

**EVALUATION OF AFRICAN DIATOMACEOUS EARTHS (DEs) AS  
POTENTIAL MAIZE GRAIN PROTECTANTS AGAINST THE MAIZE  
WEEVIL  
(*SITOPHILUS ZEAMAI*S )**

**By**

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**A thesis submitted in partial fulfillment of the requirements of the Bachelor of  
Science Honours Degree in Agriculture.**

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## **ABSTRACT**

Six diatomaceous earths (DEs) samples were evaluated for efficacy in the laboratory under controlled relative humidity and temperature of  $65 \pm 5\%$  and  $27 \pm 2$  °C respectively against the maize weevil (*Sitophilus zeamais*). Each DE sample was applied at rates of 0.10, 0.25 and 0.50gDE/100g maize grain and an untreated control was also set to allow for comparison. The efficacy for each sample was compared to the control and likewise to other samples under study. Bioassays were conducted on 100g pesticide free white maize grain using 50 unsexed, 15 days old *Sitophilus zeamais* species reared under controlled conditions. Mortalities were assessed after 7, 14 and 28 days of insect exposure to DEs. No insects survived the 28 day exposure in all the treatments and only a small population emerged after 7 weeks in the treated grain than in the untreated control treatment.

The efficacy of diatomaceous earths on *Sitophilus zeamais* varied within the same DE samples. Sample B was the most efficacious as it achieved 100% mortality just after 7 days of insect exposure to DEs and had the least mean number of adult emergent insects. Sample D only attained considerable mortality after 28 days and had the highest number of F1 generation after 7 weeks. In all the samples highest mortality was achieved at 0.50gDE/100g grain application rate although for sample B even 0.10g DE/100g grain attained 100% mortality after 7 days of insect exposure. Diatomaceous earths dust, particularly sample B, have potential as grain protectants. Field trials are required to confirm these laboratory findings.

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## **CHAPTER ONE**

### **INTRODUCTION**

#### **1.1 Background.**

Diatomaceous earths (DEs) are geological deposit consisting of the fossilized skeletons of numerous species of siliceous marine and fresh water unicellular organisms, particularly diatoms which are the most widespread group of plants on the earth with more than twenty five thousand species of different morphologies (Desmarchelier and Dines, 1987).The different species of diatoms extract silicon from water to produce a hydrated amorphous silica skeleton which sink to the bottom when the diatoms die and over centuries these shells form thick layers which when fossilized and compressed give rise to a layer of soft-chalky rock that is termed diatomaceous earths (Quarles and Winn, 1996).

On extraction of the soft chalk rock, it contains 50% or more moisture content with between 86 and 94% silica (Quarles, 1992). Upon processing of the raw material the moisture content is reduced to between 2 and 6%.Particle size is also reduced by crushing or milling and sieving a process known as pulverizing which reduces particle size to between 0.5 and 100 micrometers (Quarles, 1992). Crushing is done so as to increase the insect chances of picking up the dust. Drying allows ability of the dust to adhere to grain coat and insect cuticle.

DEs vary in colour depending on composition from white grey to yellow red with amorphous silicon dioxide being the active ingredient.

Research on the efficacy of DEs has been done on numerous insects such as ants, textile pests, termites, poultry mites and ticks (Snetsinger, 1982). Different and often completely opposite results were obtained but however, there was a general conclusion that can be drawn from these conflict results. The sensitivity of stored product insects to DEs varies with species. Pest in the genus *Cryptolestes* being more sensitive and *Sitophilus* species less susceptible followed by *Rhyzopertha dominica* and *Tribolium* species which appear most in almost any dry interior environment, including empty grain storage containers, bins and elevators (Quarles Winn, 1996). Typically, it is used for crack and crevice treatment but can also be used on surfaces as long as it stays dry. DEs either repel or kill insects that come in contact with them on dry surfaces.

## **1.2 JUSTIFICATION**

### **1.2.1 Advantages of using DEs over synthetic pesticides.**

DEs are extremely stable and do not react to leave toxic chemical residues on treated produce thus have no health problems to the final consumer of the treated grain. Winnowing, a physical process removes about 98% of the dust from the treated grain (Desmarechelier and Allen, 1999). Synthetic

insecticides usually leave some residues even after processing thus causing some health concerns hence they are being replaced by the inert dusts.

DEs are gradually replacing some synthetic insecticide such as pyrethroids and organophosphates due to the development of resistance against them by several stored product insects. Synthetic insecticides affect the nervous system of the insect while DEs only cause a physical effect on the concerned insect's cuticle. Quarles and Winn (1996), indicated that there were no crawling insects where DEs had been exposed on the earth's surface.

