BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

THE EFFECTS OF LEAD WOOD (*Combretum imberbe.* L) ON MAIZE WEEVILS (*Sitophilus zeamais*. L) IN STORED SORGHUM (*Sorghum bicolor*. L) GRAIN.

GANDIWA EVELIN TENDAI

B1335114

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE BACHELOR OF SCIENCE HONORS DEGREE IN AGRICULTURE (CROP SCIENCES).

JUNE 2022

DEDICATION

To my husband Luckson Chathlaza, my parents Mrs I. Gandiwa and the late Mr N. K Gandiwa, my brother Lawrence, my son Learnmore and my daughter Kupakwashe.

ACKNOWLEDGEMENTS

I would like to thank the Mighty God for his wisdom and protection throughout the entire course of my studies. I give my most sincere gratitude to my supervisors Dr T.J. Chikuvire and Ms A Kamota for supporting me during my period of study and for their time in editing this document. I want to extend my heartfelt gratitude to ZSAES staff for their assistance in carrying out my experiments at their laboratory.

Many thanks to my family for the support and encouragement which highly revered. To my friends Mutambara Victor, Chitonho Innocent you have been friends indeed. I thank you for your distinctive ideas.

ABSTRACT

Sitophilus zeamais. M is the major insect pest seen damaging stored sorghum in Zimbabwe. The environmental hazards of synthetic insecticides, the unreliabile supply and high costs of these chemicals resulted in the search for cheaper and safe use of the naturally available plant material to control the pest. This study evaluates effective form and rates of *Combretum imberbe*. L ash and leaf powder. Bioactivity of *Combretum imberbe* ash was evaluated under average room temperature at three different dosage levels (5g, 10g and 20g). Bioactivity of *C. imberbe* leaf extracts was also evaluated under the same room temperature again at three different dosage levels (5g, 10g and 20g). A negative control of untreated sorghum grain and a positive control Actellic Gold dust were also used at label rates. The effect on grain damage, weight loss and weevil mortality was assessed. *C. imberbe* ash and leaf powder showed significant difference between 5g and 10g on one hand and 20g and the positive control showed no statistical difference. The 20g *C. imberbe* ash and leaf powder that recorded the highest mortality inflicted 81.25 % and 87.5 % respectively. The sorghum grain treated with 20% *C. imberbe* leaf powder also showed much promise by significantly reducing the number of damaged grain by the weevil as well as weight loss of grain compared to the negative control. Grain weight loss in all botanical treatments was dose dependent ranging from 90 % in the highest dose to 46% in the lowest dose with untreated grain showing significant differences after 8 weeks.

KEY WORDS: *Sitophilus zeamais*, *Combretum imberbe*, Bioactivity

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

AGRITEX: Agricultural Technical and Extension Services

ANOVA – Analysis of Variance

CABI- Centre for Agriculture and Bioscience International

CIMMYT- International Maize and Wheat Improvement CDr - Doctor

FAO – Food and Agriculture Organisation

FAOSTAT: Food and Agricultural Organization Statistics

g: Grammes

IPM- Integrated Pest Management

kg: Kilogrammes

LSD: Least Significance Difference

P<0.05: Probability less than 5%

CRD – Complete Randomized Design

t/ha: Tonnes per Hectare

Wt - weight

ZCATF - Zimbabwe Conservation Agriculture Task Force

ZIMVAC – Zimbabwe Vulnerability Assessments Comm

ZSAES - Zimbabwe Sugar Association Experimental Station

CHAPTER ONE

1.0 BACKGROUND

Sorghum bicolor (L) Moench is one of the main staple cereal crops grown worldwide. It ranks fifth after maize, rice, wheat and barley (FAO, 2012). The crop is used for food, feed, and fodder and bio- ethanol. It is a diploid and a c4 plant belonging to the family *gramineae*. Sorghum is a small grain crop widely grown by small scale farmers that performs well in marginal areas due to its ability to withstand harsh conditions. It is mostly grown in semi-arid tropics where water is scarce and drought is frequent (Mailafiya, 2003; Beshir, 2011). However, its production is hindered by biotic and abiotic constraints. These biotic constraints include devastating storage insect pests attacking the grains. The weevil (S*itophilus zeamais)* is one of the pests of economic importance in stored sorghum. It is devastating and is capable of multiplying to large populations causing tremendous damage to the grain. Infestation is encountered on farm storage where it causes high loss in grain weight and quality deterioration thereby affecting viability (Giga et al, 1991). Rounet (1992), propounded that post-harvest losses and quality deterioration is a barrier to food security in the country.

Market quality and quantity of sorghum will be achieved with effective control of weevils. Synthetic chemicals are products with high knockdown effect on pest organisms, this means this technique of using synthetic pesticides is more effective and efficient, however it is expensive to smallholder farmers and not conducive to the environment. Reliance on the use of modern pesticides has led to pest resistance and resurgence (Duke et al, 2005).

According to UNESCO, indigenous knowledge is passed from generation to generation, usually by word of mouth and cultural rituals, and has been the basis for agriculture and other wide range of activities that sustain societies in many parts of the world. A number of traditional grain protectants used to reduce *Sitophilus zeamais* damages are, for example, *colophospermum* mopane (Murdock and Kitch, 1997) and leaves of *combretum imberbe* (Leadwood or " mutsviri") ashes. Still (2000), states that wood ash from fires has been used as grain protectant. However, effective rates of application or dosages remain unknown. Farmers who have tried to use *combretum imberbe* leaves and ash lack knowledge on application rates and appropriate forms. The research aimed at assessing the effectiveness of using *combretum imberbe* in controlling *sitophilus zeamais* in sorghum grain.

