



Research Article

Insecticidal Activity of Diatomaceous Earth against *Sitophilus zeamais* in Stored Maize Grains

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ABSTRACT

Sitophilus zeamais (Maize weevil) is an insect pest that has a global distribution and causes post-harvest losses that plague African agriculture, threatening food security and economic development. Despite this challenge, natural products can provide sustainable solutions. This paper aims to explore the Diatomaceous earth's insecticidal potency as natural alternative to chemical pesticides against the weevil by laboratory experimentation, on a 14-day exposure trial. The study involved the use of three (3) replicates at treatment doses of 0.5 g/kg, 1 g/kg, and 1.5 g/kg for diatomaceous earth. Forty (40) mature *S. zeamais* were exposed in each jar containing 50 g of the treated maize in dose replicates of the powder for 24 h on days 3, 7 and 14. Results showed that mortality was 100% and dose-dependent, except at 0.5 g/kg (96.52%), and there was also a significant difference in mortality rates of the weevil across all treatments ($P < 0.05$). Following exposure to the powder, the maize weevil's decreasing LC50 of 0.377 g/kg confirms its effectiveness in killing the weevils. By exploring this natural pest control product tested within laboratory settings, we recommend further studies on the use of Diatomaceous Earth powder on mammalian toxicity, field validation, as well as farmers' application of the powder as a grain protectant in storage against the weevil.

Keywords: Diatomaceous earth; Insecticidal activity; Maize; Post-harvest loss; *Sitophilus zeamais*

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INTRODUCTION

The primary cause of the major issues with maize storage is insect infestations (Kebede *et al.*, 2024). The maize weevil (*Sitophilus zeamais*) Motschulsky (Coleoptera: Curculionidae), is a pest bug that has spread throughout the world and damages stored cereals, including maize grains. While an infestation may start in the field, most damage occurs in storage, leading to post-harvest losses because both adults and larvae consume grains internally (Jean *et al.*, 2015; Suleiman *et al.*, 2015). Although losses are typically 4–5%, severe infestations of these pests in stored maize can result in weight losses of 15–30% in developing nations such as Nigeria (Bergvinson, 2021). Maize weevil, *S. zeamais* has been identified as one of the most significant maize pests in Europe

(Trematerra *et al.*, 1999), Asia (Peng, 2024) and USA (Arbogast & Throne, 1997).

In the past, the weevil was controlled with dichlorodiphenyltrichloroethane (DDT), malathion, pirimiphos-methyl, pyrethroids, and other chemicals which often led to resistance and other negative effects (Jean *et al.*, 2015). Research on alternative suppression techniques has focused on the use of various inert dusts, however, there is paucity of information on the performance of diatomaceous earth (DE) formulation under laboratory condition (Athanasios *et al.*, 2011). Diatomaceous earth alone and expanding its use with other items showed the high efficacy of non-chemical methods (Marina *et al.*, 2023). This study's objective is to explore the diatomaceous earth's bio-potency as a natural alternative to chemical pesticides against the weevil.

MATERIALS AND METHODS

Laboratory location

Two locations were used for the experimental investigation. The Federal University of Lafia's Zoology Department laboratory in Nasarawa State, Nigeria, was the location where all the bioassays were conducted, between the months of July and September, 2025. The proximate analysis was carried out in the Chemistry Department, Federal University of Lafia, Nasarawa state, Nigeria.

Study Design

The study used a contact toxicity test *in vitro* to assess the insecticidal effectiveness of DE powder against the maize weevil on stored maize grains.

Diatomaceous earth (DE)

Fossil Field 90.0 fine brownish powder was the DE used; it contained amorphous silica particles ranging in size from 5 to 30 µm, and batch number is 240815. The percentage composition of each ingredient is: 73% amorphous SiO₂, 2% water, 3% alumina, and other mineral compounds (Fossilfield company, Bein GmbH, Eiterfield, Germany).

Chemical composition of diatomaceous earth

The composition of DE are the percentage composition of alumina, water content, and silica which was obtained from the product label.

