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Determination of the efficacy of rice husk biochar as biopesticide against *Sitophilus zeamais*

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Abstract

Maize weevils (Sitophilus zeamais) are a significant pest of stored maize in Africa, causing substantial damage to its physical, nutritional, and economic value and rendering it unsuitable for replanting. This study, conducted at the Demonstration Farm of the Agricultural Technology Department of Federal Polytechnic, Ile-Oluji, Nigeria, investigated the efficacy of Rice Husk Biochar (RHB) as a biopesticide against this pest. Three concentrations of RHB (15 g, 10 g, and 5 g) were tested against Sitophilus zeamais infesting stored maize, using a Completely Randomized Design (CRD) with three replicates. The dependent variables measured after treating infested maize with the RHB were the Susceptibility Index (SI), Mortality Rate (MR), Grain Weight Loss (GWL), and Germination Percentage (GP) of the stored maize. Results indicated that RHB significantly influenced all dependent variables. The SI reached its highest value (56 %) at the lowest concentration (5 g) of RHB compared to 36 % at 15 g. MR was highest (84 %) at 15 g of RHB compared to other concentration levels. GWL was lowest at higher RHB concentrations, showing only a 4 % loss at 15 g compared to a 9 % loss in the control group for the same weight of RHB. GP was highest (98 %) at RHB (15 g) Analysis of variance showed significant effects across all dependent variables at a p-value ≤ 0.05. Rice Husk Biochar demonstrates potential as a biopesticide for managing Sitophilus zeamais, offering a sustainable and environmentally friendly alternative to synthetic pesticides.

Keywords: Biopesticide; Rice Husk Biochar; *Sitophilus zeamais*; Stored maize

1. Introduction

Maize (*Zea mays*) is one of the essential crops consumed locally in Nigeria and serves as a major raw material in livestock feed production due to its mineral, vitamin, and carbohydrate content (Maitra *et al.,* 2020; Sintim and Ansah, 2023). It has become a cash crop that is exported for industrial use, and Nigeria was once among the highest producers of maize in Africa. In 2018, approximately 10 billion metric tons of maize were produced globally, with Nigeria contributing about 10.2 million tons, according to Okparavero *et al.* (2022). The United States led production with 30%, followed by China (21%) and Brazil (7.9%). In contrast, Africa's contribution was only 7%, with Eastern and Southern Africa accounting for two-thirds of this total (Ranum *et al.,* 2014; Olaniyan, 2015; Suleiman and Rosentrater, 2015; FAO, 2018; Verheye, 201).

As observed by FAO (2022), the low Maize production in Africa is attributed to postharvest losses among other reasons. In Nigeria, pest infestation during storage as noted by Kitinoja *et al.* (2019) tops the list of postharvest losses in stored maize. This post-harvest challenge has hindered the continent, and Nigeria specifically, from becoming a leading global producer of maize. Mohammed and Mark (2023) corroborated Kitinoja *et al.* (2019) observation, stating that up to 50% of losses of harvested maize in storage are due to insect infestation, primarily from the maize weevil (*Sitophilus*

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zeamais). Taulu *et al.* (2020) found that *Sitophilus zeamais* bores into the grain to feed on the starchy endosperm, rendering the Maize useless for planting. Their activity also increases the moisture content and temperature of stored grains, which promotes the growth of pathogenic fungi that produce aflatoxins. The infestation of *Sitophilus zeamais* poses a significant threat to food security in Africa, as it led to post-harvest losses of up to 90% in stored maize (Sujata *et al.,* 2019). Ehisianya *et al.* (2019) identified *Sitophilus zeamais* as a severe pest of *Zea mays* in storage. The pest follows the grain from the farm, and if left unchecked, it can destroy the quality and quantity of the grains. Babarinde *et al.* (2013) reported that *Sitophilus zeamais* also infests and damages processed maize products (pasta) like macaroni and spaghetti. Investigations by Trematerra and Suss (2006), Murata *et al*. (2008), Stejskal *et al.* (2004), and Trematerra *et al.* (2004) revealed that pasta products on supermarket shelves were infested by *Sitophilus zeamais*. This pest infiltrates these food products because proper care is not taken during storage in silos, warehouses, and other facilities.