1.2 Statement of the Problem

Natural region V is too dry for general crop production. Households in the communal lands in this region grow grain crops (especially small grains) for their food security and some cash crops such as cotton. Crop yields are extremely low and the risk of crop failure is high in one out of three years (Rukuni and Eicher, 1994). Grain loss caused by insect pests for example, weevils pause a great threat to food security. These can be controlled by using synthetic and alternative traditional methods. Farmers has limited information on the use of the *combretum imberbe* as an alternative control method for controlling *sitophilus zeamais* in stored sorghum due to lack of technical know-how on application rates or dosage of traditional pesticides.

1.3 Justification

The rising costs of synthetic pesticides, the development of pesticide resistance (Giga *et al*., 1986) and the availability of *combretum imberbe* make it possible to evaluate the effectiveness of traditional methods in controlling weevils. This research will create awareness of the traditional methods for *Sitophilus zeamais* control in storage for smallholder sorghum farmers. After finding the appropriate rate or dosage, the farmers have to use locally available methods which are cheaper and environmentally friendly.

1.4 Main Objective

To reduce post harvest losses caused by *sitophilus* spp in sorghum

1.5 Specific objectives

To determine the effects of using traditional methods (*Combretum imberbe*) and synthetic methods (Actellic gold dust) in controlling *sitophilus zeamais* on *sorghum bicolor (L) Moench.*

1.6 Hypothesis

Ho: There is no significant difference between traditional and synthetic methods of controlling *sitophilus zeamais*

CHAPTER 2

2.0. LITERATURE REVIEW

2.1 Importance of Sorghum

The centres of origin and domestication of cultivated sorghum were reported to be north-eastern regions of Africa (Ethiopia and Sudan) where cultivation began approximately 4,000-3,000 BC (Dillon *et al*., 2007). According to Doggett (1988), early domestication takes place by a process of disruptive selection where several traits advantageous to cultivation were favoured. Cultivated sorghums arose from wild *Sorghum bicolor* subspecies *arundinaceum*. The genus Sorghum belongs to the grass family Poaceae, subfamily Panicoideae, tribe, Andropogoneaea and subtribe Sorghinae (Clayton and Renvoize, 1986). The genus consists of 25 recognized species classified morphologically into five subgenera (USDA ARS, 2018). Cultivated sorghum belongs to the subgenus Eusorghum. Eusorghum contains three species: *S. halepense* (L.) Pers., commonly known as Johnsongrass, a weed species; *S. propinquum*; and *S. bicolor* (de Wet 1978).

Sorghum is an important staple food in the diets of more than 500 million people in 30 countries of Africa and Asia (ICRISAT, 2018). Globally, sorghum is the fifth most widely cultivated cereal after maize *Zeamais* L.), wheat (*Triticum aestivum L.)*, rice (*Oryza sativa L*.), and barley (*Hordeum vulgare L*.), and is the most principal cereal in terms of production and area planted (FAO, 2018). In Africa, sorghum undergirds food security because of its drought tolerance and its ability to resist periods of warm temperatures and water logging. Sorghum is well adapted to semi-arid and sub-tropical climatic conditions of much of Africa where high rainfall often takes place during short periods of time (Doggett, 1988). Most cultivation in Africa is by subsistence agricultural systems as opposed to industrialised production methods used in most other regions of the world.

Sorghum has a wide range of uses, including human food, animal feed, and production of alcoholic beverages and biofuel.

Sorghum is a warm-weather crop that requires warm temperatures for good germination and growth (DAFF, 2010). The best time to plant is when there is enough water in the soil and the soil temperature is 15°C or warmer at a depth of 10 cm. Temperature plays an important role in sorghum growth and development after germination. A temperature of 27 to 30°C is required for optimum growth and development. However, the temperature can be as cool as 21°C without a drastic effect on growth and yield. Day-time temperatures can be as cool as 21°C and as warm as 36°C without drastic effect on growth and yield when night-time temperatures are cool (19°C). Night-time temperature affects sorghum development, with a warm night temperature of about 31°C reducing yield (Downes, 1972).

2.2. Challenges in sorghum storage

Stored grain suffers serious attack from pests (insects, birds and rodents) and pathogens especially when not protected and when storage hygiene is poor. Amidst other constraints of sorghum production, insect pests constitute a great threat, destroying almost 20% of food produce (Pimentel, 2007). The damage caused by postharvest pests is very much bigger than that caused by other agents like micro-organisms and rodents. The *Sitophilus zeamais* and the larger grain borer *Prostephanus truncatus* are postharvest pests of stored grain that are of great importance (Abate *et al*., 2000). Furthermore, the presence of insects has direct influence on grains, causing increase in grain temperature and moisture content. These lead to an increase in respiration and consequent loss in quantity and quality of the grain. This pre-disposes the stored grain to secondary attack by disease-causing pathogens such as fungi which produce mycotoxins. The postharvest losses due to the *Sitophilus zeamais* have been recognized as an important constraint, with grain losses ranging from 20 - 90% being reported for stored untreated sorghum grains (Derera *et al*., 2001). The damage caused is irreversible and affects both farmers and traders. Since adults and the larvae of the weevils are internal feeders on the sorghum grains, apart from weight loss, the *S. zeamais* also reduce the aesthetic and market value, viability and nutritive value of grain (Cosmas *et al*., 2018). Maize weevils infest grain in the field and in storage.

Food losses can be quantitative as measured by reduction in weight or volume, or qualitative, such as reduced nutrient value and unwanted changes in taste, colour, texture, or cosmetic features of food (Buzby and Hyman 2012). Quantitative food loss can be defined as decreased weight of edible grain or food available for human consumption. Quantitative loss is caused by reduction in weight because of factors such as spillage, consumption by pests, physical changes in temperature and moisture content, and chemical changes (FAO 2011). Qualitative loss can occur because of insect pests, mites, rodents, and birds, or from handling, physical or chemical changes in fat, carbohydrates, and protein, and by contamination with mycotoxins, pesticide residues, insect fragments, or excreta of rodents and birds and their dead bodies (FAO 2011). Qualitative deterioration that makes food unfit and rejected for human consumption contributes to food loss.

