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EFFECTIVENESS OF BOTANICAL CONTROL OF *SITOPHILUS ZEAMAIS* (MAIZE WEEVILS) IN STORED MAIZE GRAIN (*Tephrosia candida, Lantana camara and Eucalyptus tereticornis*)

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Abstract - Maize producers in rural areas are challenged by storage pests particularly the S. *zeamais.* Affordable and available maize grain protectants are needed to provide a sustainable and degradable pesticide to poor resource farmers. This study was conducted to determine efficacy of botanical extracts of affordable and available plant materials of *tephrosia*, eucalyptus and *lantana camara* on the control of *Sitophilus* zeamais (maize weevils) in stored maize grain. The research involved an experiment and a complete randomized design with five treatments which had three replicates in the storage facility. The treatments tested in this study were as follows; Treatment 1: control in which no pesticide was applied, Treatment 2: synthetic pesticides (actellic super dust) were employed, Treatment 3: *Tephrosia candida* was employed. *Eucalyptus tereticornis* was used for treatment 4 and *Lantana camara* was used for treatment5. A 50 kg bag of maize grain was deliberately exposed to maize weevil attack and allowed to multiply naturally. Another 50 kg bag of maize grain was stored in a metal silo to naturally control the maize weevils without chemical application. 100 maize weevils were deliberately put in each of the 1kg bags of maize grain and tied. Thereafter, the treated 1 kg bags of maize grain were put on planks in storage. Data collection was done after 7, 14, 21, 28, 35 and 42 day after treatment. Gen start 12th edition statistical software was used to analyze the data. Results of this study revealed that all botanical products tested performed well in controlling *S. zeamais* in stored maize grain as compared to no pesticide application. However, *tephrosia* leaf powder was the most effective controlling maize weevil population and mean maize grain weight loss percentage followed by eucalyptus which revealed no significant difference except in mean grain damage. The weight loss was also minimal in maize grains treated with botanical products compared to no treated maize grains. This study suggests that *tephrosia*, eucalyptus and *lantana* leaf powders can be used as better alternatives to synthetic pesticide against the control of *Sitophilus zeamais* in stored maize grain due to significant differences revealed on mean maize weevil mortality percentage, reduced mean grain damage and weight loss in stored maize grain as compared to no application of pesticide maize grain which had a least mean maize weevil mortality percentage, highest mean grain damage and weight loss. Hence, it was concluded that botanical materials can be used to control maize weevils in stored maize grain.

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Introduction

Maize (*Zea mays* L.) is one of the major cereal crops produced worldwide (Blackie and Jones, 2009). It is a staple food in many countries throughout Africa, Latin America and Asia. Maize (*Zea mays L.*) is the world's widely grown highland cereal and primary staple food crop in many developing countries (Kandil, 2013). World production of white maize is currently estimated to be around 65 to 70 million tons. Among the individual geographical regions of the developing countries, white maize production has a paramount importance in Africa. The main white maize producers in Africa include Kenya, Tanzania, Zambia and Zimbabwe (Kidist, 2015).

Increasing production and productivity of maize has been achieved through the development of high yielding stress tolerant varieties. Despite this intervention at production level, there is evidence of food insecurity arising from food storage losses. Storage losses due to pests threaten livelihoods of farmers across Africa (Kamanula et al., 2011). The maize weevil (Sitophilus zeamais Motschulsky) is the most serious storage pest of maize in the tropics (Bosque-perez and Buddenhagen, 1992). The maize weevil affects the crop before harvest and multiplies further after storage (Caswell, 1962). Giga and Mazarura (1991) reported maize loss of 20 - 90 % worldwide due to the` maize weevil, S. zeamais.

Maize is an important crop and the staple food in Zambia. Maize is grown on more than 2 million ha (15%) of Zambia's from 14 million ha cultivated land (FAO, 2010). Approximately 9.3 million smallholder farmers in this country grow maize, mainly for human consumption (FAO, 2010; Mukanga et al., 2010). It is also an important source of income for these farmers. Zambia is the sixth largest producer of maize in Africa and smallholder farmers make up 94 % of the crop production (FAO, 2010). The country produces white maize, the preferred type of maize in neighboring markets.

However, maize suffers heavy losses during storage due to insect pests. According to FAO report, 10 to 25% of world harvested food is destroyed annually by storage pests. Losses caused by Maize weevil (*Sitophilus Zeamais*) have been reported to range from 0.2 to 2.9% over a period of 1 to 12 months. Insect pests cause damage to stored grain and processed products by reducing dry weight and nutritional value (Talukder and Howse, 2011).

Insect control currently depends on the use of synthetic insecticides. However, the use of synthetic pesticides to protect maize grain against the attack of grain weevil in storage may cause serious health hazards (Talukder and Howse, 2003), problem of pest resistance and resurgence and is quite expensive to smallholder farmer situation (Iloba and Ekrakene, 2006). Health conscious and environmentalists, to date, are advocating for pest remedies that are not a threat to human health and the environment at large. It is of utmost importance that people use natural plant based insecticides (botanicals) in controlling weevils since they are easily available and cheap. Briskin (2000) postulates that plant based insecticides are preferred as they have little or no negative effect on agricultural environment. Botanicals are organic compounds, hence they do not dissolve completely in water therefore they do not pollute water as well as the environment. They are more readily biodegradable and are less likely to contaminate the environment (Rajashekar *et al*., 2012).

