae observed, and number of larvae dead or alive after each foliar treatment, number of healthy or attacked ears, and yield.

2.2.3.1 Infestation rate

The assessment of the rate of maize plants infested by *S. frugiperda* larvae involved weekly monitoring of the field and counting the number of infested plants in each EP. The infestation rate in each EP was calculated according to the following formula:

Infestation rate = (Number of infested plants x 100) / (Total number of plants per EP).

2.2.3.2 Presence of larvae

The number of live or dead larvae in the four central rows of each EP and each treatment was counted from day 7 to day 28 (before the 1st foliar treatment), day 35 (5 days after the 1st foliar treatment), day 42 (before the second foliar treatment), and day 49.

Live larvae rate= (Number of live larvae X 100) / (Total number of larvae in the EP).

2.2.3.3 Severity of attack

The severity of armyworm attacks was assessed using the Davis and Williams [19] scale. The damage caused by *S. frugiperda* larvae to maize leaves, stems and whorls was first noted, then the level of damage was plotted on the scale followed by a score which was assigned to each plant observed. There is a specific scale for leaf observations and another for kernel observations, and the scores on each scale range from 1 to 9.

2.2.3.4 Yield

Cobs were harvested from plants in the four central rows of each EP. These were then dried and dehulled, before the dry weight of the kernels was determined. The formula used to calculate yield was as follows:

Yield (per EP) = ((Grain dry weight (t) × 10000 (m^2))) / ((Useful plot area (m^2).

2.3 Data Analysis

The data collected were entered and processed using Excel 2020. Data were subjected to the Shapiro and Fligner tests using R software to check normality and homogeneity of variances. For data not meeting these criteria, the non-parametric Kruskal-Wallis test was performed. The pairwise-test was used to separate the different means at the 5% probability threshold.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Average rates of infestation of maize plants by *Spodoptera frugiperda*

The average rate of infestation of maize plants by *S. frugiperda* varied between treatments over the two consecutive wet seasons. Analysis of variance revealed a highly significant difference (*P < 0.001)* between treatments in both growing seasons. The 2023 wet season recorded on average a higher level of damage compared to the 2022 wet season. In the 2022 wet season, the highest average infestation rate was recorded with T0 (48±1.1%), followed by T1 with 30.44±0.09%, T2 with 18.2±0.5% and the lowest with T3 (12.5±0.7%). The same trend was observed in 2023 (Fig. 2).

3.1.2 Evolution of the average rate of infestation of maize by *Spodoptera frugiperda*

Fig. 3 illustrates the evolution of the average rate of infestation of maize by *S. frugiperda*. In the 2022 wet season, analysis of variance revealed a highly significant difference (*P <0.001*) between treatments at the 5% probability threshold at 42 days after sowing (DAS) in 2023 and 56 DAS in 2022. In 2022, the highest average larvae count was recorded in treatment T0 at 56 DAS (44.25±0.91), followed by T1 (30.5 ±0.67), T2 (25 ±0.91) and finally T3 (19.5), which recorded the lowest average larvae count. Furthermore, a highly significant difference (*P=0.01; P= 0.004* and *P= 0.01*) was observed between treatments at the 42nd, 70th and 84th DAS. On the other hand, no significant difference was observed between treatments at the 14th and 28th DAS. In the 2023 wet season, a highly significant difference (P <0.001) was observed between treatments at 42nd DAS. The highest average larvae rate was observed in treatments T0 (56.14±0.54), followed by T1 (39.86±0.38), T2 (30±0.38) and T3 (22.75). There was no significant difference between treatments at 14 and 28 days of age. However, a highly significant difference (*P=0.002*) was recorded at 42nd and 70th (*P= 0.008*) days. A significant difference (P=0.02) was observed at 84th DAS.