The primary method of controlling this pest has been the application of chemical pesticides, insecticides, and fumigants (Zettler and Arthur, 2000; Liu *et al.,* 2020; Rajendran *et al.,* 2004). However, Edde (2012) and Popoola *et al.* (2015) noted the hazardous effects of chemical residues on consumers. Other challenges include the ineffectiveness of these chemicals due to overuse and the development of pest resistance to their potency. Additionally, these chemicals can harm the storage environment where they are applied. Therefore, there is a pressing need for research into natural methods of controlling *Sitophilus zeamais* in grain storage in Nigeria that will not be toxic to humans and the environment. Nboyine *et al.* (2015) discovered the potential of certain biological control agents and entomopathogenic fungi to manage the spread of Sitophilus zeamais. However, none of these biopesticides have been registered in Nigeria for effective control of this pest. This study aims to explore biological means of controlling *Sitophilus zeamais* to preserve the quality and quantity of maize while safeguarding the storage environment from the adverse effects of chemicals.

1.1. Aim and Objective

The aim of the study was to determine the effect of Rice Husk Biochar (RHB) as biopesticide against *Sitophilus zeamais* in stored maize. The specific objectives were;

- To evaluate the efficacy of RHB as a biopesticide against *Sitophilus zeamais* attack on stored maize
- To determine the optimal concentration of RHB require to achieve significant mortality of *Sitophilus zeamais*.

1.2. Research Question

The following questions were asked as a lead to the study;

- What is the effect of rice husk Biochar on the mortality rate of *Sitophilus zeamais*?
- What is the concentration level of RHB required to achieve significant mortality of *Sitophilus zeamais*?

1.3. Research Hypothesis

Based on the research questions, the following null (H_o) and alternative (H_a) hypotheses were formulated at significance level, $\alpha = 0.05$. This means that if the p-value is less than 0.05, the null hypothesis will be rejected, indication a significant effect.

1.3.1. Null Hypothesis (H_o)

- There is no significant difference in the mortality rate of *Sitophilus zeamais* between the treatment and control groups
- The concentration of RHB does not affect the mortality rate of *Sitophilus zeamais*

1.3.2. Alternative Hypothesis (H_a)

- There is a significant difference in the mortality rate of *Sitophilus zeamais* between the treatment and control groups
- The concentration of RHB has a significant effect on the mortality rate of *Sitophilus zeamais*

2. Material and methods

2.1. Study Area

The experiment was conducted at the workshop of the Agricultural Technology Department of Federal Polytechnic Ile-Oluji, Nigeria. The workshop is located within the coordinates of Lat. 7.236935^o and Long. 4.861769^o. A Completely Randomized Design (CRD) with three treatments and three replicates was employed for the experimental design.

50 g of rice husk and 1 kg each of local yellow SAMMA 5 maize infested with Maize weevil (*Sitophilus zeamais*) and non-infested respectively were purchased from the rice millers and maize sellers in the Odolua market of Ile Oluji community. The rice husk was sundried to 18 % moisture content from the 32 % moisture content when purchased. This was loaded into the inner retort drum of a locally fabricated Biochar kiln (Akinfiresoye and Ogidan, 2024). The loaded inner retort drum of the rice husk was placed inside the outer kiln drum. The heat was manually supplied to the inner retort drum through dried wood set on fire at a temperature up to 650^{o}C measured with an infrared thermometer through a pyrolysis method. The rice husk was converted into Biochar at the end of the operation. Upon cooling down, the Rice Husk Biochar (RHB) was removed and milled into powdery form. 30 pairs of adult *Sitophilus zeamais* were sieved out of the purchased infested 1 kg maize. This was mixed with 500 g out of the 1 kg clean maize for infestation. After 40 days of infesting the 500 g maize, the new F_1 offspring of *Sitophilus zeamais* were sieved out. This assured us of the source of the *Sitophilus zeamais* used for the experiment.

Thirty (30) seeds out of the clean maize purchased were each counted into four places in a clean jar as A_1, A_2, A_3, and A_4 respectively. The thirty seeds in each of the jars A_2, A_3, and A_4 were rubbed with 15 g, 10 g and 5 g RHB respectively, while that A_1 which was the control has no RHB rubbed on the seeds. Twenty (20) pairs each of the F_1 offspring of *Sitophilus zeamais* were now introduced into each of the jars and closed for 10 days for infestation. At the end of this 10 days, the dead and live *Sitophilus zeamais* were sieved out and the jars covered for another 30 days for the emergence of new *Sitophilus zeamais.* This treatment were replicated thrice. At the end of the treatment, the *Sitophilus zeamais* were sieved out and counted both dead and alive. Damaged grains were also counted against the undamaged ones for each of the jars. The undamaged seeds were planted for the germinability test.