Therefore, control programs should rely on the extent possible on safe, low cost and locally available alternative tactics and affordable to small scale farmers that prevent maize grain losses by preventing storage losses from pests. Plant and plant products are useful and desirable tools in

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most pest management programs because they are effective and often complement the actions of natural enemies (Schmutterer, 1990; Ascher, 1993). A number of investigators isolated and identified chemical compounds from leaves and seeds of many plant species as potential pesticides. For example, the potential pesticides activities of eucalyptus, Lantana Camara, pyrethrum and tephrosia products have been reported for several insects in storage (Akhtar and Isman, 2004; Greenberg *et al*., 2005; Mbaiguinam *et al*., 2006; Iloba and Ekrakene, 2006). The present study was conducted to evaluate the efficacy of locally available botanical products as grain protectants on the feeding response and survival of *Sitophilus zeamais*. Identification of locally available effective botanicals will provide a sustainable alternative to control storage pests, thus contributing to increased food security in the country.

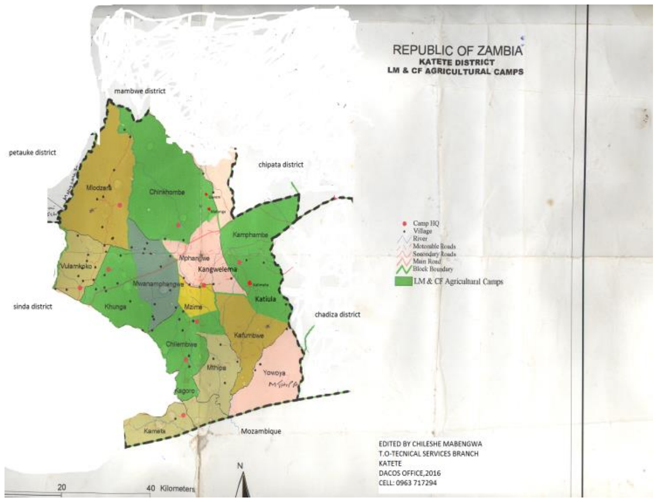
On the other hand developing an appropriate use may enable its eradication from the fields. Coming up with the right form effective for weevils will take the farmers far in keeping their grain safe from damages. The heavy reliance on the synthetic insecticides has led to insect resurgence and resistance and has a negative effect on non-target organisms (Duke et al, 2003). This has raised concern to search for environmentally friendly storage pest control measures. Therefore, this research aimed at assessing the effectiveness of botanical control of *Sitophilus zeamais* in stored maize grain.

The main research objective was to:

a) To determine effectiveness of botanical materials on mortality rate of *Sitophilus zeamais* (maize weevils).
b) To determine the effectiveness of botanical control of *Sitophilus zeamais* on damage of maize grains in storage.
c) To determine the effectiveness of botanical control of *Sitophilus zeamais* on weight loss of maize grains in storage.

Study site Location and description

The study was conducted at Katete Farmers Training Centre in Katete in Mphangwe camp, Eastern province of Zambia. It is located about 4km from Katete stores off the Great East Road to the South and about 2km off the Mozambique Road to the East. The study area lies in agro ecological region II of Zambia, It is characterized with sand clay soils and rainfall ranges from 800 mm-1000 mm per annum with average annual temperatures ranging between 18^{0}C and 28^{0}C, and prominently covered with miombo woodland comprising Brachystegia and *Julbernardia Parinari tree* species of vegetation (Muliokela, 1997).



Map of Katete district. (Ministry of Agriculture & Livestock, 2013)

Materials and Methods

The experiment was laid out in a complete randomized design (C R D) with five (5) treatments that were Actellic super dust (Synthetic), untreated grain (control),pounded leaf powder of *Tephrosia candida, Eucalyptus tereticornis* and *Lantana camara*. The experiment had five treatments with three replicates each.

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Pannar 53 commonly known as shanga ubone seed variety was used in the experiment since it is one of the commonly grown variety by most farmers in the area around Katete FTC. The grain from the metal silo with weevil free was weighed into 1kg samples which were put into small sacks at moisture content of 12.7%.The moisture meter called Dickey-john was used for testing the moisture content of the maize grain that was used in the experiment. The maize grain was graded manually and cleaned of broken kernels and debris as suggested by Fekadu, Waktole, Dante and Santiago (2012). The maize grain was kept in a cool dry room to avoid accumulation of moisture. The mass of maize grain was weighed, using a digital laboratory scale, at the beginning of the experiment as well as at the end of the experiment. This was meant to establish grain weight loss during the experiment. Bagging was done after cleaning the grain by sieving and manually removing broken grains and other debris.

Before tying the sacks, 100 weevils were introduced into each sack immediately. Maize weevils were collected from a 50kg maize bag which was exposed to weevils. 30grams of leaf pounded powders of *Tephrosia candida*, *Eucalyptus tereticornis* and *Lantana camara* was used to treat the maize grain in the three replicates. 10grams per 1000grams of maize grain was used as a rate for botanical control. No sexual category of weevils was done as female and male presence was inevitable, as was case with other experiments done by Chinwada and Giga, (1997) on bean bruchids and the larger grain borer.

Fresh *Eucalyptus tereticornis* leaves were collected from Mindola Forestry which is a government plantation within Katete. The leaves for *Lantana camara* and *Tephrosia candida* were collected within the fields of Katete FTC and dried under the shade for 21 days together with the eucalyptus leaves and later pounded in a mortal and sieved them. The fine powders were applied immediately into the maize grain. The amounts of powder mixed with the maize grain were calculated on a weight of powder/weight of grain (w/w) basis that was 10 g of plant materials/1000 g of maize grain seeds. The synthetic chemical (Actellic Super Dust) used in this study was applied as recommended on the label instructions. The chemical contains 0.3% permethrin and 1.6% pirimiphos methyl as specified on the label.

Eucalyptus leaves are known to contain essential oils (citronella and 1.8cineole) which have some repellent and insecticidal properties (Song, Wang and Liu, 2009; Isiaka, et al., 2011). It was, however, beyond the scope of this study to determine the actual amount of essential oils that were in the leaves.