### **1.2.2 African Diatomaceous Earths.**

Synthetic insecticides are usually imported using valuable foreign currency, which is usually scarce in developing nations like Zimbabwe. Availability of synthetic insecticides is not certain during peak periods and they require skilled manpower for application after purchasing them at higher prices. With the DEs from regional deposits as grain protectants in farm stores of Africa, their potential low costs, readily availability and easiness to use, they are to be common to many farmers and grain dealers. DEs geological deposits occur in the region from Tanzania, Kenya, Zambia, South Africa and Zimbabwe hence minimum foreign currency will be required compared to importing other dusts and synthetic insecticides mainly from overseas. The efficacy of DEs from different sources on insects is not the same (Snetsinger, 1998) but depends primarily on the physical

properties of the dust other than the chemical traits of the inert dusts. For instance, DEs from marine sources are more common but less efficacious (Korunic, 1998). Using locally available DEs would enable farmers to select the best dust and at reasonable cost.

### **1.1.3 Test insects.**

*Sitophilus zeamais* is a major pest for whole cereal grain and some solid cereal products such as pastas thus forcing many Saharan farmers to sell their stored produce prematurely in fear of deterioration. In Zimbabwe, it is the most notorious and common pests that causes uncertainty in food security since sadza from maize is the staple food of the country (Giga *et al.*, 1992)

### **1.1.4 Laboratory bioassay.**

This mode of investigating efficacy of diatomaceous earths samples in the laboratory enable studies to be carried out more closely than in the wide field where environmental conditions fluctuate. Fluctuations may cause variations and give firm fewer conclusions as mortality might be due environmental factors other than the inert dusts effect on the epicuticle. Laboratory bioassays also enable screening of the less efficacious samples before time and resources are wasted by taking none or less efficacious samples into the field. Lethal dosage rates could also be determined at laboratory level to avoid wastages and under doses.

## **OBJECTIVES**

The overall objective was to evaluate some African DEs as potential grain protectants against *Sitophilus zeamais* on threshed maize through bioassays.

The specific objectives were;

- i. To evaluate effectiveness of African DEs against *Sitophilus zeamais*.
- ii. To establish optimum application rates of the DEs.
- iii. To assess the effect of DEs on *Sitophilus zeamais* oviposition.

## **Hypothesis**

- 1 Regional DEs are efficacious against *Sitophilus zeamais*
- 2 DEs have the same lethal effect regardless of dosage.
- 3 DEs affect oviposition and further development of the insects.

## **CHAPTER TWO**

### **2.0 LITERATURE REVIEW**

#### **2.1 Diatomaceous Earths mode of action.**

The dust is physically stable and will affect insects as long as it stays dry and in sufficient concentration to ensure that the insect is in contact with the DEs. The inert dusts have certain abrasive properties and often after pulverizing, particles size is reduced to between 2.5 and 3.0 micrometers (Korunic, 1997). All particles contain very small inner pores which have the physical ability to absorb wax (lipid) molecules from the epicuticle of the insect in contact resulting in water loss, dehydration and death (Quarles and Winn, 1996). DEs, since they are dusts also tends to repel crawling insects wherever they are exposed on the grain and anywhere on the earth's surface.

#### **2.1.2 Factors affecting efficacy of DEs.**

Factors affecting insect desiccation are likely to affect the efficacy of DEs and these include temperature, humidity, grain moisture content, type of insect, grain type and the length of the storage period.

Surface area on which the dust covers is also an important factor, hence the need to thoroughly admix the grain and the dust to enhance more chances of the insect contacting the dust (Quarles and Winn, 1996). Grain moisture content should be less than 14.5 % moisture content so that the

insects will not have a constant source of water to replace losses due to DEs action of dehydrating the insect. Higher relative humidity affects DEs efficacy in the same way as higher grain moisture content and higher temperatures make DEs more effective as it enhances water loss from the insect cuticle to cause dehydration and death (Korunic, 1996).

The higher the concentration of DE applied to the grain the more effective it will be. This is because since much dust is applied to cover containers and grain surface there will be greater chances of the insect picking up the dust to cause enough damage. Also the grain type matters much since for the DEs to work effectively they should first adhere onto the grain surface where it will be easily picked up by the mobile insect cuticle to cause desiccation (Quarles 1992). Rough and wider surfaced grains have high adherence as in the case of maize, smaller and smooth surfaced grains like millet have low adherence.

