

Efficacy of Biorational and Synthetic Insecticides on *Busseola fusca* (Fuller, 1901) on Maize in Nigeria's Southern Guinea Agro-Ecological Zone

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Summary

In 2021 and 2022, two field studies were carried out to determine the effects of botanicals and synthetic pesticides on maize stem borer, *Busseola fusca* (Fuller, 1901). The experiment was laid out in a randomized complete block design with three replications. The botanical extract (*Azadirachta indica* A. Juss., *Moringa oleifera* Lam., and *Citrus × sinensis* (L.) Osbeck) was formulated using water as a solvent. Phytochemical analysis was carried out on the extract with the presence of secondary metabolites such as alkaloids, flavonoids, tannins, glycosides, steroids, triterpenoids, anthraquinones, and saponins. In the 2021 planting season the experiment recorded high efficacy of *A. indica* extract on larvae of *B. fusca* population of 4.33 and untreated plots having the highest number of infestations of 10.00. Among the botanicals, *M. oleifera* extract underperformed compared to *A. indica* in the two-planting seasons. The yield output of *A. indica* outperformed the two botanicals in the two-planting season with 4.70 t ha⁻¹ and 4.53 t ha⁻¹ in 2021 and 2022 planting seasons respectively, while *M. oleifera* had the lowest yield with the untreated plot with 3.22 and 3.01 t ha⁻¹ therein with a lowest yield. These findings indicate that botanical formulations of various plant components may be useful for the control of stem borer populations on maize.

Key words

Azadirachta indica, Botanical, *Busseola fusca*, *Moringa oleifera*

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Introduction

Zea mays L. (Poaceae) is one of the most significant cereal crops in the world (Ishaya et al., 2018). Maize is widely grown as a key source of food for humans and livestock feed and as raw material for agro-allied industries across Nigeria's several agro-ecological zones, ranging from the rain forest belt in the south to the Northern Guinea savannah (Agboola and Fayemi, 2019). Nigeria's annual production of maize is predicted to be 5.4 million metric tons from 3.4 million hectares of land; however, because of agricultural insect pests, there is a growing concern in Nigeria about maize production's long-term viability. In Africa, reported yield losses due to lepidopterous borers range from 10% to 100% depending on the ecological zone, region and season (Usua, 1968; Sosan and Daramola, 2001; FAO, 2004). Kakule et al. (1997) report that the amount of damage caused to maize differs between locations and regions in Africa, with sub-Saharan Africa having the greatest population of stemborers, which is linked directly with the amount of damage and grain lost.

Stemborer infestation of maize in the field frequently results in a 'windowpane' effect on the leaves, 'dead heart' stem breakage or lodging and a reduction in grain yield, due to their ability to infest the crop at all phases of its development, from seedling to maturity (Sosan and Daramola, 2001). Consequently, maize stem borers pose a significant threat to the potential yields of maize (Sosan and Daramola, 2001). The tunnelling and feeding of caterpillars, as well as the introduction of ear-rotting microorganisms during eating, might compromise the development of the ear (Azerefege, 1991). It is known that late crop damage is greater than early crop damage (Oigiangbe et al., 2014; Kakule et al., 1997). Further, chemical insecticides used to treat borers and other insect pests are expensive and dangerous (Kreutzweiser, 2011).

Various insecticides, such as persistent and broad-spectrum pesticides, have been used for the control of cereal stemborers, raising a variety of problems (Westbom et al., 2008). Due to the extensive use of chemicals by farmers, excess toxic compounds are released, polluting the soil, water and air (Adeyinka et al., 2018). Moreover, the toxins released in the environment can cause severe health risks such as cancer, diseases of the nervous system and reproductive problems, while the frequent use of pesticides can result in the rapid evolution of stem borer resistance in crops (Adeyinka et al., 2018). This necessitates additional research to develop non-chemical methods of controlling the insect-pests. Shah et al. (2017), reported the effectiveness of moringa leaf and neem seed against field insect pests. Given *B. fusca* infestations in the southern Guinea agroecological zone, the findings of this study will offer vital empirical evidence for sustainable insect pest management strategies using biorational insecticides that can maximise maize yields for smallholder farmers.

Materials and Methods

Study Site Description

The field experiment was conducted in the 2021 and 2022 cropping season at the Teaching and Research Station of the Federal University of Agriculture, Makurdi, Nigeria (FUAM). The site occurs at latitude 06° 47' N to 06° 52' N, longitude 08° 43' E to 08° 47' E with an average altitude of 98 m.