Five sacks of maize grain containing 1kg each was replicated three times were prepared making the total to 15sacks by 1kg. There were five treatments used in this study and these included;

i. Treatment 1 Actellic Super Dust (T1) as standards.
ii. Treatment 2 was control (untreated maize grain)
iii. Treatment 3 was *Tephrosia candida* leaf powder
iv. Treatment 4 *Eucalyptus tereticornis* leaf powder
v. Treatment 5 was *Lantana camara* leaf powder

Different pesticides were introduced except in the sacks of the control where no pesticide was applied.

Samples of the *Tephrosia candida*, *Eucalyptus tereticornis* and *lantana camara* at Katete FTC

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during collection and drying of botanical materials as shown above. (Modesto Mbewe, 2019)

Data Collection

Data collection on effectiveness of botanical control of *Sitophilus zeamais* on stored maize grain was done in each treatment which was replicated three times and at an interval of seven (7) days and for six times for the number of dead insects during the experiments. Grain damage and weight loss percentage was collected on the 42nd day after treatment.

Measurement of Parameters

Weevil counts were done every 7 days up to the end of the experiment on 42nd day after treatment. Weevil mortality was assessed on day 7, 14, 21, 28, 35 and 42 after the introduction of pests and treating the grains with different pesticides except in the control where no pesticide was applied. This was done to establish whether insect infestation was decreasing per individual treatment. The numbers of dead pests were counted from each sack (sample) to obtain the adult weevil mortality. The researcher used the white paper when counting the weevils in order to make the identification of the pests easier. Weevils suspected to be dead were exposed to light so as to verify. Those that did not respond to the light and heat were further examined by prodding with a sharp object so as to make sure that the pests were really dead (Amenga, 2011).

The following formula was used to calculate the percentage of weevil mortality:

%=A/B*100

Where;

A = total number of dead insects

B = Total number of insects inoculated and

100 represents the 100%

%Weevil mortality = (number of dead insects/Total number of pests inoculated) X 100

This means that the total number of dead insects was divided by the total number of pests inoculated in the sample which was 100 and then multiplied by 100 to find the weevil mortality percentage.

Besides weevil count, the samples were weighed using a digital laboratory scale. This was done at the beginning of the experiment and at the end of the experiment in order to establish grain weight loss percentage. On the 42nd day after treatment the maize grain was sieved, dust removed and the clean grain weighed. Differences were calculated and expressed as a percentage weight loss of the original weight, using the following formula:

Grain weight loss% = {(Original weight – weight after 42 days)/original weight X 100

Data analysis

Data analysis refers to examining what has been collected in a survey or experiment and making deductions and inferences (Kombo and Tromp, 2006). This involved selecting, categorizing, comparing, and interpreting the information collected. The data which was obtained from the experiment was subjected to randomized complete block design (CRD) analysis of variance (ANOVA) using Gen start 12th edition computer software. Treatment means were separated from one another by least significance difference (LSD) test at 5% significance level.

RESULTS

The Mean percentage Mortality rate of Maize Weevils

Maize Weevil Mortality on day 7 after treatment

There was a highly significant difference, amongst the treatments, for mortality on the 7th day after treatment as shown in table 2. The mean mortality percentage for synthetic control was 99% for maize weevil, 16.67% was the mean percentage mortality rate for Tephrosia candida, 14.33% and 8.33% were the mean maize weevil mortality percentage rates in the samples treated with

Eucalyptus tereticornis and *Lantana camara* leaf powder respectively at 7th day after treatment. There was no mortality in the control were no chemical was applied. Moreover, all the treatments with the same letter in the same column are not significantly different.

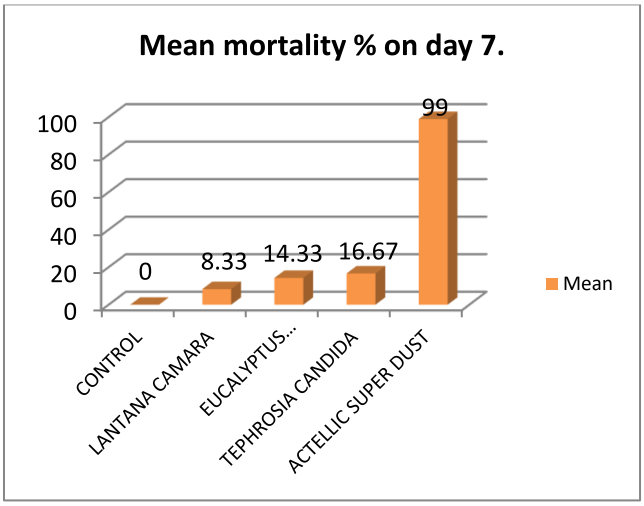
The control had zero mortality rate followed by *Lantana camara* which recorded mean percentage mortality rate of 8.33% with significant difference with *Eucalyptus tereticornis.* There was no significant difference between *Eucalyptus tereticornis* and *Tephrosia candida.* The significant difference was obtained between botanical materials and actellic super dust.

Table of Mean mortality rate of maize weevils on 7th day after treatment

TREATMENTS	Mean mortality %
CONTROL	0^a
Lantana camara	8.33^b
Eucalyptus terreticornis	14.33^c
Tephrosia candida	16.67^c
Actellic Super Dust	99^d

Note: L.S.D = 2.845, CV%= 2.2, P-Value < 0.001. (Modesto Mbewe, 2019)

The mean maize weevil mortality rate was high in the maize grain treated with actellic super dust and no mortality in the control.



Mean mortality rate of maize weevils on 7th day after treatment. (Modesto Mbewe, 2019)

Maize Weevil Mortality rate on day 14 after treatment. (Modesto Mbewe, 2019).