### **2.1.3 Resistance of insects to DEs.**

Quarles and Winn, 1996 indicated that there are no crawling insects where DEs are exposed onto the earth's surface since insects avoid such areas because the dust repels the insects also. Physical properties of the inert dust make it more effective since resistance is not likely. Silicon dioxide and other trace metal oxide in DEs, do not, like chemically active insecticides interfere with metabolic or enzymatic functions hence no resistance have been documented so far (Quarles and Winn, 1996). DEs

with higher silicon dioxide (SiO<sub>2</sub>) content of even above 80% does not necessarily mean that it is more effective (Fields and Muir, 1996).

#### **2.1.4 Merits of DEs as stored product protectants.**

DEs leave no chemical residues on treated products thus pose no health problems after consumption by man since the inert DEs are non toxic even if consumed by mammals. There is no evidence of any acute or chronic toxicity. If livestock feed is treated with DEs at 1 to 2% and given to cattle and poultry, internal parasites are controlled (Allen, 1972). The inert dust can be applied to grain silos for on-going protection (Quarles and Winn, 1996). Below 300 ppm DEs have no adverse effects on grain milling or baking qualities other than synthetics that need proper handling and processing to avoid toxicity to both workers and the final consumer of the treated grain (Korunic *et al.*, 1996).

DEs work by physical mode of dehydrating the insects by adsorbing the insect's epicuticle (Korunic, 1996) since stored grain pests only depends on metabolic water will die due to dehydration. This mode of killing and the insect's status posed no resistant of the insect pest to the inert dust. DEs are chemically stable and they are likely not to dissipate over time compared to the synthetics that have their efficacy diminishing with time (Allen, 1972).

Locally available DEs will be relatively cheaper compared to synthetic insecticide which even degrade with time and must be repeatedly applied to



achieve long term protection. Amorphous silica applied as an aqueous slurry has potential for structural treatment to control populations of stored grain insects resident in bulk grain storage facilities like silos and granaries thus offering a cheaper and convenient treatment both during and after storage (Bartlett, 1951).

### **2.5 Demerits of DEs as stored product protectants.**

On admixing, DEs produces dusts which if inhaled by the worker contain crystalline silica which can cause silicosis and other respiratory diseases such as emphysema and pneumoconiosis (Golob, 1997). DEs also cause irritation of the eyes, lungs and skin when splashed during handling and admixing. Care thus should be taken to purchase and wear respiratory masks together with rubber gloves to prevent skin contact that will cause irritation. Excessive amounts of the dust are required, so their use remains confined to small scale use only, particularly for the preservation of small quantities of seed grain in communal areas granaries (Golob, 1997). Berrato *et al* (1983), in laboratory studies with beans in Brazil and Golob *et al.*(1982), in small scale stimulated field with maize in Malawi showed that, dolomite at lower application rates of 1% (w/w) or less could protect the grain community against insect pests damage just as higher DEs dosages (Korunic, 1996).

## **2.2 *Sitophilus zeamais***

### **2.2.1 Introduction**

*Sitophilus zeamais* (maize weevil) belongs to the order Coleoptera, family Curculonoidae.

### **2.2.2 Biology**

The female weevils bores a hole into the grain, deposits an egg and covers it with a gelatinous fluid that seals the oviposited hole for protection as it waits to hatch (Hall, 1970). The egg hatches within a few days into a soft, white, legless grub (larvae), which feeds on the interior of the grain kernel. The larva lives entirely within the kernel, producing powdery excreta, which makes the grain unpalatable. Only one larva normally lives within the kernel as the existence of more than one will result in cannibalism (Hall, 1970). Pupation and exclusion occurs within the grain and the adult insect emerges and then moves out of the grain kernel. It lives for a period of four to five months during which each mature female lays between 300 and 4000 eggs during its life cycle. The minimum life cycle of the maize weevil is about 28 days under favourable environmental conditions, that is temperature of 27 °C and relative humidity of 65% (Hill,1987),which was maintained in the incubator.

### **2.2.3 Distribution and ecology.**

The maize weevil is found in both tropical and temperate areas, thus it is a cosmopolitan pest of grain inside grain stores in temperate regions. Harney (1993), indicated that maize weevils are abundant in areas with optimal temperatures of between 24°C and 30°C and relative humidity around 65% during the storage period. Conducive environment for the insect to oviposit and multiply during the storage period enable it to damage grains and seeds of a number of products including sorghum and millet (Giga *et al.*, 1992).