2.3 Description and biology of *Sitophilus zeamais*

The maize weevil, *Sitophilus zeamais* is the most destructive pest of stored sorghum. It belongs to the Curculiodae family and order Coleoptera. It has a 2-4mm body length with its head protruded into a snout, with mandibles at the end of the snout (Bbosa, 2014). Generally has reddish brown colour (Suleiman and Abdulkarim, 2014). The snout is long with clubbed segmented elbowed antennae and four light reddish brown oval spots on the elytra (Khare, 1994). There may be five to seven generations a year.

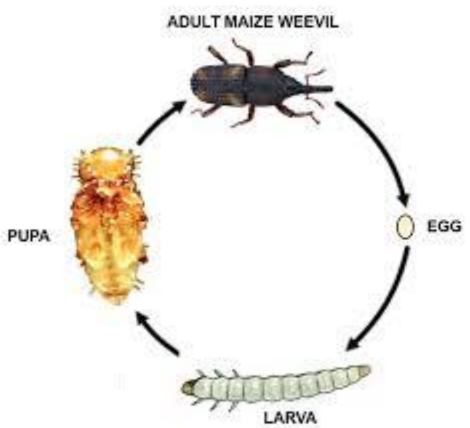
Fig 2.1 M*aize weevil*

The lifecycle of *sitophilus zeamais* is 36 days at 27± 10 and 69±3% relative humidity on average (Ojo and Omoloye, 2016). *Sitophilus zeamais* consists of 5 life stages: egg, larva, pupa, pre-adult and adult, with the larva instars being the most destructive stages on stored grains. According to Ojo and Omoloye, (2016) the optimum temperature for oviposition is about 25°C with grain moisture contents of above 10%. Depending on environmental conditions like temperature and humidity, adults will live up to 6-12 months.

An adult female burrows into the grains with the help of its rostrum (Siwale *et al.*, 2009). Up to 400 creamy white tiny eggs are laid per female in cereal grains in the field as well as in sorghum.

After about 5-9 days, eggs hatch to legless 4mm long larva that have 4 larval development instars that last 25 days with moderate temperature (National Research Institute, 1996).Under optimal laboratory conditions of 30°C with 14% moisture, development from eggs to adult may take from 30- 40 days while unfavourable conditions such as slightly higher temperatures and high moisture content might take up to 110 days. The larva is creamy white in colour, with a sclerotized light brown head, legless, short, stout and matures in 3- 6 days, (Ojo and Omoloye, 2016). The larva feed and develops inside the sorghum kernels for about 25 days and the total development periods range from 35 to 110 days (Kasozi, 2013).

Fig 2.2 Life cycle of Sitophilus zeamais (Solomon and Azare, 2019).



2.4. Hosts of Sitophilus zeamais

The maize weevil has a host range similar to that of rice and granary weevil even though mostly found on maize, it can also feed on most cereal grains. It can be found in storage of wheat, oat, rye and wheat. It can also be able to deteriorate beans, nuts, birdseeds, sunflower seeds as well as processed food such as pasta (Ojo and Omoloye, 2016).

2.5.0 Strategies to Control Storage Insect Pests

2.5.1 Cultural control

This control option involves cleaning the granaries, sealing cracks and holes on floors of storage facilities as well as shelves, before and after use, furthermore avoid mixing old grain with new grain, practice first in, first out rule. Due to the fact that most infestations develop from already existing pests usually starting from small numbers, a sanitation programme is necessary to effectively reduce chances of serious damage (Lale, 2001). Well managed aeration together with effective hygiene can overcome up to 85% of *Sitophilus zeamais* infestations.

2.5.2 Biological control

The method is a component of integrated pest management of stored product pest. Important natural enemies in the biological control of storage pests include parasitoid wasps and predatory pirate bugs. Use of parasites and insect pathogens studies by Kassa (2003) demonstrated the possible successful control for *S. zeamais* on stored and infested cereals using dustable powder formulation of conidia of *Beauveria bassiana* and *Metarhizium anisopliae* isolates. *Lariophagus distinguendus* is an ectoparasitoid of several beetle species that feed on durable stored products. Its potential for the control of S. zeamais was assessed in stored sorghum. This parasitoid significantly reduced the emergence of *S. zeamais* in stored sorghum (Adarkwah *et al*., 2008).

2.5.3 Ionizing irradiation

There are two types of irradiation that have been used to control insects in stored grain; these two include beta and gamma radiation. According to Fields and Muir (1996), irradiation with an electron beam is much safer and easier to work with because it can be turned off. Ionizing irradiation damages organisms by causing production of ions (free- radicals) which are highly reactive. However in order to cause immediate death, higher doses are required.

2.5.4 Thermal control

Low temperatures below 13°C reduce insect development thus lengthening the time before insect populations increase to a point of significant damage. Low temperatures minimise the rates of development, feeding, fecundity and survival (Logstaff and Evans, 1983). Because this method only prevents further development of heavy infestation but not killing, it is only implemented as a preventative rather than cure. High temperature, infrared waves, microwaves as well as solar radiation have been used to satisfactorily disinfest grain. High temperatures of about 60- 65°C are the ideal (Logstaff and Evans, 1983).

2.5.5 Chemical control

Synthetic insecticides use is the most common and effective control strategy. Insecticides whose mode of action is by contact are the most prevalently used chemicals among small-scale farmers (Suleiman and Abdulkarim, 2014). Fumigation with a gaseous pesticide aids in suffocating pests within stored grain. Methyl bromide and phosphine are the mainly used fumigants commonly used on a global scale. Carbon disulphide, carbaryl are the other chemicals used to subdue the nature of these entomons (Kaguchia et al., 2018). Stored product insects vary considerably in susceptibility to insecticides, (Arthur and Peckman 2006).