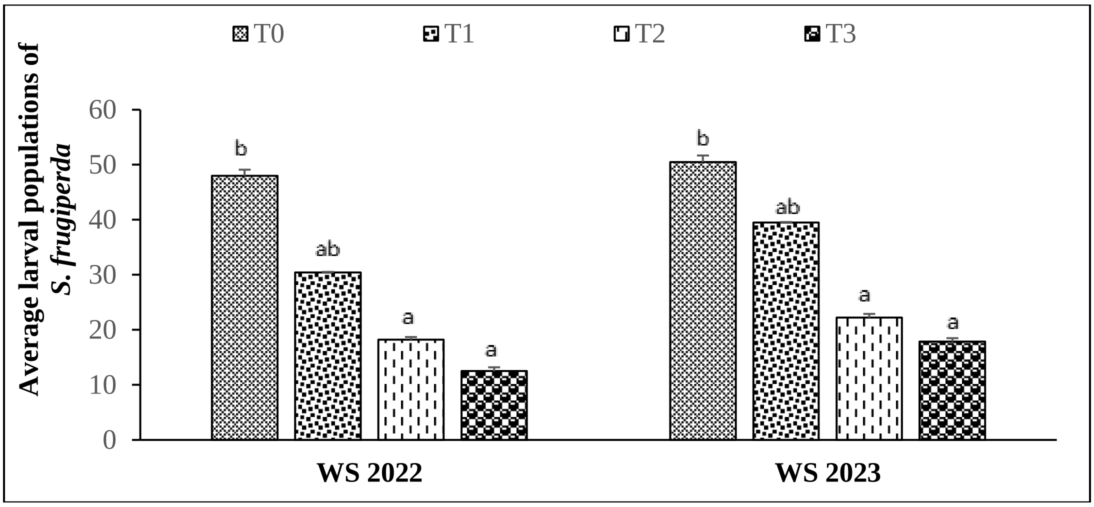

Fig. 2. Average *Spodoptera frugiperda* infestations rates

T0: Untreated control; T1: Bacillus thuringiensis; T2: Azadirachta indica; T3: Diflubenzuron WP ; WS : wet season.Values followed by the same letter (s) are not significantly different from each other at the 5% threshold

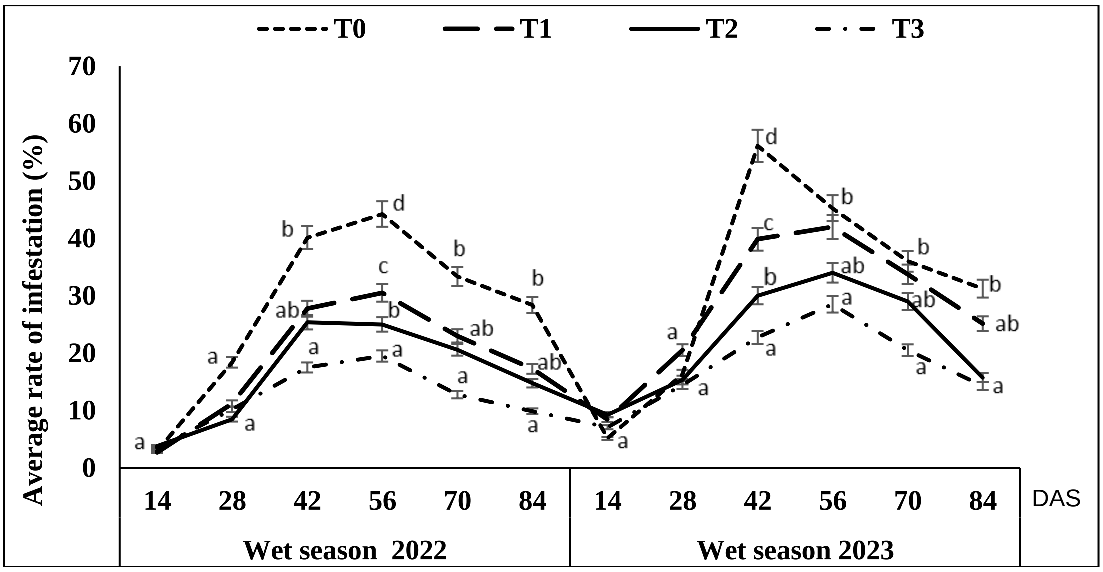

Fig. 3. Evolution of average *Spodoptera frugiperda* larval populations rates

T0: Untreated control; T1: Bacillus thuringiensis; T2: Azadirachta indica; T3: Diflubenzuron WP. Values followed by the same letter (s) are not significantly different at the 5% probability level