The Susceptibility Index (SI) measures the vulnerability of *Sitophilus zeamais* to the treatment of RHB on stored maize, the Mortality Rate (MR) which is the percentage of *Sitophilus zeamais* that die to the RHB treatment, the Grain Weight Loss (GWL) and Germination Percentage (GP) which measure the number of seeds that germinated after the treatment were determined using the Equations 1, 2, 3, and 4 according to Akinbuluma (2020)

$$SI = \frac{DS}{MPD} \times 100 \text{ ……………..equation 1}$$

$$MR = \frac{DI}{LI} \% \qquad \text{……………..equation 2}$$

$$GWL = \frac{(W_1 - W_2)}{W_1} \% \qquad \text{…………..equation 3}$$

$$GP = \frac{GS}{TNG} \% \qquad \text{……………..equation 2}$$

DS is the Disease Severity represented by the number of damaged seeds and MPD is the Maximum Possible Damage, which is the total number of seeds under treatment. DI is the number of dead insects, while LI is the expected or estimated number of live insects. W_1 is the initial weight before the treatment and W_2 is the final weight after treatment. GS is the number of germinated seeds and TGN is the total number of grains planted. Figure 1 shows a picture of the experiment.

The data collected from the experiment were analyzed descriptively using Microsoft Excel v. 2013 and IBM SPSS Statistics v. 28. A one-way analysis of variance, (ANOVA) was conducted to compare the means of the dependent variable (*Sitophilus zeamais*) across the different levels of the independent variable (different concentrations of RHB) at significance level $\alpha = 0.05$.

Figure 1 Pictorial View of the Experiment

3. Results and Discussion

The results of the experiment is discussed here.

3.1. The Susceptibility Index

As observed from the bar chart of Figure 2, the Susceptibility Index (SI) of *Sitophilus zeamais* and RHB treatments have dose relationships. When the RHB was 15 g, the mean SI was 36 %. When the dose was reduced to 10 g and 5 g, the mean SI increased to 47 % and 56 %, respectively. This was observed for the control, which had higher SIs of 67 %, 73 %, and 87 for the 15 g, 10g, and 5 g, respectively. As the RHB concentration increased, the SI values decreased indicating enhanced protection against *Sitophilus zeamais*. A significant negative correlation (-0.998) between RHB and SI values showed increased protection against *Sitophilus zeamais* infestation with a higher dose of RHB.

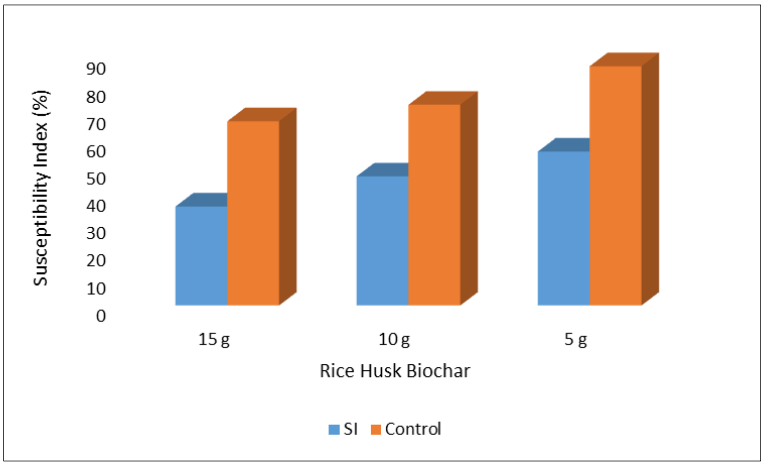

Figure 2 Susceptibility Index of Rice Husk Biochar on *Sitophilus zeamais*

According to Temesgen and Emana (2023) in related studies, the SI of stored maize is a function of the genotype, the type of maize, and the storage facility. However, the SI is also affected by the application of biopesticide as shown in this study. The application of RHB prevents the breeding of the *Sitophilus zeamais* thereby reducing their attack on the stored maize. In their similar study, Law-Ogbomo and Enobakhre (2007) and Mulungu and Ng'ombe (2019) observed that biopesticide impaired the respiratory organs of *Sitophilus zeamais* larvae, thereby preventing them from destroying the grains.