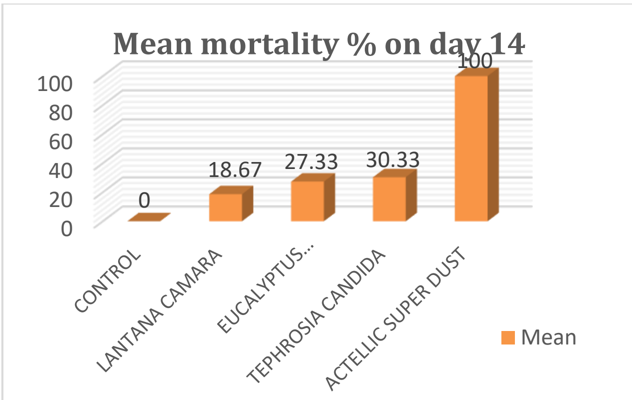
On the 14th day after treatment there was a highly significant difference, amongst treatments, for maize weevil mortality. The mean mortality percentage for synthetic control was 100%, 30.33% and 27.33% were mean maize weevil mortality in samples treated with *Tephrosia candida* and *Eucalyptus tereticornis* respectively. 18.67% mean maize weevil mortality rate was shown under *Lantana camara* leaf powder treatment and no mortality was observed in an untreated maize grain samples which was a control.

Table for the Mean mortality of maize weevils on 14th day after treatment

TREATMENTS	Mean mortality %
Control	0^a
Lantana camara	18.67^b
Eucalyptus terreticornis	27.33^c
Tephrosia candida	30.33^c
Actellic Super Dust	100^d

Note: L.S.D = 4.096, CV% = 1.8, P-value < 0.001

The table above shows different means obtained at 14th day after treatment. By 14th day after treatment, all maize weevils were dead in synthetic treatment and *Tephrosia candida* showed the highest mean percentage of maize weevil mortality rate where *Lantana camara* had the lowest amongst the botanical treatments. The control still recorded zero mean percentage maize weevil mortality.



(Modesto Mbewe,2019).

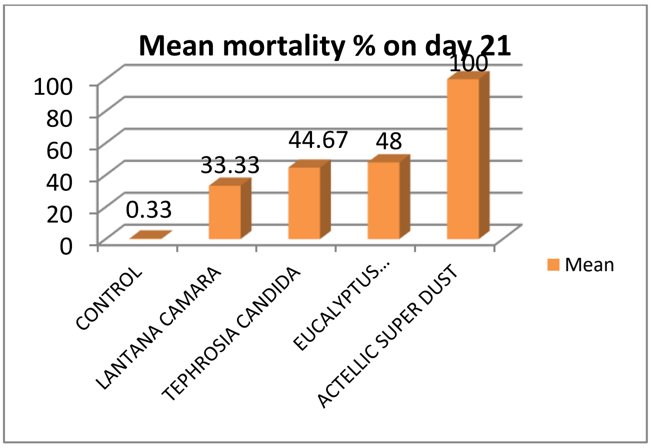
Maize Weevil Mortality on day 21 after treatment.

There was a highly significant difference, among the treatments, for the mean maize weevil mortality rates on day 21st. Synthetic treated samples recorded 100% maize weevil mortality rate since they were all wiped out within 14 day after treatment. The mean maize weevil mortality rate for *Tephrosia candida* and *Eucalyptus tereticornis were* 48% and44.67% respectively. The mean maize weevil mortality rate for *Lantana camara was 33.33%* whilst control was 0.33%. All treatment in the same column with same letters has no significant difference. This means that there was significant difference between synthetic and all other treatments and no significance difference between *Eucalyptus tereticornis and Tephrosia candida* despite eucalyptus scoring higher maize weevil mortality than tephrosia. *Lantana camara* scored the lowest maize weevil mortality rates amongst the botanical treatments there was still significance difference between *Lantana camara and control.*

Table for the Mean mortality rate of maize weevils at 21st day after treatment

Note: L.S.D. = 5.336, CV% = 2.0, P– Value< 0.001. (Modesto Mbewe, 2019).

The figure below explains on the mean percentage maize weevil mortality rates on 21st day after treatment. They are arranged in ascending order from the left to the right.



Mean mortality rate (%) of maize weevils at 21st day after treatment. (Modesto Mbewe, 2019).

Maize Weevil Mortality on day 28 after treatment.

On the 28th DAT (day after treatment) of maize with *Eucalyptus tereticornis*, *Tephrosia candida*, *Lantana camara* leaf powders and synthetic pesticide, there was a significant difference amongst different treatments for mean percentage mortality rates as shown in table 5, p < 0.001. Amongst the treatments synthetic pesticide recorded 100% maize weevil mortality rate, *Tephrosia candida* 70.33%, *Eucalyptus tereticornis* 69.67%, 55.33% and 0.67% for *Lantana camara* and control respectively.

However, treatments in the same column with same letters signify no significance differences between treatments. In table 5, there is significant difference between control and lantana camara and no significant different between *Eucalyptus tereticornis* and *Tephrosia candida* despite having different mean maize weevil mortality rates. However, there is significant different between synthetic pesticide and botanical control.

Mean mortality rate of maize weevils at 28th day after treatment

Treatments	**Mean mortality**
Control	0.67^{a}
Lantana camara	55.33^{b}
Eucalyptus tereticornis	69.67^{c}
Tephrosia candida	70.3^{c}
Actellic Super Dust	100^{d}

L.S.D = 6.067, CV % = 2.4, P- Value = <.001. (Modesto Mbewe, 2019).

The figure below reveals the significant differences amongst the treatments of botanical and synthetic pesticide. The height of the graph signifies the mean maize weevil mortality rates at 28th day after treatment where synthetic is the highest and control (Untreated) the lowest.