Insect culture and treatment of maize grains

The first *S. zeamais* population was acquired from infected maize grains that were bought from Lafia Modern Market, and adults of *S. zeamais* were obtained and identified by entomologist from a colony kept in the Applied Zoology Laboratory of the Federal University of Lafia. Insects aged between 7 to 14 days were used for all bioassays with maize as substrate. Freshly harvested, uninfested maize varieties were acquired from the College of Agriculture, Lafia, and kept for three hours in ambient laboratory settings (20–29°C, 59–90% rh) before being allowed to cool for an additional hour. The maize Shaba variety was identified with the Department of Agronomy, Faculty of Agriculture, Federal University of Lafia, and kept in a freezer at -4°C for seven days in order to kill hidden infestation and the initial grain moisture content was 12.65%, measured using an Insto Moisture Tester (Insto, Auburn, IL, U.S.A.). After being added to the uninfested (sterilised) maize grains and given time to oviposit, the adults of the original population of *S. zeamais* were taken out. A second jar of recently collected maize seeds was filled with the emerging adults (F1). This is to guarantee that the F1 adults used as the experiment's culturing stock are of the

same age and size. According to Masuda *et al.* (2004), the insect culture was maintained at a temperature of 27 to 29 oC and a relative humidity of 70 to 80%.

Insecticidal efficacy test

Fifty gram (50 g) of maize was weighed and placed in each glass jar containing three replicates each of 0.5 g/kg, 1 g/kg, and 1.5 g/kg of diatomaceous earth for the insecticidal test. Control experiment was untreated maize with insects.

Adult mortality test and F1 progeny suppression

Forty (40) mature *S. zeamais* were exposed in each jar of the treated maize in three replicates of the powder, and kept in a completely randomised design, the treatments were placed on a shelf at laboratory conditions (23.7±1.87oC, 59.0±7.63 RH.). F1 parents were removed before counted within 7 days post-infestation. Within 24 hours and on days 3, 7, and 14 following treatment, insect mortality was noted. To guarantee that the dusts were evenly distributed throughout the grain mass, each jar was shaken by hand for five minutes (Nukenine *et al.*, 2007).

Examination of insect population decline and grain damage reduction

Similar concentrations of the powder used in the previously stated toxicity test were considered for 50 g grains. Forty (40) adult insects were placed in each jar of treated or untreated grains at storage condition of 27±2°C; 70±5% RH. Each procedure was performed three times. Two weeks after storage, the number of live and dead insects in each jar was determined. Grain damage was assessed through sorting and counting of damaged and undamaged grains from the 50g of sampled grains and measuring the perforated and non-perforated grains as well as calculating the percentage of weight loss (Schulten *et al.*, 1978) as follows:

$$\frac{(UuNd)-(UdNu)}{Uu(Nd+Nu)} \times 100$$

Where;

Uu = Weight of undamaged grains;

Nu = Number of undamaged grains;

Ud = Weight of damaged grains;

Nd = Number of damaged grains

Assessment of persistence of DE on maize grains

Twenty (20) mature fresh insects were introduced after 7 days of treated grains in storage and were exposed to the treated maize (same order as previously mentioned for bioassay above) (Obeng-efori *et al.*, 2005). Persistence of dust on grain was evaluated by counting the live and dead weevils and the mortality was evaluated within 7 days of re-treatment, using the formula:

$$\frac{\text{Number of dead weevils}}{\text{Total number of weevils}} \times 100$$

Data analysis

The variables (% cumulative corrected mortality, % reduction in F1 progeny, % grain damage, % weight loss and % persistence) were arcsine-transformed [$\sqrt{x/100}$] and the number of F1 progeny produced was log-transformed ($x + 1$). Analysis of variance (ANOVA) approach was applied to the converted data using the statistical analysis system (Finney, 1971). Statistical software and version used are SPSS/R using shapiro-wilk test to check for normality of residuals, and homogeneity of variance was also checked using levene's test in SPSS. Abbott's Formula (Abbott *et al.*, 1925) was used to adjust for more than 5% control mortality before ANOVA. Tukey's test ($P=0.05$) was used for mean separation, and Probit analysis (Zar, 1999) was used to determine the lethal content (LC) causing 50% (LC50) mortality of *S. zeamais* following treatment application. Level of Significance was set at $P<0.05$.

