__Original Research Article__

Efficacy of Neem and Eucapyptus leaf powders in the management of maize weevil (*Sitophilus zeamais*) in dried sweet potatoes

ABSTRACT

Maize weevil (*Sitophiluszeamais)* is a polyphagous storage pest for crops of economic and food security importance. Its management currently relies on synthetic chemical pesticides.However, plant botanicals are known to exhibit insecticidal properties which can be used to manage the weevil in stored dry sweet potatoes.To study the effect ofneem and eucalyptus leaf powders, an experiment was set up at Busitema University laboratory. Neem and eucalyptus leaves were processed into powders.400g of dried sweet potato chips were weighed and placed in 4 different plastic buckets. Under laboratory conditions, experimental buckets were inoculated with 30 unsexed newly emerged adult weevils. To each bucket, 40g of leaf powderswere introducedas single powders and a combination. The experiment was replicated three times.Data on mortality, growth inhibition, produce damage and weight loss was collected over a period of 84 days. Analysis of variance showed that all plant powders showedsignificant ($P<0.001$) increase in mortality and inhibition, a decrease in damage and weight loss compared to control. The combination showed superiority in all parameters measured.

Keywords;Efficacy, Neem, Eucalyptus, leaf powders, *Sitophilus zemais,* sweet potatoes.

Introduction

Sweet potatoes (*Ipomea batatas*) is an important crop that covers 55% of arable land in Uganda (Tinyro & Mayanja, 2018; Abong' *et al*., 2016). The crop is ranked third to cassava and plantains in terms of food security importance. In Teso-sub region, it ranks second after cassava as a food security crop (Epeju & Rukundo, 2017). The crop is considered drought tolerant, hardy and can grow in marginal areas, it ~~has~~ can be~~is~~ produced in two growing seasons (Namanda *et al*., 2011)thus contributing to improved food security(FAO/TECA., 2020) for farming communities in semi-arid conditions and marginal soils. Based on production characteristics of sweet potatoes, it hence possess immense potential to contribute to addressing Sustainable development goals of zero hunger and no poverty (UN, 2022).Despite its importance, farmers have continued to incur losses of this valued crop in storage mostly due to storage pests like; larger grain borer, lesser grain borer, and *Sitophilus zeamais*. It is observed that farmers make huge losses even in the dried sweet potato chips due to storage *S. zeamais*, as the stored chips become pulverized in 2-3 month of storage due to insect pests (Agona *et al*., 1999).

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Maize weevil (*Sitophilus zeamais*) a polyphagous chewing pest that has been reported as a serious pest in maize storage including other crops (Barre & Jenber, 2022). The~~maize~~ insect pest~~weevil~~ also infests other types of stored, products such as sweet potatoes, cassava, and various coarse, milled grains causing quantitative and qualitative lossesup to 90% under serious infestation (Muzemu et al.., ~~, Simbarashe. Chitamba,~~ 2013). The management of storage pests has relied on synthetic insecticides inform of fumigants (Ojo & Omoloye, 2016). However, the chemical insecticides have limitations such as food safety, human health and environmental hazards associated with their use in stored agricultural produce (Ileke et al., 2020, Mandudzi & Edziwa, 2016). Due to ~~associated~~ several challenges associated with the use of chemical insecticides in stored foods, research efforts on alternative plant-based products has gained momentum in the recent years (Akinneye & Ogungbite, 2013).

Traditionally, farmers have employed indigenous knowledge like use of whole plant parts and plant ash in control of storage pests. The indigenous knowledge is based on local perceptions and is relative to given farming community.Botanicals plants are historically known to have insecticidal properties(Belmain et al., 2022). Insecticidal plants such as Neem and Eucalyptus (*E. tereticornis*) are common and easily accessibleto a majority of farmers in Uganda(Erenso&Berhe, 2016; Trivedi*et al*., 2018), this together with ~~their~~ thembeing cheap, safe and environmentally friendly makes the use of powders from the plants as protectants an appealing alternative in control of *Sitophilus zeamais*~~(Soujanya et al., 2016)~~among smallholder farmers(Soujanya et al., 2016).