### **2.2.4 Economic importance of the maize weevil.**

The maize weevils (*Sitophilus zeamais*) is a serious pest of many stored grain particularly maize in the warmer parts of the world .It also pose serious problems to small grains such as millet, sorghum and wheat (Smith, 1997). It is a primary pest that is able to penetrate the intact testa of grains to cause loses in grain weight during storage. Infested grains have less weight and would be a disadvantage to the farmer and grain dealer where grain is sold in accordance to weight (Giga *et al*, 1992). The presence of insects in a grain sample will cause cash discounts, as the grain will be assigned to a lower grade on the market. Insects induce direct damage on stored produce resulting in reduction in nutritional value, seed viability and commercial losses (Hill, 1987).

They also cause heating due metabolism lead to the development of 'hot' spot, a condition not desirable for the grain. The moisture from insect bodies condenses on the cool grain at the edge of the hot spots resulting in caking, fungal development and also germination of the stored grain (Hill, 1987) which may cause total rejection of the grain for human consumption.

Infestation of the grain by the weevils also leads to the addition of the fatty acid content of the grain and quantities of uric acid which cause grain rancidity (MacDonald, 1989). Fines and broken kernels created by the weevils during feeding reduce airflow through the grain and prevent proper aeration resulting in deterioration of the stored produce (Hill, 1987)

### **2.2.5 Management of the weevils.**

Smallholder farmers are receptive to methods of conservation of stored products that lie within their technical and financial means. Accumulated research and development efforts over several years in sub-Saharan Africa have produced a variety of post harvest protection before the grain is infested in the field. Proper drying to reduce moisture content and store hygiene are stressed in work done on maize weevil management by Hall (1970). Natural plant products with potential antifeedent, repellents and insecticidal action, synthetic insecticides were all evaluated of their efficacy against *Sitophilus zeamais* and have proved to be of somewhat impotency

though the cheaper and locally available may be of much benefit against the notorious pest as it give long term protection (Hall, 1970).

## CHAPTER THREE

### GENERAL MATERIALS AND METHOD

#### **3.1 Laboratory culturing of *Sitophilus zeamais*.**

The maize weevil was reared by placing unsexed adults in glass consul jars of 100g capacity filled three quarter way with pesticide-free white maize collected from Buhera District of Zimbabwe's Natural Region 3. The jars were not filled to the brim to allow for free air circulation for the respiring insects. Perforated lids inserted with a filter paper at the bottom to prevent foreign bodies from outside through the perforations were used to tightly close the labeled culture jars and where placed in a monitored incubator to be routinely maintained in the Entomology Laboratory of the Crop Science department at the University of Zimbabwe.

According to Hill (1987), at 28 days minimum weevil life cycle will be completed at temperature 27°C and relative humidity of 65%, so after this period all insects were sieved out thoroughly. The infested and oviposed grain was retained into the incubator at relative humidity 65± 5 % which was maintained by random placement of plastic jar filled with concentrated salt solutions. Temperature was maintained at 27±2°C, since the incubator was thermostatically controlled this was easy to monitor. After a week, all the emerged insects were removed by sieving and introduced to fresh pesticide free grain for another week to set healthy and vigorous insects for the study and of known age.

### **3.2 Grain source and quality.**

Uninfested, clean white maize grain was used for the study. In the laboratory, the grain was sieved to remove fluffy material and other foreign matter and placed in a deep freezer for at least 14 days to disinfect the grain from any insects that can be present. Grain was then removed from the freezer two weeks before the set up, allowed to defreeze and was preconditioned in plastic bags at about 27°C for two weeks in an incubator to allow the grain to acclimatise to the required experimental conditions (Russel, 1962). Relative humidity was also controlled by the use of saturated salt solutions randomly placed in the incubator as not to allow too much moisture content in the incubator which will decrease insect desiccation by the inert dust.

Prior to the experiment set up, the grain moisture content was determined by placing samples of known mass in an oven at 105°C for 72hours (Hill, 1987). Korunic (1996), indicated that for DEs maximum action grain should not provide a constant water source to the dehydrated insect thus moisture content should always be lower than 14.5%moisture content. The moisture content of the grain used in this study was 7.46% which was within the recommended region for DEs maximum action. Too low relative humidity was also avoided as it would affect the insects feeding thus would enhance mortality.

### 3.3 Grain treatment and sampling.

Glass jars of 100g capacity were disinfected and labeled accordingly before 100g of preconditioned maize grain was introduced. Each jar was labeled indicating the DE sample contained (DE samples were coded A-F) and the dust concentrations were replicated four times. Therefore, 76 jars were prepared and filled with 7500g (7.5kg) of preconditioned maize grain (100g in each jar) as summarised in table over leaf.