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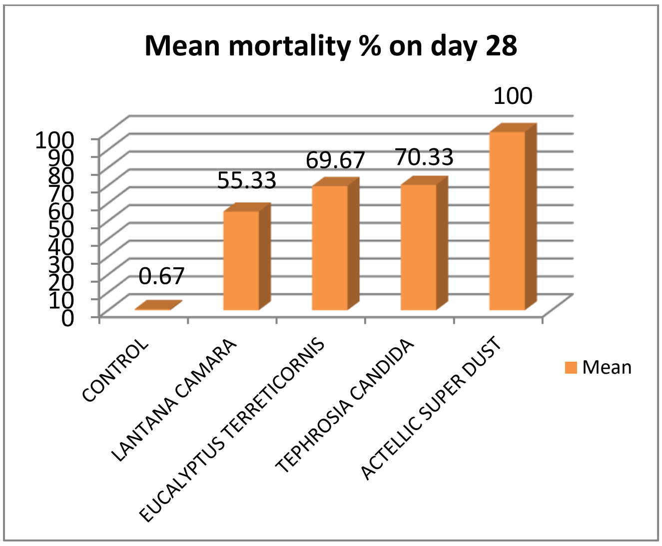
Tephrosia candida scored highest mean maize weevil mortality rate followed by *Eucalyptus tereticornis* and *Lantana camara* is the least amongst the botanical controls.



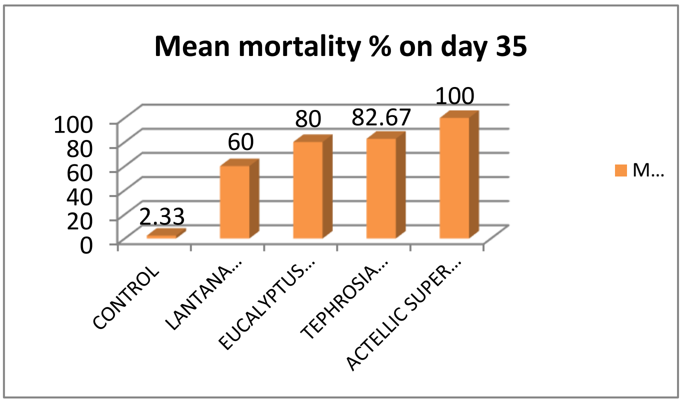
Mean mortality rate (%) of maize weevils on 28th day after treatment. (Modesto Mbewe, 2019).

Mean Maize Weevil Mortality on day 35 after treatment

There was a significant difference amongst treatments for mean maize weevil mortality as shown in table 6 $p < 0.001$. There was no significant difference between *Tephrosia candida* and *Eucalyptus tereticornis*. The mean maize weevil mortality percentages were as follows; synthetic pesticide 100%, eucalyptus leaf powder 80%, tephrosia leaf powder 82.67%, *Lantana camara* 60% and control were 2.33%. However, treatments with different letters in the same column are significantly different and those with same letters are not significantly different.

Mean mortality rate of maize weevils at 35th day after treatment

The graph figure below shows the mean maize weevil mortality rates at 35th day after treatment. *Tephrosia candida* leaf powder has a higher mean maize weevil mortality rate than *eucalyptus tereticornis* there was no significant difference but performed better than the *Lantana camara* scoring 80% as mean maize weevil mortality rate. Control was the lowest with mean mortality rate of 2.33%.



L.S.D.=4.618, CV%=1.1, P-Value= <.001. (Modesto Mbewe, 2019).

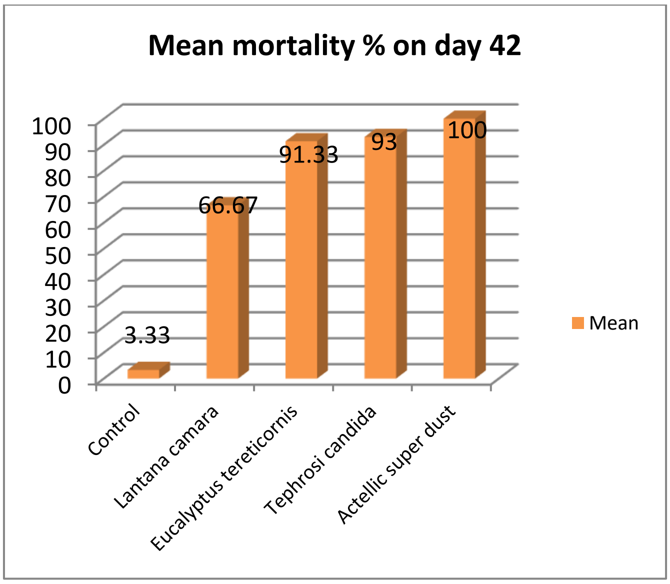
Maize Weevil Mortality on day 42 after treatment.

The results on 42nd day indicate that, there were significant differences amongst the treatments in terms of mean maize weevil mortality percentage rate on 42nd day after treatment. The mean maize weevil mortality rates for synthetic pesticide was 100%, *Tephrosia candida* was 93%, 91.33%, 66.67% and 3.33% were for *Eucalyptus tereticornis*, *Lantana camara*, and control respectively.

There was significant difference between control (untreated) and *Lantana camara* and also with *Eucalyptus tereticornis.* However, despite of different figures between *Tephrosia candida and Eucalyptus tereticornis* there was no significant different between these two treatments. There was also no significant difference between synthetic and *Tephrosia candida.*

Mean mortality rate of maize weevils at 42nd day after treatment

The figure below reveals the heights of graphs representing the mean percentage mortality rate of maize weevils. The control only recorded 3.33% mean mortality of maize weevils at day 42 after treatment.