Land Preparation and Sowing

The experimental field was manually cleared with the use of hoes and cutlasses. Sammaz 53 was sourced from the Institute for Agricultural Research, Zaria which is a high-yield variety with a potential of 5.3 tonnes/hectare. Two seeds were sowed per hole with a spacing of 25 cm intra-row and 75 cm inter row. After two weeks of germination, seedlings were pruned to one stand per hole.

Treatment Preparation and Application

In this study, the botanicals (*M. oleifera* leaf and *A. indica* peels) were collected from the environment around Joseph Sarwuan University in Makurdi, while the peel of *C. sinensis* was gathered from orange juice vendors in the Wurukum market, Makurdi, Benue State. *M. oleifera* and *A. indica* leaves and *C. sinensis* peel were formulated in accordance with Emosairue (2007) with modification. The gathered plants used were collected when they had just reached their maturity state. The leaves and peel were washed and dried in the sun, and throughout the drying process the leaves and peels were turned over on a frequent basis to ensure even drying. After they had been dried, the components were ground. After being stirred for a total of 30 minutes and remaining undisturbed for a period of 48 hours in the dark, a total of 500 g of paste was submerged in 10 liters of water. After passing the solution through muslin, the container was filled with more water until it reached the desired volume of 10 l. After that, 5 mL of liquid soap was added since it acts as an emulsifier. The three botanical specimens underwent the aforementioned treatment process.

Land Preparation

The experimental field was cleared using cutlasses and hoes and manual ridges were then created with hoes. The maize seeds were promptly planted following the ridge preparation. The planting took place at the beginning of the rainy season, in both May 2021 and 2022 rainy seasons.

Experimental Design

A Randomized Complete Block Design (RCBD) with three replications was used in the study. The three blocks were divided into five equal plots of 3 m × 5 m each. Each block was comprised of *Moringa oleifera* leaves, *Azadirachta indica* leaves, *Cirtus sinensis* peel, Lambda-cyhalothrin and a control. The crop was managed following the recommended agronomic practices for maize production.

Phytochemical Composition Analysis

The phytochemical analysis of the extract was performed using the method outlined by Odebiyi and Sofowora (1978) for detecting saponins, glycosides, tannins, phenolics, alkaloids, triterpenes, phlobatannins, steroids and flavonoids.

Field Sampling/Parameter Measured

Leaf damage was collected from five randomly selected plants on each plot at fifty (50) and 80 days after treatment. The measurement of tunnelling lengths caused by maize stemborers on the maize stalk was conducted after the completion of the harvesting process. Ten (10) maize plants at the vegetative stage

of V12 were chosen at random from each experimental plot. Borders were carefully avoided and sampling was conducted at the center without causing any harm to the plants. This was achieved by inspecting the leaves and leaf whorls of selected, intact maize plants, using a non-destructive sampling approach. Larvae detection was done by observing the presence of larvae on leaves, stems and leaf whorls, the leaf whorls were opened using forceps and observed with a hand lens. Dead heart data was collected by examining 10 maize plants per pot for damage. After the harvest, a total of one hundred seeds was enumerated for each plot, and their weights were measured using a weighing scale.

Statistical Analysis

Analysis of Variance (ANOVA) model for experimental parameters

The ANOVA model is as follows:

$$Y_{ij} = \mu + T_i + \beta_j + \varepsilon_{ij}$$

where

Y_{ij} = leaf damage, tunnel length, number of borer holes, dead heart, 100 -seed -weight and yield

μ = overall mean

T_i = effect of the i-th treatment

β_j = effect of the j-th block

ε_{ij} = random error.

Data collected were subjected to analysis of variance using GENSTAT version 17 to analyze the data. Significant difference mean values were separated using Duncan Multiple range test at $P < 0.05$ significance level.

Results

Phytochemical Screening of Treatments

The phytochemical analysis results are presented in Table 1. They show the presence of secondary metabolites ranged from alkaloids, flavanoids, tannins, phenols, glycoside, steroids, triterpenoids, anthraquinones and saponins. The presence of the secondary metabolites varied from each treatment, with *A. indica* having more abundant secondary metabolites compared to moringa and orange in which glycoside, steroids and triterpenoids were low.