**Table 3.1 DEs treatments and their concentration.**

<b>DEs Samples</b>	<b>Treatments</b>
A — F	Concentration 1      0.10gDE/ 100g maize grain Concentration 2      0.25gDE/ 100g maize grain Concentration 3      0.50gDE/ 100g maize grain
G (untreated control)	0.00gDE/ 100g maize grain

A sensitive, wind free electronic balance model AE163 Mettler was used to weigh dust samples in the balance room of the Soil Science Department at the University of Zimbabwe. Precautions were taken not to splash the dust;



hand rubber gloves and a specified respiratory mask were worn to prevent inhaling the dust and irritation caused by the dust when on skin surface. A spatula was used to transfer the dust into the weighing bottle on the four decimal place balance, starting with the lowest concentration of 0.1gDE/100g maize grain.

Treatment G had no amount of dust added to it and served as the untreated control. Like all the other samples, it also had four replications and was subjected to the same conditions as all the other samples.

After addition of measured dust quantities to their respective preconditioned 100g of grain samples in labeled jars. Jars were tightly closed with the perforated lids covered at the bottom with filter papers to avoid foreign materials inside. Lids were tightly closed and the jars were thoroughly shaken by hands for two minutes to ensure complete admixing of the DEs and the grain. This was to ensure complete coverage of all grain surfaces to enhance insect chances of picking up the dust onto their delicate epicuticle (Golob, 1997).

### **3.4 Introduction of insects to the treated grain.**

After thorough admixing, 50 unsexed insects aged between 15 days were introduced with the use of a soft forceps and a hand tally for accuracy. Sieved insects were placed onto a clean tray, few at a time since the species are so mobile. Reserve containers were used to temporarily store the insect during counting, starting with only the more vigorous, healthier and mobile

ones. Reserve containers enabled the introduction of the insects to the treated grain almost at once to avoid variations.

Glass jars containing fifty unsexed adult insects, 100g grain admixed with the inert dust were randomly placed in an incubator. No jars were placed to the edges in the incubator; this was done to avoid edge effects. Relative humidity was maintained at  $65\% \pm 5\%$  by means saturated salt solutions (sodium chloride) in plastic trays randomly placed in the incubator. A wet and dry bulb thermometer was hung strategically in the incubator to provide a check against the digital thermometer built onto the incubator.

### **3.5 Insect mortality and progeny assessments.**

Test insects were exposed to the above conditions for a period of 7 days after which the first mortality assessment was done. This involved the counting and removal of all the desiccated insects. Sterilized trays; soft forceps together with hand tallies were used. Care was taken to retain all the live insects. Live insects were then returned in their respective jars together with the treated grain. Assessment was repeated at 14 days (dated from the beginning of the experiment). Much attention was given to the infested grain for some insects tended to hibernate in grain cavities. Numbers of dead and live insects were recorded and percentage mortalities calculated. Dead insects were discarded.

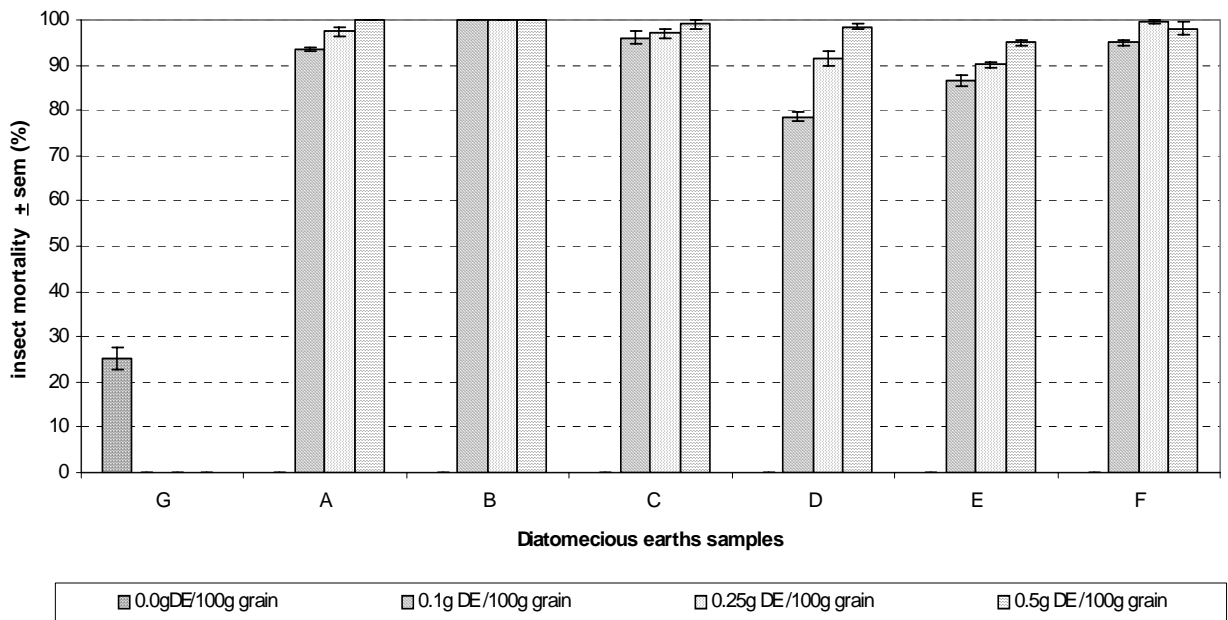
After 28 days of insect exposure to DEs, mortality assessment was done just as on day 7 and 14, after which the insects were removed (both dead and live) and placed in a freezer for discarding. Infested grain was returned into the incubator to allow for the oviposited eggs to hatch and develop. Progeny emergence assessment was then done after 7weeks.