RESULTS

Chemical Composition of Diatomaceous earth

The primary composition of DE as indicated by the commercial label is shown in Table 1.

Determination of lethal concentration of DE (LC50)

When it came to reaching a 50% mortality rate, the dose had the efficacy in reaching a 50% mortality rate, as indicated by the LC50 value of 0.377 g/kg at a lowest dose of 0.5 g/kg.

Mortality Effects of DE powder against the Weevil

DE at initial dosage exposure of 0.5 g/kg resulted in 95.52% *S. zeamais* mortality. However, at the fourteenth day of treatment, the weevil's maximum mortality from the highest studied doses (1 g/kg and 1.5 g/kg,) was 100%.

Effects of DE powder on F1 progeny suppression

Progeny emergence was significantly decreased at the initial dosage (0.5 g/kg) in comparison to the control, and this effect was dependent of dosage (Table 4). At this lowest dose level of 0.5 g/kg, DE inhibited the emergence of F1 progeny by 16.67, while it increased to 33.33 and 44.44% at 1g/kg & 1.5 g/kg, respectively.

Effects of DE on insect population, progeny reduction of grain damage suppression and weight loss

With treated samples showing fewer damaged grains than the control, all the treatment groups considerably decreased grain damage from the weevil infestation (Table 4). For instance, weevil damage was prevented (0.33%) by D.E. at a dose of 1.5g/kg, 2.66% weight loss was seen at the tested dose of DE, while 74.77% of the negative control group experienced the same weight loss (Table 4).

Effects of Persistence of DE powder on maize grains 7-days post-treatment

The overall efficacy of D.E decreased 7 days post-treatment at the lowest dose (0.5 g/kg) with 96.67% mortality potency. This suggests that dose appears to influence insecticidal efficacy, as the potency of D.E. remained constant at the highest tested dose rates of 1g/kg and 1.5 g/kg respectively.

Table 1: Chemical Composition of DE

Parameter	Content in DE (% w/w)
Moisture Content	2.00
Fixed Carbon	-
Volatile matter	-
Amorphous silica (SiO ₂)	73.00
Alumina	3.00

Table 2: Lethal Concentrations of DE Powder for Day 1

Treatment	Slope $\pm$ SE	χ^2	LC50 (95% CL)
Diatomaceous earth	20.922 $\pm$ 0.345	0.971	0.377g/kg (0.436; 0.622)

The L-values were obtained by extrapolation.

*df=3; P=0.25

Table 3: Lethal Concentrations of DE Powder for Day 14

Treatment	Slope $\pm$ SE	χ^2	LC50 (95% CL)
Diatomaceous earth	20.652 $\pm$ 4.740	0.692	0.456g/kg (0.398; 0.521)

The L-values were obtained by extrapolation.

*df=3; P=0.361

Table 4: Percentage mortality, Progeny suppression, Damage reduction, Weight loss and Persistence of DE (7days post-treatment)

Treatment groups	%Mortality	%Progeny suppression	%Damage	%Weight loss	%Persistence
Control	0±0**	0±0**	64.67±2.03*	74.77±2.9*	0±0**
DE0.5g/kg	95.52±0a	16.67±16.67c	2.33±0.33a	2.66±2.12b	96.67±1.67
DE1g/kg	100±0a	33.33±33.33b	0.33±0.67a	4.34±3.97a	100±0a
DE1.5g/kg	100±0a	44.44±5.56a	2.67±0.33b	9.09±2.52c	100±0a
F	1073.59*	2.496*	215.029	39.365*	3308.05*
Df	29**	29**	29**	29**	11*
P-value	0.07490*	0.316*	0.3572*	0.2195**	0.298**

*= Mean ±SE followed in same lines and a column differ significantly at 0.05 level (Tukey's test)