Leaf Damage

The effect of botanicals and synthetic insecticides on plant leaves damage in the 2021 and 2022 planting season is shown in Table 2. In the 2021 planting season at 50 days after planting the number of leaves was significantly different from the control that had the highest amount of damage at 3.33 while *A. indica* and Lambda-cyhalothrin damage was lower and not significantly different. At 50 and 80 days after treatment in 2021 and 2022 planting season the control maintained the level of infestation by larvae damage on leaves with 4.33 and 8.67 respectively while the *M. oleifera* and *C. sinensis* were not significantly different, both having 4.33 in the 2022 season.

Table 1. Phytochemical screening of botanicals

| Chemical compound | <i>Moringa oleifera</i> | <i>Citrus sinensis</i> | <i>Azadirachta indica</i> |
|-------------------|-------------------------|------------------------|---------------------------|
| Alkaloids | + | + | + |
| Flavonoids | + | + | + |
| Tannins | + | + | + |
| Phenol | + | + | + |
| Glycoside | + | + | ++ |
| Steroids | + | + | ++ |
| Triterpenoids | + | + | ++ |
| Anthraquinones | + | + | + |
| Saponins | + | + | + |

Note: + Present; ++ Abundant

Tunnel Length

In planting season of 2021, lambda-cyhalothrin had the lowest stem borer larvae tunnelling with 4.28 cm and *A. indica* (5.63 cm) which is not significantly different but significantly different when compared to control with 27.13 cm showing serious tunnelling in maize stalk. Although, *M. oleifera* and *C. sinensis* were not significantly different also at 13.48 and 10.74 cm respectively. In 2022 the same trend of the high rate of tunnelling was observed in control with 29.61 cm with a highly significant difference at $P < 0.01$ with other biocontrol insecticides and synthetic insecticides. *A. indica* had the lowest tunnelling of larvae among the three botanicals.

Larvae Population of *Busseola fusca*

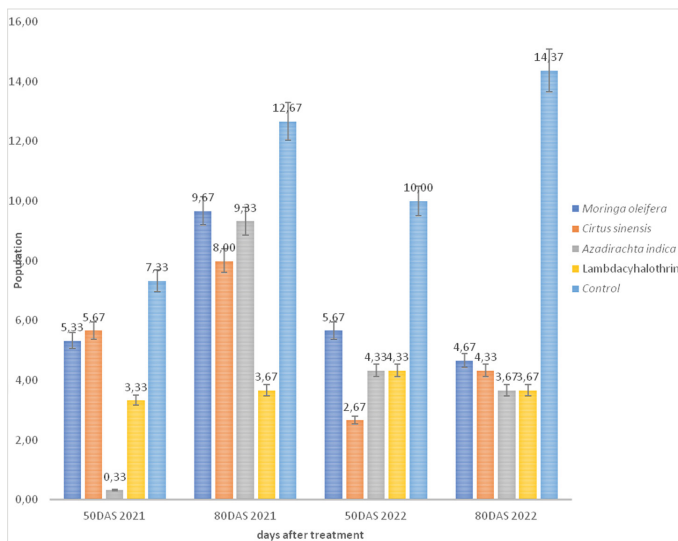
Fig. 1. shows the effect of botanical and synthetic insecticides which affected the population and gave room to dead heart in maize during the 2021 planting season. At 50 days after treatment the population of *Busseola fusca* on the untreated plot was 7.33, followed by *Citrus sinensis* which had 5.67 of larvae population at 80 days after treatment. The untreated plot at 80 days after treatment showed moringa at 9.67 and lambda-cyhalothrin at the lowest but they are significantly different.

Table 3. presents the data corresponding to the number of bore holes and occurrences of dead hearts. During the planting season of 2021, there was no significant difference observed between the indica and Lambda-cyhalothrin treatments in terms of the number of maize stem borer holes. The average number of holes for the neem treatment was 1.56, while for the Lambda-cyhalothrin treatment, it was 1.12 ($F = 11.85$; $df_{4,20}$; $P > 0.05$). However, it is worth noting that the control group had the maximum number of drilled holes. In the 2022 season, a consistent trend was observed wherein the populations of *B. fusca* were the highest in the moringa and control treatments. However, there was a substantial difference in the bore, with the moringa treatment having an overall number of 4.76 and the control treatment having a number of bore holes of 5.33.