2.5.6 Botanical insecticides.

Plants with insecticidal properties, commonly referred to as botanicals, have been used traditionally for generations throughout the world. Botanical pesticides are naturally occurring chemicals extracted from plants (Regnault-Roger et al. 2005, Regnault-Roger and Philogène 2008). Botanical products are available as an alternative to synthetic chemical insecticides, but are not necessarily less toxic to humans. Some of the most deadly, fast-acting toxins and potent carcinogens occur naturally, due to low toxicity (Grainge and Ahmed 1986) compared with many insecticides. If applied even in very low quantities, botanicals are characterised favourably for low acute toxicity and ready dissipation in nature (Soloway 1976). They can be used in small quantities to prepare combined insecticidal formulations for controlling pests in storage. Botanical treatments are especially relevant during post-harvest storage of commodities by small-scale farmers (Proctor 1994, Dales 1996). Botanicals are one of the most important locally available, biodegradable, and inexpensive methods for controlling stored-grain pests (Mishra et al. 2012). The main advantage of botanicals is that they are produced easily by farmers and small-scale industries and are potentially less expensive (Nikkon *et al*., 2009).

Utilisation of botanical insecticides to protect stored products is promising, mostly because of the possibility of improving environmental conditions inside storage units and maximising the insecticidal effect (Guzzo *et al*., 2006). The natural botanical product can be used as powder, extract, or oil in storage facilities. Moreover, use of plant materials to protect grain in storage is sustainable; the plants can be continuously propagated year after year. The use of botanicals is seen to be an effective alternative and suitable for smallholder farmers for preserving stored grain from insect damage. In a study by Ivbijiro (1983), the application of neem seed powder *Azadiachta indica* to weevil infested sorghum grains prevented oviposition at the high dose while mortality of adult weevils reached 100% within five days.

2.5.6.1 Eucalyptus

It is one of the most cultivated tree genera globally and has more than 700 species. Eucalyptus species produce a pungent odour even before squashing the leaves which repel insects which according to Brito *et al.*, 2006 is an insecticidal property. Many studies on the efficacy of Eucalyptus species showed effectiveness in the control of *S. zeamais* in stored grain (Muzemu *et al*., 2013, Mulungu *et al*., 2007). Cimanga *et al* ., (2002) asserts that leaves of *Eucalypus globules* cause high mortality of *S. zeamais* while the study by Machingura (2014) revealed that integrated pest management involving synthetic chemicals and *eucalyptus citriodora* leaf powder achieved 100% insect pest mortality.

2.5.6.2. *Tagetes minuta* (Southern cone marigold/Mexican marigold)

In Zimbabwe it is considered a crop weed and leaves can be irritant. Its roots are nematicide and insecticide, leaves are good insecticide effective to against a wide range of crop and soil pests and the whole plant can protect post-harvest products against pests. The major constituent of *T. minuta* is piperitone, which is an antioxidant having insecticidal activity (Dar *et al.*, 2011).

2.5.6.3. Jatropha curcas

Jatropha curcas is a widely available tropical plant often used for fencing by many farmers.

Its seed oil is used as biofuel and its potential as a bio-pesticide (Nash 2005). However Jatropha leaves contain phytochemicals tannin,cardiac glycosides, antraquinones, saponins and flavonoids (Trease and Evans 1998). These have strong activities against plant pathogens and pest (Karamanoil *et al* 2011) killing them by chelating and enzyme inhibition.

2.5.6.4 *Lantana camara* (lantana/ black sage)

This is a highly invasive shrub, forming dense thickets and repels insect pests in households.

It is very effective in the control of *S. zeamais* in maize and sorghum (Daisy 2014).

2.5.6.5. Lippia javanica

It is commonly known as Lemon Bush, Fever Tea tree. It’s a woody shrub found throughout eastern and southern Africa. It is used in pre- and postharvest management and ecto-parasite control on livestock. The plant is high on essential oils with fumigant effect and has contact toxicity of Perillaldehyde and Ipsdienone against *S. zeamais*. It is easily propagated from seed or cuttings and can be invasive. *Lippia javanica* have been used in controlling aphid population on cabbage (Brassica capitata by 24.65%. The plant also has antibacterial, antifungal, antiprotozoal and insect-repellent activity and seems to repel antestia bug (Akunne et al (2013). According to Tapondjou e al (2005), *L. javanica* have also been evaluated to contain toxic substances against many microbes and insect pest.

2.5.6.6 Efficacy of combretum imberbe as a grain protectant

Combretum imberbe is a characteristic and often impressive bushwillow species of the southern Afrotropics. It has a spreading, rather sparse, roundish to slightly ambrella-shaped crown. Its leaf powder and wood ash are mainly used by resource poor farmers to control storage pests for cereals and cowpeas, it is also used for medicinal purposes, for example it is used to treat against coughs.

CHAPTER 3

3.0 METHODOLOGY

3.1 Brief description of study area

The research was carried out at ZSAES , Chiredzi district of Masvingo Province Zimbabwe. It lies in agro- ecological region V, it receives an average rainfall of less than 650mm per year that is highly erratic and a temperature range of 12°C to 40°C annually (Mugandani etal, 2012) The area is dominated by *Colophospermum mopane* and lead wood trees. The study site is within large scale and A2 sugarcane.

3.2 Experimental design

The experiment was laid out in a complete random design (CRD) at ZSAES chemistry laboratory with eight treatments that are from wood ash of *combretum imberbe*, grounded *combretum imberbe* leaves, actellic dust (synthetic) and untreated sorghum grain as shown on table 3.2 below. The experiment was replicated three times.