3.2. The Mortality Rate (MR)

As shown in Figure 3, the effect of the RHB on *Sitophilus zeamais* Mortality Rate (MR) revealed about 84 % MR when treated with 15 g of RHB compared to the control, which was just 20 % MR. This was followed by 10 g of RHB, with a 79 % MR and 74 % MR when treated with 5 g of RHB, as against 27 % and 23 % of the control, respectively.

It was observed that the MR increased with increment in the concentration of RHB as the highest MR (84 %) was obtained at 15 g RHB concentration compared to the values obtained for 10 g (79 %) and 5 g (74 %). The correlation test showed RHB's significant positive (0.99) effect on the MR of *Sitophilus zeamais.*

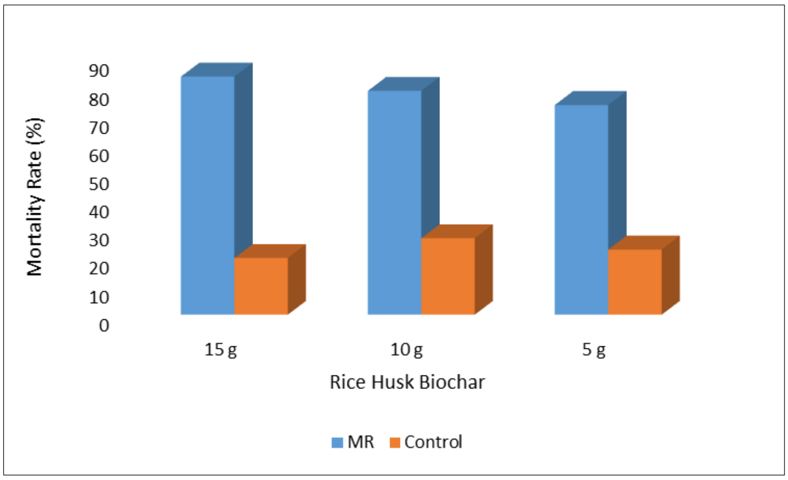

Figure 3 Mortality Rate of Rice Husk Biochar on *Sitophilus zeamais*

The findings of this study agree with the work of Shiberu and Negeri (2017) and Marilei *et al.* (2010), which found that biopesticide obtained from neem extract effectively increased the mortality rate of *Sitophilus zeamais*. Biopesticides can replace insecticides made from chemicals hazardous to human health from this study and as corroborated by other researchers like Chouka (2007), and Nukenine *et al.* (2007) who had worked on similar research. In their study, Ileke and Oni (2011) discovered that *Sitophilus zeamais* in wheat grain can be mitigated using powdered biopesticide to coat the surface of the grains, this is in agreement with this study because the coating remains toxic to the pest.

3.3. The Grain Weight Loss

As described in the bar chart of Figure 4, the lowest grain weight of 4 % was observed at the highest concentration of RHB (15 g), this was followed with that of 10 g (11 %) and 5 g (14%). For these three treatments, the correspondent grain weights for the control were 9 %, 11 %, and 14 % respectively. This shows that the higher the concentration of the RHB, the lower the weight loss of the grain which means the lower the attacks on the grains are.

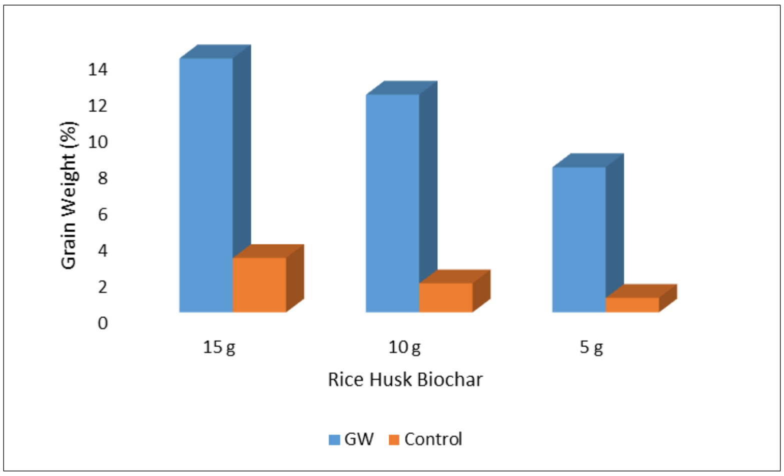

Figure 4 Grain Weight of Rice Husk Biochar on *Sitophilus zeamais*

The reduction of the weight loss of the grain at the highest concentration of RHB was due to the effect of RHB on the *Sitophilus zeamais* by repelling their larvae from feeding on the endosperm of the stored maize, which reduces the weight of the grains. In a similar study by Ehisianya *et al.* (2019), it was equally discovered that biopesticide shields the stored grains away from *Sitophilus zeamais* larvae because of this repellent effect. This research revealed that RHB of lower concentration recorded higher grain weight loss. This may be due to the insignificant effect of the RHB on the mortality of the *Sitophilus zeamais.* There was a direct link between mortality and grain weight. The higher the mortality rate, the lower the grain weight loss.