Table 2. Effect of botanicals and synthetic insecticide on plant leaf in the 2021 and 2022 planting seasons

| Treatment | Leaf Damage | | | | Tunnel Length (cm) | |
|---------------------------|-------------------|-------------------|-------------------|--------------------|--------------------|--------------------|
| | 2021 | | 2022 | | 2021 | 2022 |
| | 50 (DAS) | 80 (DAS) | 50 (DAS) | 80(DAS) | | |
| <i>Moringa oleifera</i> | 0.33 ^b | 3.00 ^b | 2.33 ^b | 4.33 ^a | 13.48 | 14.93 ^b |
| <i>Citrus sinensis</i> | 0.33 ^b | 2.67 ^b | 3.67 ^b | 4.33 ^{ab} | 10.74 | 11.33 ^b |
| <i>Azadirachta indica</i> | 0.00 ^c | 3.16 ^b | 0.33 ^c | 3.67 ^a | 5.63 | 6.72 ^c |
| Lambda-cyhalothrin | 0.00 ^c | 0.33 ^c | 0.33 ^c | 2.67 ^b | 4.28 | 3.13 ^c |
| Control | 3.33 ^a | 6.33 ^a | 4.33 ^a | 8.67 ^b | 27.13 | 29.61 ^a |
| CV % | 23.33 | 8.01 | 16.26 | 5.48 | 17.49 | 13.45 |

Note: Means with the same alphabet(s) are not significantly different at $P < 0.05$; DAS: Days After Sowing

**Figure 1.** Effect of botanical and synthetic insecticide on *Busseola fusca* larvae population

In the 2021 growing season, the incidence of dead hearts was seen to be greater in control groups. However, in the 2022 season, no instances of dead hearts were observed in the Lambda-cyhalothrin group. Notably, the neem treatment exhibited comparable efficacy to the synthetic insecticides in preventing dead hearts at 0.33.

One hundred-seed weight and Crop yield are shown in Table 4. In 2021 growing season neem and lambda-cyhalothrin recorded the highest seed weight ($F = 5.07$; $df_{4,20}$; $P > 0.05$) of 28.06 g and 27.41 g respectively compared to other botanical and untreated plots, while the control and moringa did have the lowest hundred seed weight for both seasons of 2021 and 2022. The effect of botanical and synthetic insecticides on yield of maize in 2021 and 2022 planting seasons recorded high yield in neem and lambda-cyhalothrin (4.70 and 4.73 t ha⁻¹) while *Moringa oleifera* recorded the lowest yield at 3.32 t ha⁻¹. In the 2022 season neem and lambda-cyhalothrin still maintained the same trend with 4.53 and 4.72 t ha⁻¹ respectively in yield while the control had the lowest yield at 3.01 t ha⁻¹ followed by moringa and *Citrus sinensis* with 3.22 and 3.51 t ha⁻¹.

Table 3. Effect of botanical and synthetic insecticide on number of bore holes and dead hearts in 2021 and 2022 planting seasons

| Treatment | Number of bore holes | | Dead hearts | |
|---------------------------|----------------------|-------------------|-------------------|--------------------|
| | 2021 | 2022 | 2021 | 2022 |
| <i>Moringa oleifera</i> | 4.23 ^b | 4.76 ^b | 2.33 ^b | 1.33 ^{bc} |
| <i>Citrus sinensis</i> | 3.67 ^b | 2.34 ^c | 1.33 ^c | 2.33 ^b |
| <i>Azadirachta indica</i> | 1.56 ^c | 1.89 ^c | 0.66 ^d | 0.33 ^c |
| Lambda-cyhalothrin | 1.12 ^c | 1.89 ^c | 0.66 ^d | 0.00 ^c |
| Control | 7.30 ^a | 5.33 ^a | 8.00 ^a | 10.67 ^a |
| CV | 10.60 | 28.67 | 12.06 | 22.83 |

Note: Means with the same alphabet(s) are not significantly different at $P < 0.05$

Table 4. Effect of botanical and synthetic insecticide on 100-seed weight and yield in 2021 and 2022 planting seasons

| Treatment | 100 Seed Weight | | Yield (t ha ⁻¹) | |
|---------------------------|---------------------|--------------------|-----------------------------|--------------------|
| | 2021 | 2022 | 2021 | 2022 |
| <i>Moringa oleifera</i> | 18.21 ^{cd} | 19.53 ^b | 3.32 ^{bc} | 3.22 ^{bc} |
| <i>Citrus sinensis</i> | 21.32 ^b | 20.83 ^b | 3.42 ^b | 3.51 ^b |
| <i>Azadirachta indica</i> | 28.06 ^a | 27.33 ^a | 4.70 ^a | 4.53 ^a |
| Lambda-cyhalothrin | 27.41 ^a | 20.43 ^b | 4.73 ^a | 4.72 ^a |
| Control | 15.76 ^d | 16.83 ^c | 3.22 ^c | 3.01 ^c |
| CV | 33.67 | 23.87 | 21.84 | 42.67 |