Table 3.1 Treatment description table

Treatment	Description
T1	Untreated sorghum grain
T2	Sorghum treated with *combretum imberbe* wood ash at a rate of 5g/ 200g sorghum (Parwada et al, 2017)
T3	*Combretum imberbe* wood ash at 10g/ 200g sorghum.
T4	*Combretum imberbe* wood ash at 20g/200g sorghum
T5	*Combretum imberbe* grounded leaves at 5g/200g sorghum

T6	*Combretum imberbe* grounded leaves at a rate of 10g/200g sorghum
T7	*Combretum imberbe* grounded leaves at a rate of 20g/200g sorghum
T8	Positive control, 4g/200g sorghum (treated with 4g Actellic gold dust thus synthetic pesticide).

3.3 Experimental procedure

Smile sorghum variety was used in the experiment since it is the most grown variety in the area of study. The grain was weighed into 200g samples and for two days the samples were placed in a freezer in order to kill residual *sitophilus zeamais*. The sorghum was sieved to remove all unwanted particles, (Masaya, 2004).After the grain achieved the 12 to 13% moisture content (Muzemu *et al*., 2013), then 16 *sitophilus zeamais* were introduced into each sample and covered with mosquito net to prevent weevil escape if any weevil escapes there was need to restart sampling. Application rate of 5g, 10g and 20g for both wood ash and for grounded leaves of *combretum imberbe* was used. Application rate of 4g Actellic dust was used basing on proportionate calculations from recommended rate (20g/kg). Physical weevil count was done two days after setting the experiment to observe if there were no weevils escaped, if escaped the process will be repeated. Dead weevil counts to be done physically at two week interval for eight weeks.

3.3.1 Parameters measured

Grain weight loss will be assessed at two week interval for eight weeks by using a Thousand Grain Mass (TGM).

TGM - Mass (wt) of 1 000 grains at beginning of storage period is compared with mass of a 1 000 grains at intervals during storage season

-To establish TGM, number of grains in working sample are counted & weighed.

-Average weight/grain is determined and X 1 000 to get TGM

-Mass should be converted to dry wt. to avoid variance due to moisture difference.

TGM= X 1000 X () =

where:

m = mass (wt) of grain in sample

N = number of grains in sample

h = moisture content of grain

TGM = Thousand grain mass (dry basis)

-total wt loss in sample of grain

% wt loss = X 100%

Weevil deaths from each sack were counted on day 14,28,42, 56 and recorded. Insects were certified dead on seeing motionless legs when insect was tempered with or teased using a small smooth brush. Maize weevil mortality was assessed as: (Number of dead insects/Total number of insects) x 100. To account for death by natural conditions other than the effect of the *C.imberbe* ash and leaf powder, data on percentage adult weevil mortality was corrected using Abbott‘s (1987) formula thus:

PT = (PO-PC) / (100-PC)

Where,

PT = Corrected mortality (%),

PO = Observed mortality (%)

PC = Control mortality (%)

3.5 Data analysis method

Data was analyzed using GENSTAT and data on the weevil mortality was subjected to one way ANOVA. Prior to analysis, data to be checked for normality using box plot. Mean separation was done using the least significance difference at 5%.

CHAPTER FOUR

4.0 RESULTS

4.1 Effects of *Combretum imberbe* wood ash and grounded leaves against maize weevils (*Sitophilus zea mais.* L) in stored sorghum grain.

There were significant differences among all treatments on the mortality of *S. zeamais* in stored sorghum ($P<0.05$).However there was no statistical difference between *C. imberbe* wood ash at 20g as well as *C. imberbe* grounded leaves at 20g and the synthetic pesticide (Actellic Gold Dust) which had the highest mortalities of 81.25%, 87.5% and 100% respectively. The lowest mortality was obtained at untreated (0%) followed by 5g *C. imberbe* ash with 60.42%. The figures below shows the effects of treatments on the number of dead weevils in the study after 8 weeks.

Table 4.1 Effects of different treatments on weevil mortality

TREATMENT		Time (weeks)		
	2	4	6	8
1	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
2	1.00^{ab}	4.00^{bc}	3.00^{b}	1.67^{ab}
3	4.00^{bc}	4.67^{bc}	3.67^{ab}	1.00^{ab}
4	6.00^{abc}	3.33^{ab}	2.33^{bc}	1.33^{ab}
5	1.67^{ab}	4.33^{bc}	3.00^{b}	2.00^{ab}
6	4.00^{bc}	2.67^{ab}	2.00^{ab}	2.00^{ab}
7	7.00^{abc}	3.00^{ab}	2.00^{ab}	2.00^{ab}
8	15.33^{c}	0.67^{ab}	0.00^{a}	0.00^{a}
Grand mean	4.88	2.83	2.00	1.25
p-value	<.001	0.005	0.006	0.005
LSD	2.09	2.344	1.903	1.172
CV%	24.8	25	26.6	25.3

Means followed by the same letter are not significantly different from each other at 5% significance level.