3.1.3 Severity of *Spodoptera frugiperda* attacks on maize plants

The severity of *S. frugiperda* attacks on maize plants was recorded using the Williams and Davis (1992) scale. Analysis of variance of mean maize plant foliar scores due to *S. frugiperda* damage revealed a significant difference between treatments (*P < 0.001*). The highest mean *S. frugiperda* attack scores were recorded in the T0 treatment, i.e. 1.99 ±0.70 and 2.01±0.9 for the 2022 and 2023 wet seasons respectively. Mean scores of 1.09±0.2 and 0.9±0.26 respectively were recorded with T1 and T2 in the 2022 wet season. In the 2023 wet season, these mean scores were 1.26±0.42 and 1.23±0.5 respectively for the two treatments. The lowest mean scores were observed with treatment T3, i.e. 0.27±0.71 for the 2022 wet season and 09±0.19 for the 2023 wet season (Fig. 4).

3.1.4 Average larval presence rates of *Spodoptera frugiperda* on maize plants

The analysis of variance did not reveal any significant difference between the two consecutive wet seasons 2022 and 2023 with regard to the average rates of larval presence of *S. frugiperda*. In the 2022 wet season, T0 recorded a mean larval presence rate of 28.45±5.4%. This average rate was not significantly different from T1 (24.5±3.2%), but was different from T2 (14.28±1.6%) and T3 (4.25±1.2%). The highest average larval presence rate (35.82±7.2%) was observed with the T0 control during the 2023 wet season. This rate differed significantly from that of T1 (23.88±2.9%). Treatment T3 (Diflubenzuron WP) recorded the lowest average larval presence rate (12.4±1.8%) (Fig. 5).

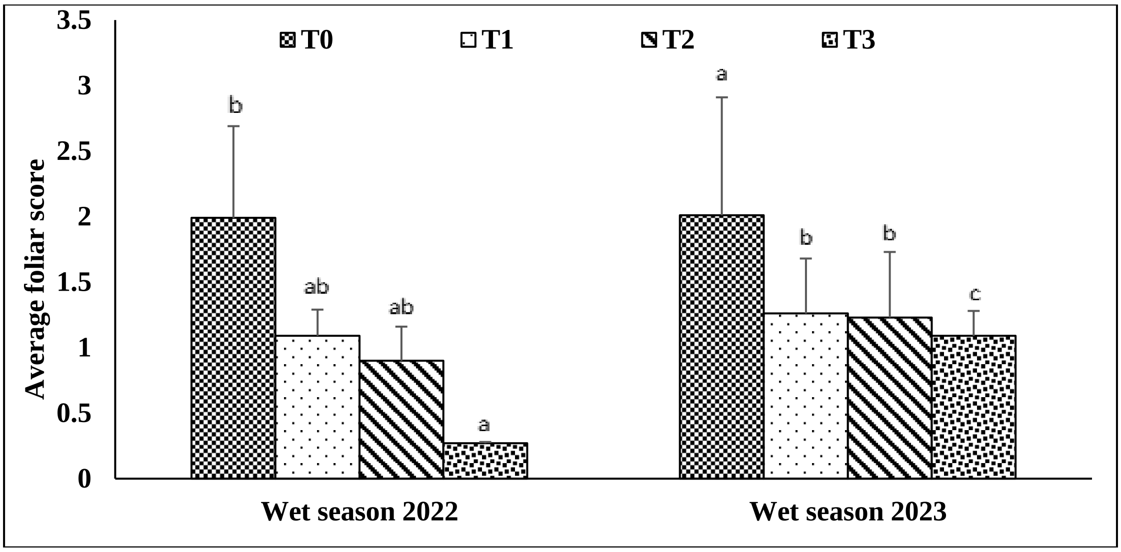

Fig. 4. Average leaf scores of maize plants attacked by *Spodoptera frugiperda*
T0 :Untreated control ; T1 :Bacillus thuringiensis ; T2 :Azadirachta indica ; T3 : Diflubenzuron WP. Values followed by the same letter (s) are not significantly different at the 5% probability level