L.S.D. = 4.958, CV% = 2.5, P- Value = <0.001. (Modesto Mbewe, 2019).

The damage on maize grains in storage

Maize grain damage on 42nd DAT/100 Grains

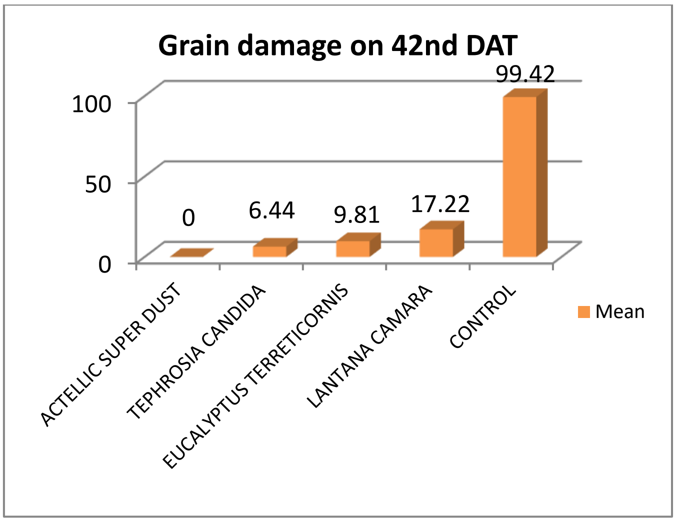
Table 8 shows that there were significant differences amongst the treatments on 42nd day after treatment. The treatments that have the same letter in the same column are not significantly different but those with different letters are significantly different. The mean percentages shown in table 8 are the grain damage percentages which were caused at 42nd day after treatment by *Sitophilus zeamais*. The mean grain damage percentages were as follows; actellic super dust 0%, *Tephrosia candida* 6.44%, *Eucalyptus tereticornis* 9.81%, *Lantana camara* 17.22% and control which was untreated was 99.42%.

Maize grain damage (%) on 42nd day after treatment/100 grains

TREATMENTS	Mean Grain damage %
Actellic Super Dust	0[a]
Tephrosia candida	6.44[b]
Eucalyptus terreticornis	9.81[c]
Lantana camara	17.22[d]
Control	99.42[e]

L.S.D.= 1.796, CV%= 2.8, P-value = <.001. (Modesto Mbewe, 2019).

Figure above shows the different mean protection percentage at 42nd day after treatment. Actellic super dust indicates that there was 100% mean protection to the maize grain in storage and *Tephrosia candida* offered 91.33% protection to the maize grain whilst *Eucalyptus tereticornis*, *Lantana camara*, control (untreated) offered 88%, 70.67% and 4%respectively and 42nd day after treatment.



Mean grain damage (%) on 42nd day after treatment. (Modesto Mbewe, 2019).

The weight loss on maize grains in storage

Grain weight loss on 42nd Day

There were significant differences amongst treatments in grain weight loss. The means of the weight loss in the same column with same letters have no significant different but those with different letters indicates the significance difference between treatments. Actellic super dust had the lowest weight loss mean percentage of 0.407 followed by *Tephrosia candida with mean percentage of 1.953. Eucalyptus tereticornis* had mean weight loss percentage of 2.773%, 3.93% and 29.9% mean weight loss for *Lantana camara* and the control (untreated) respectively.

Grain weight loss (%) on 42nd day after treatment

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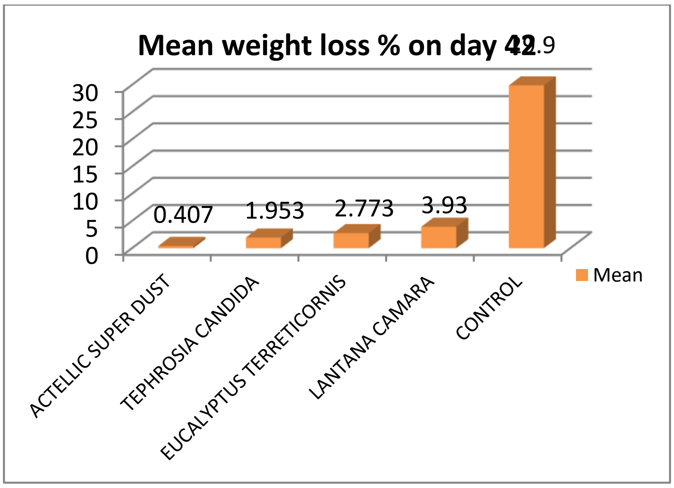
TREATMENTS	Mean weight loss %
Actellic Super Dust	0.407[a]
Tephrosia candida	1.953[b]
Eucalyptus terreticornis	2.773[bc]
Lantana camara	3.93[c]
Control	29.9[d]

L.S.D. = 1.254, CV% = 7.4, P-Value = <.001. (Modesto Mbewe, 2019).



Mean weight loss (%) on 42nd day after treatment. (Modesto Mbewe, 2019).