## CHAPTER 4

### RESULTS

#### 4.1 Mortality assessment of the *Sitophilus zeamais* insects after 7 days of exposure to various DEs

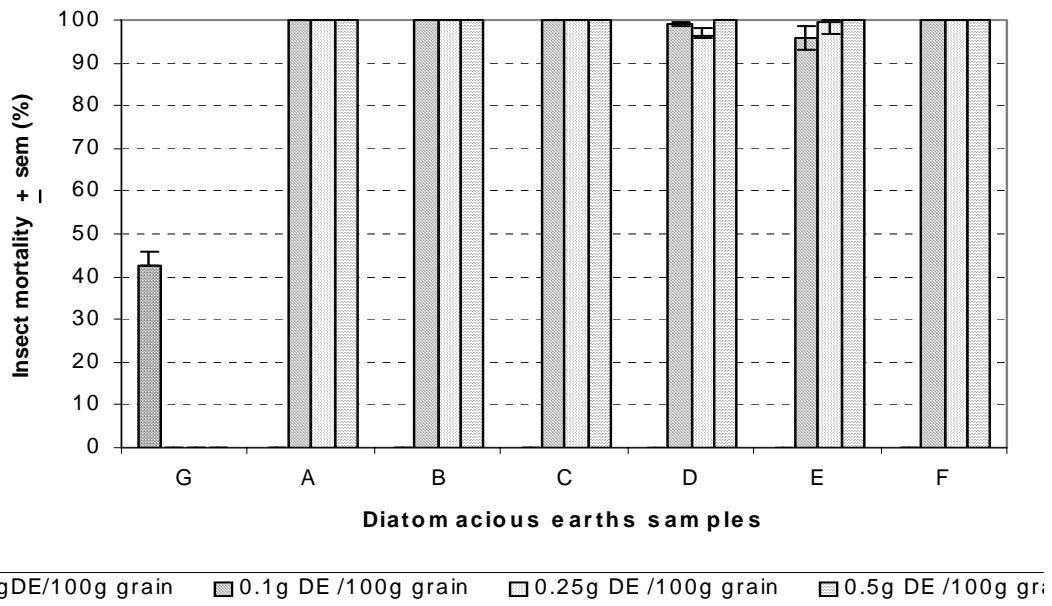
After 7 days of insect exposure to the diatomaceous earths (DEs) mortality was assessed and results are shown in Fig 4.1



**Fig 4.1** Mortality of *Sitophilus zeamais* ( $\pm$  sem)(%) after 7 days of exposure to various diatomaceous earths (n=4).

Mortality was varying within samples and also within the same sample between the concentrations as shown in Fig 4.1. Highest mortality was achieved at higher DE concentrations 0.50gDE/100g grain in almost all the samples and minimum mortality was attained were lower concentrations of DE were used. Lowest mortality after 7 days was 78 % when using a concentration of 0.10gDE/100g grain. Sample G untreated control had the least mortality of about 25%.