Note: Means with the same alphabet(s) are not significantly different at $P < 0.05$

Discussion

The result of these studies showed that neem leaf extract and lambda-cyhalothrin had a pernicious effect on the development of *B. fusca* in the year 2021 and 2022 planting seasons causing mortality and subsequently preventing and/or suppressing emergence and recording low cases of dead heart disease. These findings are in accordance with earlier studies by Sehgal (1990) and Jayanthi and Verghese (2007) who report that different extracts of neem seed extract perform better than the synthetic insecticides (cypermethrin and lambda-cyhalothrin) in suppressing lepidopteran stem borer species. The lethal activity of the botanicals extract on the development of *B. fusca* may be caused by high phytochemicals present in the extracts such as glycoside, steroids and triterpenoids which have insecticidal properties such as binding to acetylcholine receptors and causing a disruption in the neurological system, causing pests to be repelled and deterred from eating and preventing oviposition, egg hatching and moulting from occurring, as reported by Landolt et al., 1999 Naumann and Isman, 1995., Lengai et al., 2020). Lambda-cyhalothrin has a marked negative effect on overall insect abundance, as shown herein, but *A. indica*, which contains terpenes (C30 triterpenes) that are hydrophobic compounds typically stored in plants in resin ducts, oil cells or glandular trichomes and are the largest group of natural products from plants comprising essential oils, exhibits significant toxicity to insects with low mammalian toxicity and it has been recorded to have increased toxicity of polyacetylene to lepidopteran (Wink, 1999., Rattan, 2010). The presence of abundant triperpenes made the efficacy of *A. indica* to be more effective than the *M. oleifera* and *C. sinensis*. This supports the efficacy study of Mochiah et al. (2011), and Olayemi and Alabi (1994), which found that *A. indica* and *M. oleifera* had a high level of potency against various insect pests that could be attributed to the presence of steroids in the phytochemical analysis.

Conclusion

The current study has shown that yield loss is increased with the increase of infestation of maize as affected by *B. fusca*. Lambda-cyhalothrin has the highest performance on *B. fusca* as a control agent with the highest yield although not significantly different from *A. indica*. But in the case of bio-pesticides performance, *A. indica* leaf extract is best followed by orange and moringa. From the result, it may also be concluded that insect infestation control and higher yield are stronger when experimental plots are treated with neem and lambda-cyhalothrin.

To be able to provide for their ever-increasing populations, most emerging nations or developing nations will need to see steady expansion in their agricultural sectors through eco-friendly pesticides because there is a high correlation between synthetic crop protection agents and the recurrence of pests, as well as the effect on non-target insects, health and the environment. As a result of this, there is a pressing need to create alternative crop protectants (insecticides) that are not only safe but also more targeted and have a wider scope of actions.

Finally, it has been discovered that neem extract and moringa both have insecticidal characteristics that are effective against maize stem-borer. Studies have shown that neem extract and

moringa can both successfully decrease the population of stemborers, which in turn reduces crop damage and increases crop output. Alternatives to synthetic pesticides that are friendlier to the environment include using natural pesticides like neem and moringa extracts as pest control agents. The research reveals that neem extract and moringa have distinct mechanisms of action, which may explain why the two are thought to have an impact when it comes to the control of stemborers. However, further study is required to completely understand the processes behind the insecticidal capabilities of neem extract and moringa, as well as to maximise the effectiveness of these two substances when used to control pests.

Future studies might focus on the integration of neem and moringa into integrated pest management (IPM) programmes to provide sustainable crop protection. Additionally, it would be valuable to analyse the likelihood of pests developing resistance to insecticides derived from neem and moringa. Furthermore, further investigation is necessary to assess the impacts of the botanicals on diverse pest species and the populations of beneficial insects.

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CRedit Authorship Contribution Statement

Lukman I. Gambari: conceived the project, supervised the research, analyzed the data, and drafted the manuscript. **Raymond U. Akor and Onyi A. Echami:** performed most of the experiments. **Stephanie N. Ajuu and Samuel F. Babatunde:** performed some of the experiments, reviewed and edited the manuscript and provided critical feedback.

Declaration of Competing Interests

The authors declare that there are no conflicts of interest, whether personal, related to authorship, or otherwise, that could impact the research and findings provided in this publication.

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