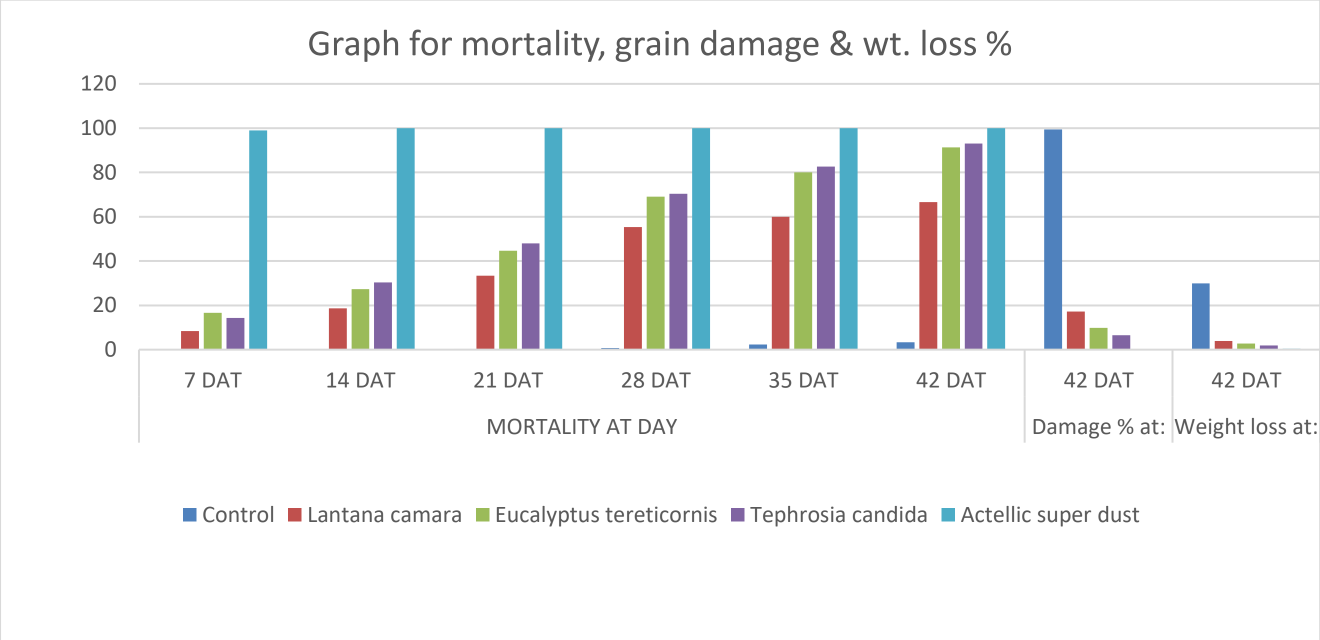
Figure 13 shows that the control had the highest mean weight loss amongst the treatments and the synthetic treatment (actellic super dust) recorded the lowest mean weight loss amongst the treatments.

DISCUSION OF FINDINGS

Summary of results on mortality rate, grain damage and weight loss percentages

Treatments	Mean maize weevil mortality % at:						Grain Damage % at:	Grain Weight loss % at:
	7th DAT	14th DAT	21st DAT	28th DAT	35th DAT	42nd DAT	42nd DAT	42nd DAT
Control	0[a]	0[a]	0.33[a]	0.67[a]	2.33[a]	3.33[a]	99.42[e]	29.9[d]
Lantana camara	8.33[b]	18.67[b]	33.33[b]	55.33[b]	60[b]	66.67[b]	17.22[d]	3.93[c]
Eucalyptus tereticornis	14.33[c]	27.33[c]	44.67[c]	69.67[c]	80[c]	91.33[c]	9.81[c]	2.773[bc]
Tephrosia candida	16.67[c]	30.33[c]	48[c]	70.3[c]	82.67[c]	93[cd]	6.44[b]	1.953[b]
Actellic super dust	99[d]	100[d]	100[d]	100[d]	100[d]	100[d]	0[a]	0.407[a]

(Mbewe Modesto, 2019)



Summary of results on mortality rate, grain damage and weight loss percentages. (Modesto Mbewe, 2019).

The Mortality rate of Maize weevils

Previous studies revealed that different plants were used in controlling pest and they proved effective and eco-friendly (Fekadu et al., 2012, Lale and Mustapha, 2000). Many researchers investigated the compounds in plants that have a variety of properties including insecticidal activity, repellence to pests, antifeedant effects, insect growth regulation, toxicity to nematodes, mites and other agricultural pests, also antifungal, antiviral and antibacterial properties against pathogens. Table 10 shows different mean percentage mortality rates of maize weevils, grain damage and weight loss percentage using different pesticides at different dates.

The reported results in this study show that botanical materials have insecticidal effects on the maize weevil, *Sitophilus zeamais*, hence they can be used as alternatives to control maize grain in storage against *Sitophilus zeamais* instead of using synthetic pesticide which has healthy issues and unfriendly to the environment and ecosystem, hence the null hypothesis is rejected which stated that botanical control has no significant effect on mortality rate of maize weevils in stored maize grain and accept the alternative which stated that botanical control has significant effect on mortality rate of maize weevils in stored maize grain The three plants species were effective in causing the mortality to *Sitophilus zeamais* with a high significant difference from the control. Results indicated that plant leaf powders such as *Eucalyptus tereticornis*, *Tephrosia candida* and *Lantana camara* can be used to protect stored maize grains against *Sitophilus zeamais*. The results also revealed that despite of the high maize grain damage recorded in botanical controls especially in *Lantana camara* leaf powder, the number of *Sitophilus zeamais* was relatively high in no pesticide application as compared to maize grains treated with botanicals, indicating that insect reproduction and development were impaired in all botanical pesticides. Schmuttere (1990) reported that botanicals have antiovipositional and fecundity reducing properties on a range of insects.