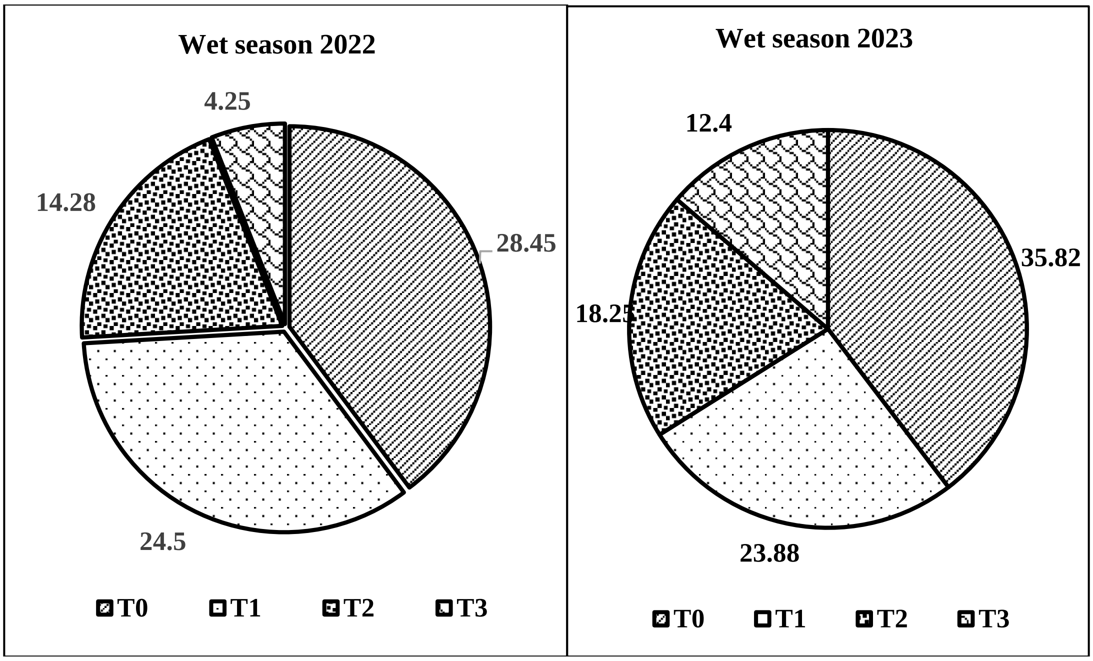

Fig. 5. Average larval presence rates of *Spodoptera frugiperda* according to treatments
T0: Untreated control; T1: Bacillus thuringiensis; T2: Azadirachta indica; T3: Diflubenzuron WP

3.1.5 Average scores for *Spodoptera frugiperda* damage on maize cobs

Table 1 shows the mean scores of maize ears attacked by *S. frugiperda*. A significant difference (P=0.05) between treatments was observed during the 2022 wet season. Treatment T2, with a mean score of 1.2±0.08 was not significantly different from T3 with 1.12±0.02. The mean scores for damage observed on maize cobs were recorded with treatment T0 (2.9±1.1), which however did not differ from T1 (2.2±0.9). In 2023, there was no significant difference between treatments T3 (1.25±0.04) and T2 (1.5±0.37). Only treatment T0 (3.2±1.5) was significantly different from T3.

3.1.6 Average grain yield

Average maize grain yields were higher in 2022 than in 2023. Analysis of variance revealed a significant difference (*P= 0.02*)* between treatments in 2022 (Fig. 6). The highest average yield (5.14 t/ha) was recorded with Diflubenzuron WP treatment (T3). This was followed by the neem oil (*Azadirachta indica*) treatment (T2) (4.62t/ha), which was not significantly different from *Bacillus thuringiensis* treatment (T1). The lowest average yield (3.92 t/ha) was recorded in the untreated control (T0), which was not significantly different from the yield observed with treatment T1. Similar results were recorded in 2023, where a significant difference (*P= 0.04*)* between treatments was highlighted. The highest average yield (4.88 t/ha) was obtained with the Diflubenzuron WP treatment (T3), which was not significantly different from the neem oil (*Azadirachta indica*) treatment (T2) (4.46 t/ha). The lowest average yield (2.89 t/ha) was observed with the untreated control (T0).