3.4. The Germination Percentage

It was observed, and as described by the bar chart of Figure 5, that the RHB of 15 g had a germination percentage of 98%. This was followed by the RHB of 10 g, which was 92 %, and 85 % for the RHB of 5 g.

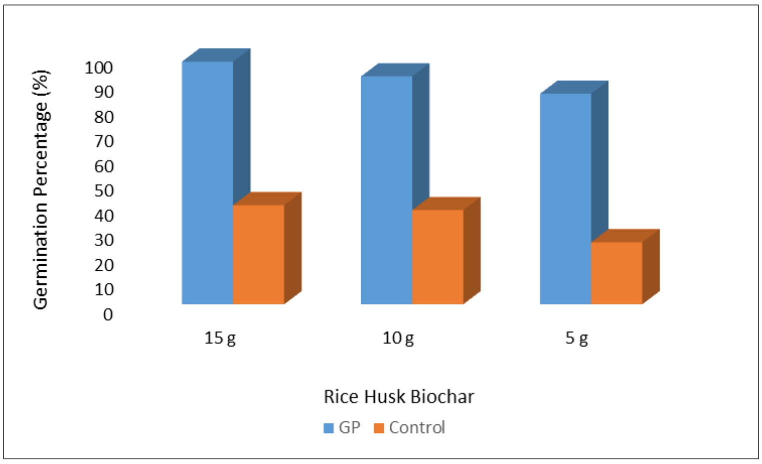

Figure 5 Effect of RHB on Germination of Stored Maize

The control recorded the lowest percentage of germination for the three treatments at 40 %, 38 %, and 25 % respectively. This indicates that the higher the concentration level of the RHB, the higher the germination percentage of the stored maize. In a related study, Sintim and Ansah (2023) also discovered that a higher biopesticide on stored grains improves their germinability. They corroborated the result that the higher the concentration level of the biopesticide, the higher the germination percentage. This was also substantiated by Gariba *et al.* (2021) that an increase in the content level of biopesticide will increase the germinability of the stored grains. This is so since the *Sitophilus zeamais* had been incapacitated from attacking the stored maize.

3.5. The Analysis of Variance

The ANOVA results presented in Table 1 showed that RHB content level had significant effects on all the dependent variables, susceptibility index, mortality rate, grain weight, and germination percentage at $p \leq 0.05$.

Table 1 ANOVA. Effect of RHB on *Sitophilus zeamais* attack on stored maize

Dependent Variables	SS	df	MS	F	P-value	F crit
Susceptibility Index	6492.667	2	3246.333	42.2211	0.000292*	5.143253
Mortality Rate	8037.556	2	4018.778	193.4171	3.56E-06*	5.143253
Germination Percentage	10548.67	2	5274.333	118.3766	1.51E-05*	5.143253
Grain Weight	159.9022	2	79.95111	6.742504	0.029198*	5.143253

*Significant at p-value ≤ 0.05

4. Conclusion

The effect of Rice Husk Biochar (RHB) as a biopesticide against *Sitophilus zeamais* in stored maize was successfully investigated at the demonstration farm of the Agricultural Technology Department of Federal Polytechnic, Ile Oluji, Nigeria. The result of the study showed that RHB significantly reduced the population of *Sitophilus zeamais,* with increased mortality rates observed at higher concentrations of RHB. This was the same observation for the susceptibility index, grain weight, and germination percentage. The findings from this study suggest that RHB has the prospective as a biopesticide for managing *Sitophilus zeamais.* It is recommended for use by peasant farmers who may not have the capital for synthetic pesticides since RHB is sustainable and environmentally friendly. Further research is ongoing to compare this study RHB with synthetic pesticides and to substitute RHB with other bio-waste as a biopesticide against *Sitophilus zeamais.*

Compliance with ethical standards

Acknowledgment

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Disclosure of conflict of interest

There is no conflict of interest to be disclosed.

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