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The neem leaf and eucalyptus powders and oils have been used as single powders in the control of *Sitophilus zeamais* in yams (Koradaa*et al*., 2010), rice(Devi *et al*., 2014), and maize(Erenso & Berhe, 2016). Musundire *et al*., (2015)investigated the efficacy of *Eucalyptus grandis*and

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*Tagetes minuta*ground leaf powders as grain protectants against *Sitophilus zeamais*in stored maize, their results showed that all powders significantly minimized grain damage and infestation 96 days post treatment. The plant materials have been reported successful in management of storage pests. Although the effectivenessof seed oil and leaf extracts have been experimentedas single applications, the potency of leaf powders of the two insecticidal plants has not been tested in stored dry sweet potatoes, therefore, the study tested the efficacy of neem and eucalyptus as single powders and their mixture in managing *Sitophilus zeamais* on dried sweet potato chips as potential cost effective and environmentally friendly management option for *Sitophilus zeamais* in stored dry sweet potato chips in smallholder farmers storage conditions. The study had the overall objective to assess efficacy of neem and eucalyptus leaf powders on management of storage pest of sweet potatoes as an ecological strategy for healthy food management among smallholder farmers. Specifically, the study sought to determine the effect of neem and eucalyptus leaf powders on infestation of sweet potato chips by Maize weevil and secondly, determine the effect of neem and eucalyptus leaf powders on damage of sweet potato chips by maize weevil.

Methods and materials

3.1. Description of study location

The experiment was conducted atBusitema University laboratory (1° 46' 48.00"N, 33° 37' 30.00"E) in Soroti District, Eastern Uganda. Dried sweet potato chips were used as experimental material for the study. Fresh Sweet potatoes were collected from Arapai market and prepared into dry chips.FAO/TECA, (2020) procedure was modified by peeling potatoes as is the practice with most farmers

Preparation of plant powders

The leaves of test plants eucalyptus and neem were obtained from Busitema University- Arapai campus, they were washed under running tap water to remove impurities and then dried under shade for 20 days at room temperature until crispy to conserve the active ingredients.~~,~~ The leaves were ~~upon proper drying the leaves were~~ crushed into powder using an electric grinding machine and then packed. In order to prevent loss of quality, polythene bags were used to store and seal the powders at room temperature (Chayengia et al., 2010)

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Rearing of the experimental insects

Adult maize weevils used in the experiment were reared in plastic containers under ambient laboratory temperature of 30 ± 3^{o}C and relative humidity of 75±3%. Weevil-infested potatoes chips were sourced from farmer stores within Arapai community and were put inculture vials before they were incubated in the laboratory cupboard so that the old insects will mate and oviposit. This was left undisturbed for one and a halfmonths and the newly emerged adults were used for the experiment.

3.6. Treatment of sweet Potato chips with plant powders and introduction of test insects

400g of dried sweet potato chips were weighed using a digital scale and placed in each of the 4 plastic buckets. A total of 30 unsexed newly emerged weevils 1-10 days old were introduced to each of the buckets containing sweet potato chips. The buckets containing weevils and sweet potato chips were then randomly treated with 40g of neem leaf powder, eucalyptus leaf powder and a combination (neem + eucalyptus) each contributing 20g. The control bucket did not receive any treatment. The experiment was replicated thrice and treatments were randomly assigned using the table of random numbers. The experiment was carried out under temperature of 30 ± 3^{o}C and humidity of 75±5% for 84 days(Muzemu *et al.*, 2013).

Description of experimental design and layout

Completely randomized design (CRD) was used in the experiment. There were four treatments in the experiment namely: control (without any powder) 0.4g of sweet potatoes (sp), neem leaf powder 40g/0.4kg of sweet potato chips, eucalyptus leaf powder 40g/0.4kg of sweet potato chips and a combination of neem and eucalyptus powder 40g/0.4kg of sweet potato chips each powder contributing 20g. Each treatment was replicated three times. Thirty unsexed maize weevils (1-10) old were introduced to each bucket containing respective treatments mentioned above, the open ends of the buckets were sealed off using a muslin cloth to prevent escape of insects while allowing in air. The experiment ran for 84 days during which data was collected.

Data Collection

Data collected included; percentage mortality of adultweevils and inhibition rate which relate to objective one of this study and then percentage potato chips damage and percentage weight loss which aided in measurement of the second objective.