**4.2 Mortality assessment of the *Sitophilus zeamais* insect after 14 days of exposure to DE.**

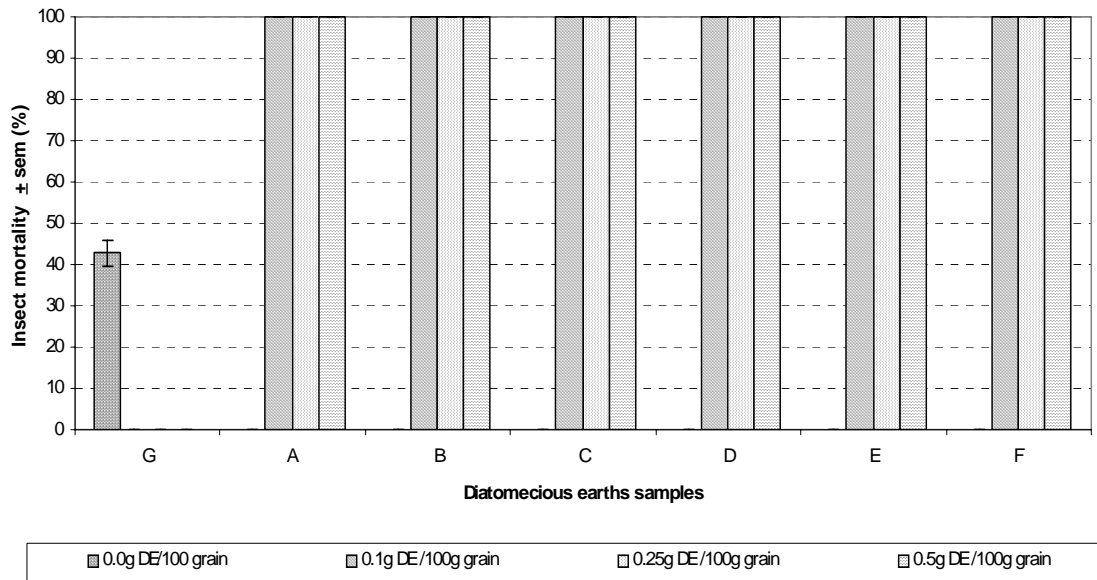


**Fig 4.2 Mortality of *Sitophilus zeamais* ( $\pm$  sem) (%) after 14 days of insect exposure to various DE samples (n=4)**

Mortality was increased with increased exposure time( Fig 4.2) .This was also true even within the different concentration of the different DE samples with most of the treatments reaching the maximum mortality percentages of 100%.However sample D and E did not reach 100 % mortality in the lower concentrations. Sample G untreated control had a considerable mortality increase but remained the lowest.

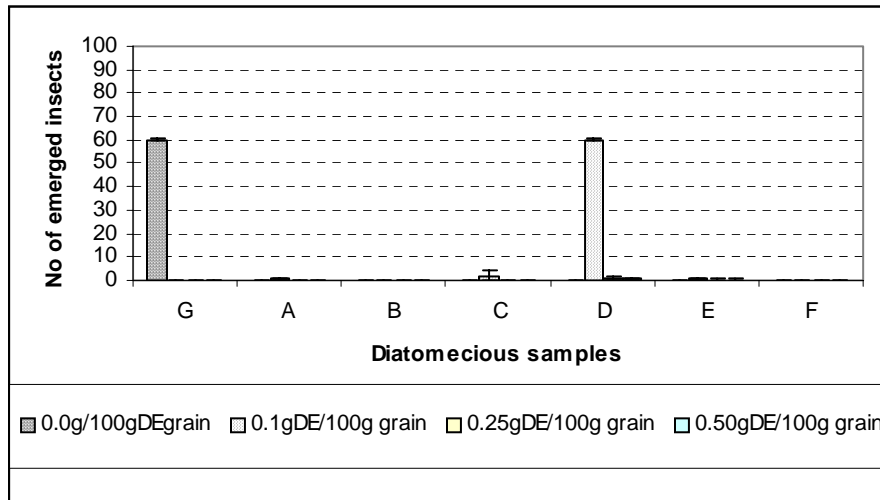
### 4.3 Mortality assessment of the *Sitophilus zeamais* insect after 28 days of exposure to different diatomaceous earths samples.

Highest mortality (100%) was attained with all DEs at all concentrations (Fig 4.3). Mortality in the untreated control remained constant after insect exposure to untreated grain.



**Fig 4.3** Mortality of *Sitophilus zeamais* ( $\pm$ sem) (%) after 28 days of insect exposure to different diatomaceous samples (n=4)

#### 4.4 Progeny assessment after 7 weeks of insect exposure to the various DEs



**Fig 4.4 Mean F1 adult *Sitophilus zeamais* emergence 7 weeks after grain treatment with various diatomaceous earths samples (n=4).**

After 7 weeks, dated from the beginning of the experiment more F1 adult emergence was recorded from sample D at the lowest concentration. In all the other samples, expect sample B, highest number of emerged insects were in the lower concentration treatment.

Appendix 1 shows the accumulated mortality percentages per DE sample at each concentration throughout the study period.