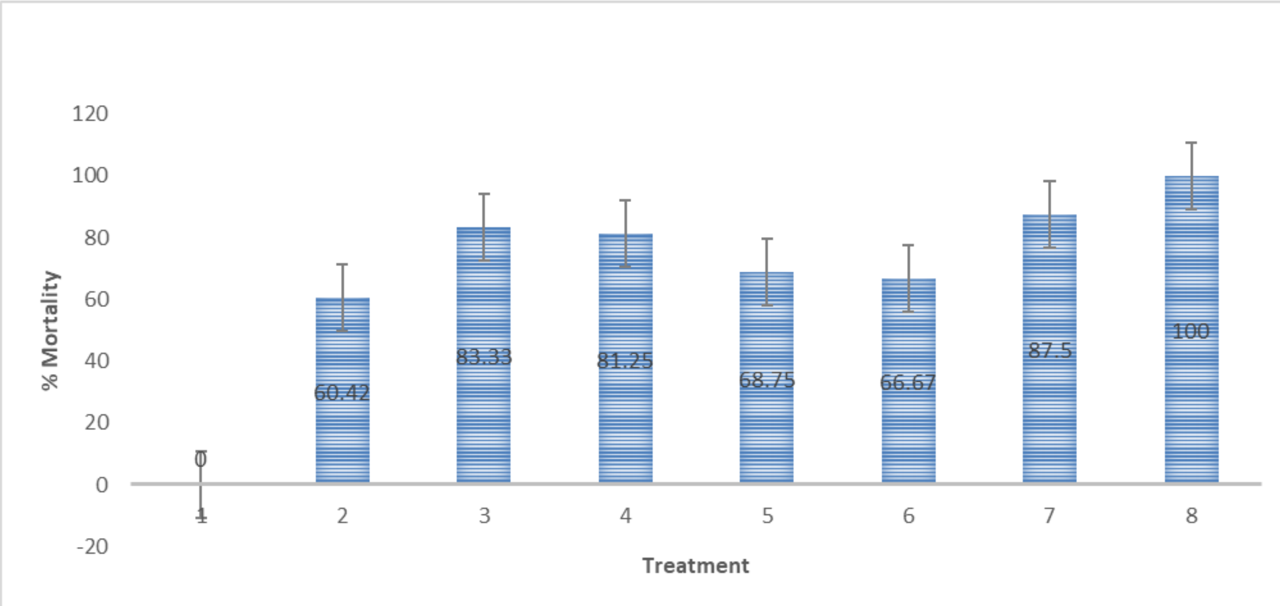


Fig 4.1 Effects of different treatments of C.imberbe ash and grounded leaf extracts on weevils in stored sorghum.

4.2 Effects of *C.imberbe* ash and grounded leaf powder on grain weight loss in stored sorghum

There were significant differences among all treatments on weight loss due to damage by *S.zeamais* in stored sorghum (P<0.05). However there were no significant differences between *C.imberbe* ash and grounded leaf extract at 20g and the synthetic pesticide (Actellic Gold Dust) which had the lowest percentage weight loss of 12%, 8% and 2% respectively. The highest percentage weight loss was obtained at untreated (98%) followed by 5g *C,imberbe* ash with 36% and 10g grounded leaf with 32%. Table 4.2 and Fig 4.2 below illustrates the differences in treatments on grain weight loss.

Table 4.2 Effects of different treatments on grain weight loss in stored sorghum

Treatment		Time (weeks)		
	2	4	6	8
1	17.967^{a}	17.133^{a}	15.800^{a}	14.200^{a}
2	17.933^{a}	16.833^{a}	16.133^{a}	15.667^{a}
3	18.533^{ab}	18.000^{ab}	17.567^{ab}	17.167^{ab}
4	18.667^{ab}	18.433ab	18.167^{ac}	17.900^{ac}
5	18.600^{ab}	18.267^{ac}	18.033^{ab}	17.767^{ab}

6	18.667^{ab}	18.367^{ab}	18.033^{ab}	17.667^{ab}
7	18.867^{bc}	18.733^{c}	18.567^{c}	18.400^{bc}
8	18.867^{bc}	18.867^{c}	18.867^{c}	18.867^{c}
Grand mean	18.512	18.079	17.646	17.204
p-value	0.002	<.001	<.001	<.001
LSD	0.4593	0.4075	0.5241	0.6079
CV%	1.4	1.3	1.7	2.0