**= Mean ±SE followed in same lines and a column do not differ significantly at 0.05 level (Tukey's test)

DISCUSSION

Pest infestation is a significant contributor to post-harvest losses that affect stored maize grains (Odogwu, 2020). Furthermore, the effectiveness of diatomaceous earth (DE) in killing the weevils in this study could help reduce maize losses, by controlling the weevil. Findings from this study revealed that DE led to a high weevil mortality of adult *S. zeamais* within 14 days at dosage rate of 1.5 g/kg. Thus, the increase in the amount of physical abrasive and desiccating action in the insecticidal materials may be the cause of the rise in adult mortality as exposure duration and dosage increased (Gwinner *et al.* 1996). This is also comparable to the findings of Mewis and Ulrich (2001), who found that after seven days of exposure, Fossil Shield dramatically decreased the survival of adult *Tribolium castaneum* and *Tribolium molitor*. As a result, the duration of exposure is essential for DE's efficiency since insects' movements enhance the cuticle's interaction with dust particles (Athanasios *et al.*, 2005).

With the exception of 0.5g/kg, DE caused complete mortality starting on the seventh day after treatment. This is in line with the findings of Demissie *et al.* (2008) who observed the same pattern against *S. zeamais* using a different commercial DE formulation (Silicosec). These authors claim that at 1% and 2% exposure rates, Silico Sec eradicated 100% of *S. zeamais* in a 7 days. Further, Mortality of weevils from DE may be due to dehydration caused by the abrasiveness of the small particles of this inert dust and the adsorption of oils in the insect's body (Field *et al.*, 2000). This causes the epicuticle's wax covering to disintegrate, which worsens the fatal water loss (Subramanyam *et al.*, 2000).

According to Abraham *et al.* (2012), DE decreases the number of offspring by lowering oviposition, ovicidal, and larvicidal activities, as well as raising adult mortality. This is in agreement with this study where

a high progeny inhibition at the highest DE content (1.5g/kg) was recorded. Thus, higher percentage of progeny suppression observed at 1.5 g/kg compared to lowest at 0.5 g/kg may be attributed to adult deterrence and rapid mortality before oviposition, coupled with clumping of grains which provided oviposition refugia. This trend has also been reported for DE against other *Sitophilus zeamais* that the dust might have limited the number of offspring by preventing emergence (Arthur and Throne, 2003). In addition, the DE powder sprayed at a rate of 20% inhibited bruchid reproduction for a 39-week storage period, according to Baier & Webster (1992).

In terms of weight losses, proportion of damaged maize grains, and insect population increase, there is observed reduction across all the three treatment replicates compared to control. The effectiveness of the insecticidal substance in terms of % weight loss, % damage and % population decrease was dependent on the dosage and storage duration. This is in line with the study conducted by Mewis (2007) that each plant material's insecticidal properties would be determined by its active ingredients and dosage concentration.

This study also showed that pesticide persistence was correlated with exposure duration and increased with storage duration. Seven days after treatment, DE proved its effectiveness in mortality over an extended period of time. This is in line with findings of Khakame *et al.* (2012), who found that Dryacide dust, a DE formulation, successfully shielded stored maize grain from *S. zeamais* for 15 days. This suggested that determining the potency of every pesticidal substance employed for grain storage, followed by the insecticide's retention in grains, was essential.

CONCLUSION

This study revealed that the DE powder has demonstrated its insecticidal potency which led to a

high weevil mortality rate of 100% against *S. zeamais* within 14 days. This makes DE a viable and natural alternative to chemical pesticides which could offer a promising laboratory-tested option that requires field and storage condition validation. In addition, its potency in suppressing progeny to as low as the dosage concentration of (0.5g/kg). Furthermore, its effectiveness in reducing grain damage to as low as 0.33% within the laboratory settings can be tested for field and storage validation.

The use of diatomaceous earth is recommended because, it increases the insecticidal efficacy in killing the weevils at all dosages (0.5g/kg, 1g/kg and 1.5g/kg) within the treatment period of two (2) weeks. More research is required to determine whether using the DE for grain storage poses a risk of toxicity to mammals. Further testing under real storage conditions, safety assessment, grain quality, as well as farmer level application of DE is recommended.

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