## CHAPTER 5

### DISCUSSION

The results of the study showed that DEs from different locations vary in their efficacy against *Sitophilus zeamais*. This was explained by Korunic (1996) that DEs from different geological locations have different efficacies. DEs from marine areas are the most common but less efficacious (Golob, 1997). Sample B attained the highest mortality even after just 7 days of insect exposure to the desiccant, a factor that will be advantageous to many small scale farmers and grain dealers since this would give protection to the grain all immediately after treatment using the lowest concentration (0.10g DE/100g grain). Sample C was also of much efficacy as it had also high mortalities of above 95% followed by sample F then Sample A. No mortality was expected in the untreated control, however reasonable mortality was recorded which was a result of other environmental abnormalities other than the dehydrating effect of the DEs, which were minimized for firm results to be obtained.

Mortality within the same sample also differed with respect to concentration; however the general trend was that higher DE concentrations of 0.50g DE/100g grain had the highest mortality in all the samples at all the assessed periods. The DEs only kill the insect through physical means of absorbing the insects epicuticle resulting in massive water loss from the insects body and since the insect only rely on metabolic water it will die of dehydration (Korunic, 1996). Therefore, the higher the DEs concentration, within a treatment the more the chances of the insects to pick up the dust and in sufficient amounts to cause desiccation to the delicate insect.

Conversely, farmers and grain traders strive to have maximum grain protection at the least possible cost at that moment, thus Sample B proved to be more cost effective since maximum grain protection i.e. high mortality was attained when using smaller DE doses (0.10gDE/100g grain). There will be no need for the farmer to apply higher doses of Sample B, which will be more costly if the same lethal effect can still be attained when using lower doses of the same DE sample.

Of main concern to the farmers and grain dealers is the duration of protection rendered by a protectant to the grain. During this study this was assessed by counting the number of F1 generation emerging 7 weeks after treating the stored grain with diatomaceous earth and in sufficient amounts. The least number of emerged insects was in grain protected using Sample B followed by sample C. Sample D had the highest number of emerged species. F1 emergence was a result of the initially introduced insects having the ability to mate and oviposit within the grain, a complex process that will only occur if the conditions are favourable. Effective dusts did not allow reproduction to occur since the insects got dehydrated before mating and oviposition occurred. Absence of the protectant in the control enabled insect population to increase as the insects were subjected to almost conducive environment for breeding.

At lower concentration, the insect might have felt the abnormally i.e. presence of the desiccant such that they would want to reproduce before death hence higher mean number of emerged insect. As concentration increased irritation within the test insects also increased

such that there was less or even no time for mating and oviposition as evidenced by lower mean numbers of emerged insects where lower DE concentrations were admixed.

## CHAPTER 6

### CONCLUSION AND RECOMMENDATIONS.

#### 6.1 CONCLUSION.

The study showed that African DEs can be potential maize grain protectants against the serious stored grain pest *Sitophilus zeamais* as they proved to be lethal to the insect by causing considerable mortalities at higher application rates. In some DEs samples for example sample B highest mortality was attained even at lower application doses.

Therefore, the source area of the desiccant should be known since not all diatomaceous earths attained the same mortality at the same application rates due to differences in DE's physical properties largely dependent on geological location of the DEs mine.

Higher application rates of about 0.50gDE/ 100g grain should be used as they achieved higher mortalities in almost all the samples .DEs are effective as they gave on- going protection to the grain .Diatomaceous earths affected the insects ability to reproduce thus have much effect on *Sitophilus zeamais* oviposition and the subsequent emergence of a new population

In conclusion the results of the current study showed that sample B can be recommended for commercial use as it was a more effective grain protectant than the other samples even at low application doses .Sample D should be discarded as it gave the least protection over the study period even when using higher doses which are less economic.

## **6.2 RECOMMENDATIONS.**

Local mines should be searched for as they will be more economic and processing firms should be established within the region particularly within our country. The commercial sector should adopt the use of this cheap and less health hazardous dust and come up with better formulations and application rates .However, a further study is required typical under field conditions the bioassay results only helped to screen the DEs samples and concentrations but only under controlled environment of temperature and humidity. Hence the laboratory findings need to be consolidated by further field studies.

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**APPENDIX**

**Table 4.1 Accumulated mean number of adult emergent insects per DE sample per concentration.**

<b>DE Concentration (DEg/100g grain)</b>	<b>Diatomaceous earth samples</b>						
	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	<b>F</b>	<b>G</b>
0.00	0	0	0	0	0	0	46.0
0.10	98.0	100.0	98.7	92.5	94.2	98.3	
0.25	99.5	100.0	99.0	96.0	96.5	99.8	
0.50	100.0	100.0	99.7	99.5	98.3	99.3	

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