The use of local plant products and other available materials to protect stored crop grains have been reported by other researchers (Golobo *et al*., 1982; Lale, 1995) Golobo and Webely, (1980). Keita et al. (2000) and Lale Mustapha (2000) had advanced that oil products from neem are particularly more effective against insects which lay their eggs outside the grain but less effective against curculionids which lay eggs inside the maize grains. *Sitophilus zeamais* lays eggs inside the maize grains therefore the present study revealed that the use of plant leaf powders could be applied in the control of *S. zeamays* Lupenza et al (2007). In this study, *S. zeamays* showed least live maize weevils in maize grains treated with tephrosia leaf powder which had the highest mean percentage mortality rate of maize weevils amongst the plant materials which recorded 93%, followed by eucalyptus leaf powder at 91.33%% as compared with *Lantana camara* with 70.67% and control or untreated with 3.33% on the control of *Sitophilus zeamais.* Despite of the low mortality percentage rate in *Lantana camara* treated maize grain, there was still a significant difference with the control (untreated), and therefore, farmers can still use all the three plant leaf powders' as an alternatives pesticide to treat their maize grain in storage to control *Sitophilus zeamais*. Moreover to control the maize weevil effectively, farmers can use *Tephrosia candida and eucalyptus tereticornis* as the best alternative. The researcher also feels that increased doses can improve on mean percentage mortality rates of maize weevils to 100%. The effectiveness can also be achieved through increase in dosage of the plant materials to maintain their efficacy. This agrees with sentiments by Khare (2007), which reveal that botanical products have pesticidal effect 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 *L. javanica* leaf powder. Although the synthetic pesticide has higher mortality percentage, according to Mkendaet 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 botanical products facilitates ecosystem services at the same time effectively managing *S. zeamais* in stored maize grain. The labour cost of collecting and processing abundant plants in surrounding bushes are less than the cost of purchasing synthetic pesticides.

Moreover, the mortality rate experienced in the control where there was no pesticide applied might have been caused due to disturbances during data collection and also natural death of weevils because during the inoculation of the maize weevils into the maize grain, they had unknown ages. Adults can live for 5 to 8 months (Mason, 2003).

The effects of botanical control on damage on Maize grains in storage

The results from this study revealed that the leaf powder and plant species have significant effect on grain damage by *S zeamais*, decreasing with specific plant leaf powder. The treatment with *Tephrosia candida* leaf powder can reduce grain damage as effective as Actellic Super Dust at label instruction if the dosage can be increased followed by *Eucalyptus tereticornis and Lantana camara* respectively. This concurs with the research on *Eucalyptus grandis* (Musundire et al 2014), *T. minuta* (Muzemu et al, 2013) *Jatropha curcas* (Constance et al 2013), *Lantana camara* (Furusa, 2008), *L. javanica* (Gadzirai et al 2006) as botanical grain protectants in powder form used to reduce weevil infestation. Also according to Bekele et al., (1997), botanical pesticides represent an important potential for integrated pest management programs in developing countries as they are based on local materials. Plant materials with insecticidal properties provide small scale farmers with chemicals that are locally and readily available, affordable, relatively less poisonous and less detrimental to the environment for pest control reducing damage of grain as said by Talukder & Howse, (1995).

Despite the higher number of grains damaged in maize treated with *botanical* leaf powders, the weight loss was low as compared to no pesticide application. This suggests that botanical leaf powders exert better repellent effect and hence reduced maize grain damage. Results also show that despite the high seed damage recorded in all the three botanical products, the *S. zeamays* numbers were relatively high in no pesticides application as compared to maize grains treated with botanicals, indicating that insect reproduction and development were impaired in all botanical pesticides. Schmuttere (1990) reported that botanicals have antiovipositional and fecundity reducing properties on a range of insects.

The damage and weight loss on maize grains in storage

Results from this study showed that as number of damaged grains reduces, weight loss decreases. Weight loss was highly observed on control followed by *L. camara* leaf powder treatment. 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 *Tephrosia candida* treated maize grain and *Eucalyptus tereticornis*, however, *Lantana camara* had high significant different as compared to the u untreated control. There was no grain damage in synthetic pesticide treatment resulting to very minimal weight loss which might have caused by loss of moisture from initial12.8% to 11.9% on day 42 after treatment. Minimal grain damage was observed on botanical treated grain leading to little weight loss when compared to the untreated control maize grain. Moreover, *Tephrosia candida and Eucalyptus tereticornis* were the most effective botanical control of weight loss because there was no significant different between them followed by *Lantana camara* which also showed no significant difference when compared with *Eucalyptus tereticornis* but there was high significant difference with the control (untreated). However, synthetic was the most effective in this study because there was also high significant difference compared to the botanical control. 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 *Tephrosia candida, Eucalyptus tereticornis* and *Lantana camara c*ould 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 whilst reducing its population.

The present investigation suggests that tephrosia, eucalyptus and lantana leaf powders can be used as good alternatives to synthetic pesticides against *S. zeamays* due to low maize weight loss recorded in this study when compared to the untreated control. The botanical treatments showed the significant differences in the mean weight losses compared to the control.

Conclusion

The present study has shown that botanical leaf powder can be used as an alternative pesticide against *Sitophilus zeamais* in stored maize grain as was shown by the statistical weevil mortality for *Tephrosia candida*, *Eucalyptus tereticornis* and *Lantana camara*. However the effectiveness of botanical leaf powder on *Sitophilus zeamais* can increase with the increase in the dosage and reapplication to maintain its efficacy. The results of the research revealed that various plant species performs differently hence playing a pivotal role in as far as their effectiveness is concerned.

Moreover, higher doses and reapplication of the botanical leaf powder may increase and maintain the efficacy and the opposite is also true and this agrees with Hall (1980), who observed that leaf powder of eucalyptus globules have a short term protection against *Sitophilus oryzae.* Therefore, it simply means that if farmers are to realize meaningful stored maize protection, there is need to increase the eucalyptus leaf powder doses to the optimal. Furthermore, the results of this research also revealed that the effectiveness of botanical leaf powder decreases with time after application hence constant reapplication of the leaf powder is greatly recommended. Since the effectiveness of botanical leaf powder increases with the increase in the dosage, it therefore means there is need to experiment further to establish the most ideal and effective doses.

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