3.2 Discussion

The results recorded on Fall armyworm infestation levels revealed that *S. frugiperda* damage was observed on maize plants as early as 14 DAS. Untreated control plots recorded a maximum average damage rate of around 57.5% at the 42nd DAS. This rate is comparable to the rates reported by Hruska and Glasdstone [20], who claimed that, in the absence of appropriate control methods, Fall armyworm damage can range from 55 to 100%. The average rate of infestation of maize by *S. frugiperda* was higher in plots treated with neem oil and Bt than in plots treated with the chemical insecticide, which proved effective on maize plants attacked by *S. frugiperda*. Our results confirm those of Mouffok et al [21], who showed that neem oil reduced moth damage. The insecticidal effects observed for neem have also been evidenced by several authors against other crop pests. The insecticidal effects of neem are due to azadirachtin [22, 23], an alkaloid that acts as a growth regulator by antagonizing insect hormones, disrupting physiological processes and the hormonal cycle, inducing malformations in the moulting process and preventing normal development, optimal growth and reproduction. Azadirachtin can also act by slowing down the feeding rate of the gut, causing paralysis and dieback in target organisms [24]. Azadirachtin's harmful effects have been observed in several types of insect orders: Lepidoptera, Diptera (flies, horseflies, mosquitoes), Orthoptera (grasshoppers, locusts), and certain Hemiptera (aphids). Authors Senthil-Nathan et al [25] listed some thirty plant species in the Meliaceae family with insecticidal properties against several Lepidoptera, including *A. indica*, which can control *S. frugiperda*. Authors Gnago et al [26] revealed the efficacy of neem seed extract against *Spodoptera littoralis*, a Lepidoptera of the same genus as *S. frugiperda*.

In terms of the severity of caterpillar damage, the results showed that the highest values were recorded in untreated control plots and plots treated with Bt. In plots treated with neem oil, infestations were less severe, but the lowest infestations were observed in plots treated with Diflubenzuron WP. Diflubenzuron, an insecticide belonging to the benzamide class, is used in field crops for the selective control of insects. The main target insect species are caterpillars, several evergreen moths and cotton weevils. Diflubenzuron is also used as a chemical for larval control in animal habitats. Results on caterpillar damage reduction confirm that treatment with Diflubenzuron WP has a larvicidal effect. Authors Gnago et al [26] reported that synthetic pesticides provide rapid and effective responses against insect pests compared with natural pesticides and biopesticides, even though the latter reduce pest damage. Neem seeds are more concentrated in azadirachtin (active ingredient). Neem seed extract acts as a repellent and appetite suppressant Vallet [27]. According to Bodji and Kouassi [28] this would explain the remarkable control of neem extract on *S. frufiperda* larvae. In general, [29] notes that neem leaves and seeds contain a substance that is effective on soft-bodied insects such as young caterpillars. *Bacillus thuringiensis* acts as a selective insecticide on *S. frugiperda* caterpillars.

Table 1. Average damage scores for maize ears attacked by *Spodoptera frugiperda*

	Average infested grains scores	
Treatments	**WS 2022**	**WS 2023**
T0	2.9±1,1[b]	3.2±1,5[b]
T1	2.2±0,9[ab]	1.7±0,5[ab]
T2	1.2±0,08[a]	1.5±0,37[ab]
T3	1.12±0,02[a]	1.25±0,04[a]
Probability	**0.05**	**0.03**
Significance	**S**	**S**

T0: Untreated control; T1: Bacillus thuringiensis; T2: Azadirachta indica; T3: Diflubenzuron WP. SH : wet season. Values followed by the same letter (s) are not significantly different at the 5% probability level