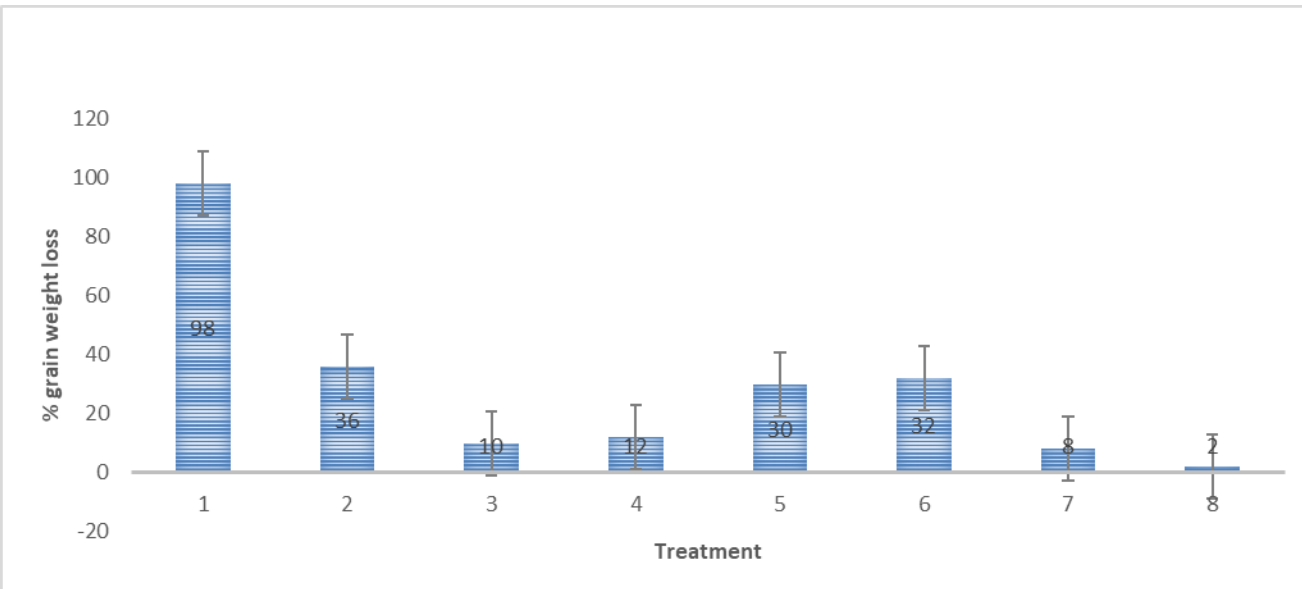


Fig 4.2 Effects of different treatments on grain weight loss after 8 weeks

CHAPTER FIVE

5.0 DISCUSSION

5.1. Effects of *C.imberbe* ash and leaf powder on mortality of *S zeamais*

Results from this study indicate that *C. imberbe* ash and leaf powder can be effectively used to control *S. zeamais* in stored sorghum. The results showed that mortality was dose dependent as more weevils where killed at high dosage levels. This agrees with sentiments by Khare (2007), which reveal that *C. imberbe* leaves contain essential oil osdienen, which has been known to intoxicate insects, as such *S. zeamais* adult cannot survive in grains treated with optimal rates of Actellic Gold Dust and *C. imberbe* leaf powder.

Although the synthetic pesticide has higher mortality percentage, according to Mkenda *et al*., (2015), plant pesticide treatments are more cost effective to use than synthetic pesticide as the marginal rate of return for the synthetic is no different from the untreated control. On the other hand the use of *C.imberbe* facilitates ecosystem services at the same time effectively managing *S. zeamais* by killing. The labour cost of collecting and processing abundant plants in surrounding bushes are less than the cost of purchasing synthetic pesticides.

5.2 Effects of *C.imberbe* ash and leaf powder on grain weight loss

Results from this study showed that as number of damaged grains reduces, weight loss increased. Weight loss was highly observed on low dosages of *C. imberbe* ash and leaf powder and untreated grain. The results support the finding of (Kham and Marwat, 2004) who reported that the leaves bark and seeds of certain plants protect grain from damage by storage pests. There was significant decrease in grain weight loss in higher levels of dosage of treatments as compared to the untreated negative control. Minimal grain damage was observed on treated grain leading to little weight loss when compared to the untreated negative control and the same level as the positive control of Actellic Gold Dust. Among the *C. imberbe* treatment rates, highest grain weight loss was experienced in the sorghum grain treated with 5g over the 8 week exposure to *S. zeamais* whilst the grain treated with 20g *C. imberbe* ash and leaf powder and the synthetic Actellic Gold Dust had least grain weight loss. High grain weight loss can be attributed to the low weevil mortality and high weevil survival as well as reproduction of the weevils resulting in high weevil population leading to higher grain damage hence high grain weight loss. The findings are in agreement with Chiu (1989) who observed that synthetic dusts like cypermethrin 1% dust is effective in protecting stored grain thereby reducing loss of grain weight. Hall (1990) and Parwada *et al.*, (2012) reported that ground plant extracts act by dehydrating and suffocating the weevil and also by reducing weevil movements thereby resulting in reduced grain damage and weight loss. The leaf powders of *C. imberbe* could also have reduced grain weight loss due to the fact that they reduce the relative humidity on the surface of the grain thereby inhibiting egg laying and larval development of the weevils. Untreated maize had the highest weight loss due to weevil damage compared to all the other treatments. According to Duke, 2002 weevils are capable of causing 80-100% weight loss if grain is left untreated for long periods. Conventional chemical control had insignificant weight loss. According to Dolob, 2001 synthetic insecticides offer no tolerance to weevil damage most synthetics are in dust form. The dusts inhibits egg laying and larval development of the weevils In the absence of synthetic pesticides, C. *imberbe* can be used to control the *S. zeamais*, as the plant has high repellent effects due to a strong aroma produced by the leaves. The environment in the untreated grain offered free movement of the weevils as wells as high chances of mating leading to increased populations. Weevils can also cause secondary effects such as fungal infection leading to further weight loss. The synthetic chemical and *C.imberbe* ash and leaf powder at 20g had lowest weight loss due to the fact that there was continual death of the weevils thereby reducing their damage threats (Sabramanyan and Roesli, 2000).

.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

S. zeamaize mortality increased as *C. imberbe* ash and leaf powder rates increased and can be used as natural pesticide in maize storage and can significantly reduce grain damage and reproduction of the maize weevil. The effective recommended rate of *C. imberbe* is 20g/kg. Increase in rates can be of great help and will have no costs to farmers since *C. imberbe* is in abundance in the area. For the adoption of this technology, *C. imberbe* should be air dried and ground into smooth powder and admixed with grain at 20g/kg at the beginning of the storage season.

REFERENCES

Abate, T., Van Huis, A. and Ampofo, J.K.O. (2000). Pest management in traditional agriculture: an African perspective., Annual Review of Entomology, 45, pp 631-659.

Adarkwah, C., Büttner, C., Prozell, S., Reichmuth, C., Obeng-Ofori, D. and Schöller, M. (2008). Biological control of Sitophilus zeamais (L.) (Coleoptera: Curculionidae) in bagged maize with Lariophagus distinguendus (Förster) (Hymenoptera: Pteromalidae) and Corcyra cephalonica (Stainton) (Lepidoptera: Pyralidae) in rice with Habrobracon hebetor (Say) (Hymenoptera: Braconidae, Department of Crop Science, School of Agriculture, College of Agriculture and Consumer Sciences, University of Ghana, Legon, Accra, Ghana.

Bbosa, D. (2014) "Pesticide free methods of maize weevil control in stored maize for developing countries" Graduate Theses and Dissertations. 14083. https://lib.dr.iastate.edu/etd/14083.