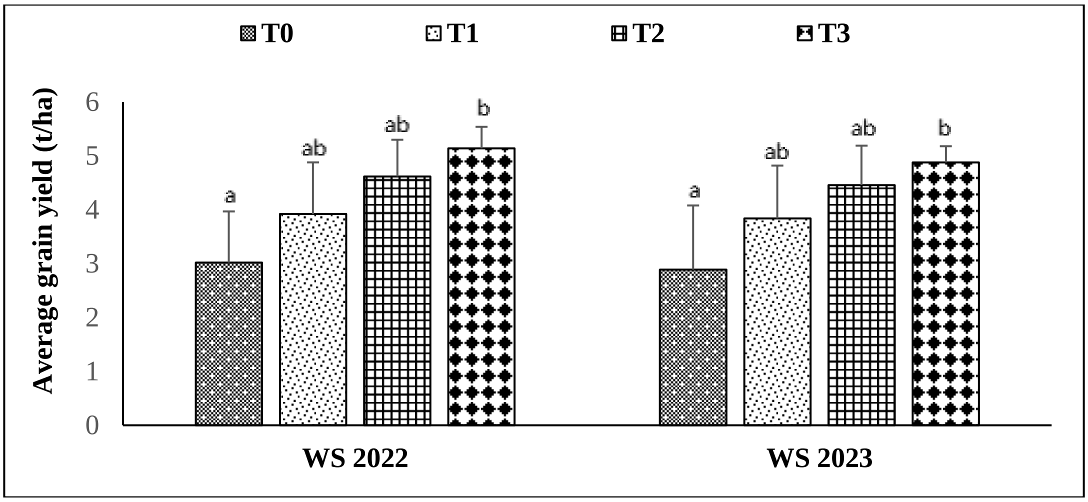

Fig. 6. Average grain yield of maize

T0: Untreated control; T1: Bacillus thuringiensis; T2: Azadirachta indica; T3: Diflubenzuron WP. WS : wet season. Values followed by the same letter are not significantly different at the 5% probability level

In addition, young caterpillars are more exposed because they feed a lot, whereas older caterpillars are less susceptible to treatment. As a result, effective biological control using biopesticides should be applied very early on in FAW infestations. Any delay in treatment could make the action of biopesticides less effective on *S. frugiperda*, whose resistance increases with the age of the larval stage.

In general, the results showed that the effectiveness of the treatments depended on the insecticide tested, with the larval population dropping considerably in treated plots. The work of Mehinto [30] showed that neem oil reduced the population of *Maruca vitrata* larvae in cowpea crops. Authors Mahapatro [31] reported the efficacy of neem extract on *Helicoverpa armigera* in cotton. Consequently, neem could be considered as the most toxic bio-insecticide against FAW because of the high mortalities observed compared with *B. thuringiensis*. Apart from neem oil, [32] reported that *B. thuringiensis* was effective against *Plutella xylostella* and *Hellula undalis* caterpillars in cabbage. The results of the analysis of variance showed that treatment with the insecticide Diflubenzuron WP yielded better results, significantly reducing the density of *S. frugiperda* larvae. Damage caused by *S. frugiperda* on maize ears was higher in plots treated with *B. thuringiensis* and neem oil. Damage to corn cobs or kernels has an impact on yield reduction, resulting in corn yield losses. The more ears are attacked, the more corn loses marketability. Authors Yaméogo et al [11] have shown that feeding by aged *S. frugiperda* larvae on the cob leads to a loss of seed quality, and therefore a drop in yield. According to Yaméogo et al [14], infestations during the mid- to late-cycle stage of maize development led to yield losses of 15 to 73% when 55 to 100% of plants were infested with *S. frugiperda*. Yields in plots treated with Diflubenzuron WP were higher than those in plots treated with neem oil insecticide and Bt. Neem seed extracts were effective on *S. frugiperda* larvae. According to Adeye et al [33], neem oil played an important role in getting higher yields.

4. CONCLUSION

Our results showed that the control plots recorded the most damage, compared with plots receiving Diflubenzuron and biopesticide applications. Furthermore, the severity of FAW attacks on plants was higher in plots treated with Bt than with neem extract, as were the mean leaf scores of maize plants attacked by *S. frugiperda*. The larval population dropped considerably in the treated plots, in contrast to the uncontrol plots. In the case of maize ears, the average score for ears attacked was higher with *B. thuringiensis* and lower with the Diflubenzuron WP treatment. Scores in control plots were higher. Yields of plots treated with Diflubenzuron WP were higher than those of plots treated with neem oil insecticide and Bt. In conclusion, Diflubenzuron WP was effective on most neonate *S. frugiperda* larvae, confirming the larvicidal effect of this insecticide compared with neem oil and *B. thuringiensis*. Neem oil and Bt also controlled the damage and reduced FAW populations. These results can be considered as important scientific achievements. Neem oil can be used as alternative insecticide for the control of FAW. But further studies are needed to determine the optimal concentration of neem oil for the control of this insect pest.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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