Derera, J., Giga, P.D. and Pixley, K.V. (2001). Resistance of maize to the maize weevil, African Crop Science Journal, 9, pp 431-440.

Dolob. P, (2002), A practical assessment of food losses sustained during storage by small holder farmers in the shire valley Agricultural Development Area of Malawi Report of the Tropical products institute slough G138, p. 32.

Duke J.A, (2001), Handbook of medicinal herbs CRC press, Bocd Raten, FL, USA, pp. 114-128.

Hall, D.W. (1970). Handling and storage of food grains in tropical and sub-tropical areas, FAO. Rome. Italy

Kaguchia, S.M., Gitahi, S.M., Thoruwa, C.L., Birgen, J.K. and Hassanali, A. (2018). Bio-efficacy of selected plant extracts against Sitophilus zeamais on post-harvest management of Zea mays, Journal of Phyto-pharmacology. 7(4), pp 384-391.

Kasozi, L.C. (2013). Genetic analysis and selection for weevil resistance in maize. African waZulu Natal, Pietermaritzburg, South Africa.

Khare, V. M. Kachare,B.V. Andpatil,C.S.(1987). Effect of vegetable oils on pulse beetle (*Callosobruchus chinensis*) in pigeonpea. Current Research Reporter. 3; 2, 53-58.

Longstaff, B.C.(1981). Biology of the grain species of the genus Sitophilus (Coleoptera, curculionidae): Acritical review. Protect Ecol. 2:83-130.

Khoza, S., Nhachi, C.F.B., Chikumo, O., Murambiwa, W., Ndudzo, A., Bwakura, E. and Mhonda, M. 2003. Organophosphate and organochlorine poisoning in selected horticultural farms in Zimbabwe. The Journal of Applied Science in Southern Africa 9 (1): 7-15

Logstaff, B.C. and Evans, D.E. (1983). The demography of the rice weevil, Sitophilus oryzae (L.) (Coleoptera: Curculionidae) submodels of age-specific survivorship and fecundity, Bulletin of Entomological Research, 73(2), pp 333-334.

Magauzi, R., Mabaera, B., Rusakaniko, S., Chimusoro, A., Ndlovu, N., Tshimanga, M., Shambira, G., Chadambuka, A. and Gombe, N. 2011. Health effects of agrochemicals among farm workers in commercial farms of Kwekwe district, Zimbabwe. Pan-African Medical Journal 9: 26.

Mkenda, P.,Mwanauta, R.,Stevenson,P.C., Ndakidemi, P., Mtei,K and Belmain,S.R.(2015). Extracts from field margin weeds peovide economically viable and environmentally benign pest control compared to synthetic pesticides.

Muzemu, S., Chitamba, J. and Goto, S. (2013). Screening of Stored Maize (Zea mays L.) Varieties Grain for Tolerance against Maize Weevil, Sitophilus zeamais (Motsch.). International. Journal of Plant Research, 3(3), pp 17-22.

Mvumi, B.M., Giga, D. P. and Chiuswa, D.V. 1995. The maize (Zea mays) post production practices of small holder farmers in Zimbabwe: findings from surveys. Journal of Applied Science in Southern Africa 1: 115-130.

National Research Institute (1996). Insects Pest of Nigerian Crops, Identification, Biology and Control. Nigerian Federal Ministry of Agriculture and Natural Resources and the Overseas Development administration of the British Government. Chatham, U.K. 253

Ojo, J. and Omoloye, A.A. (2016). Development and life history of Sitophilus zeamais (Coleoptera: Curculiodae) on cereal crops, Advances in Agriculture, 2016, pp 1-8.

Parwada, C., Chikuvire, T.J., Kamota, A., Mandumbu, R. and Mutsengi, K. (2018). Use of Botanical Pesticides in Controlling Sitophilus Zeamais (Maize Weevil) on Stored Zea Mays (Maize) Grain, Mod Concep Dev Agrono, 1(4). MCDA.000517.2018.

Pimentel, D. (2007). Area-wide pest management: Environmental, economic, and food issues. In: Vreysen, M., J., B., Robinson, A.S., and Hendrichs, J., B., (eds), Area-Wide Control Of Insect Pests: From Research to Field Implementation, Springer, Dordrecht, The Netherlands, pp. 35-47.

Siwale, V., Mbate, K., Mcrobet, J. and Lungu, D. (2009). Comparative resistence of improved maize genotypes and landraces to maize weevil, African Crop Science Journal, 17 (1), pp 1-16

Solomon, W.J. and Azare, B.A. (2019). Insecticidal Properties of Garlic (Allium sativum) Aqueous Extracts on Beans (Phaseolus valgaris) and Maize (Zea mays) Pest, Research Journal of Biology and Biotechnology, 5 (2), pp.24-33.

Suleiman, M. and Abdulkarim, B. (2014). Use of some spicy powders in the control of *sitophilus zeamais Motschulsky* [Coleoptera: Curculionidae] on maize grains, Entomology and Applied Science, 1(2), pp 20-25.

Tagetes minuta formulation effect *Sitophilus zeamais* (weevils) control in stored maize grain. International Journal of Plant Research, 2(3): 65-68. DOI: 10.5923/j.plant.20120203.04

Nhachi, C.F. (2001). Organophosphate poisoning and management update. The Central African Journal of Medicine 47 (5): 134-136

Zimbabwe Vulnerability Assessment Committee (Zimvac). 2011. Rural Livelihoods Assessment July 2011 Report. Food and Nutrition Council, Harare, Zimbabwe

APPENDICES

ANOVA table for a one factor in a CRD

Source of Variation	D.F.	SS	MS	$F_{statistic}$¡
Treatments	8-1=7	15.1667	2.1667	0.005
Error	23-7=16	7.3333	0.4583	
Total	24-1=23	22.5	2.625	