Adult Mortality

Data on adult mortality was obtained by counting the number of dead adult weevils in the plastic bucket after application of treatment. The data was recorded for a period of 35 days on a seven (7) day interval (7, 14, 21, 28 and 35 days) and the percentage mortality was computed using the formula used by (Loko *et al*., 2018) given as;

$$\text{Percentage mortality} = \frac{\text{Number of dead maize weevils}}{\text{Number of introduced maize weevils}} \times 100\%$$

Newly emerged weevils and Inhibition rate.

The number of newly emerged adults was counted starting from the 35th day after oviposition till the 84th day on a seven-day interval; days of first emergence were also recorded between the 35th and 56th days. The inhibition rate was calculated from the formula as described previously~~used by~~(Ahad *et al*., 2016)~~ below~~.

$$\text{Inhibition Rate (IR)} = \frac{\text{Cn} - \text{Tn}}{\text{Cn}} \times 100\%$$

Where;

C_n= Number of insects in control bucket.

T_n= Number of insects treated bucket.

Percentage damage on sweet potatoes chips

Plant powders were tested for potato chips damage on the 84th day of the experiment by randomly selecting 10 S. potatoes from each container, the holed chips were regarded as damaged and their number was recorded for each replicate. The percentage damage was calculated using a formula adopted from (Adedire&Lajide, 1996).

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Percentage potatoes chips damage = $\frac{G1}{G2}$ ×100%

Where, G_1 = Number of potatoes chips with hole, G_2= Total number of the randomly selected dried potatoes chips.

Percentage Weight Loss

Data on weight loss was taken on the 84th day of the experiment~~, on the 84th day~~ by sieving off all the powder particles of sweet potatoes and the plant powders and leaving behind the sweet potato chips which were weighed using a digital scale for each replicate and their weights recorded as the final weight. The initial weight had been noted early on the first day of experiment set up as 400g for all replicates. Weight loss was then obtained by subtracting final weight from the initial eight of the sweet potatoes and percentage weight loss was computed from the formula adopted from (Loko *et al*., 2018) as;

$$\text{Percentage weight loss} = \frac{\text{Initial weight of chips} - \text{final weight of chips}}{\text{initial weight of chips}} \text{x100\%}$$

Data analysis

The % mortality, % damage, %weight loss and inhibition rate were subjected to the analysis of variance (ANOVA) procedure using GenStat 12th edition (Payne *et al*., 2011) to generate Means, least significant Differences (LSD), Coefficients of Variation (CV) and F-probability. Treatment means were compared using Bonferroni test at 0.05 level of significance.

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Results

Mortality of *Sitophilus zeamais*

The analysis of variance showed that there was significant variation in mortality (P<0.001) in all the treatments during the treatment period and among treatment interaction with time (T~~t~~able 2). When mortality of weevils was studied at 7,14, 21, 28 and 35 days of exposure to treatments, the results ~~showed~~revealedthat there was increase in mortality with time for all the treatments. ~~, t~~The greatest mean mortality (92.2%) was achieved on the 35th day after treatment. However, ~~however~~ there was no statistical difference in mean mortality between the 28th and 35th day. The treatment interaction showed that the combination (Neem + eucalyptus) increased mortality up to 74.9%, the least mortality was observed in the control 13.8%. There was no significant difference in mortality of *S. zeamais*between neem leaf powder and eucalyptus leaf powder (T~~t~~able 3).

Table 1; Anova table showing Mean sums of square for parameters measured

Source of variations	df	MS	df	MS			
		Mortality (%)		Emerged insects (Numbers)	Inhibition rate (%)	Damages (%)	Weight loss (%)
Treatment	3	10746.2***	3	269.4***	18567.9***	875.0***	564.2***
Time interval (Days)	4	9445.7***	3	386.4***	1786.1***	-	-
Treatment X Time interval	12	495.4***	9	27.1***	370.5***	-	-

Numbers followed by the stars are the mean sums of squares, df= degree of freedom, Ms= mean sums of square, %=percentage, *** means highly significant at P<0.001

Table 2: Effect of treatments on the mortality of *Sitophilus zeamais*

Time interval (Days)	7	14	21	28	35	Mean
Treatments	Mortality (%)					
Control	0.0	8.9	16.7	17.8	25.6	13.8a
Eucalyptus	10.0	35.6	77.8	86.7	87.8	59.6b
Neem	13.3	38.9	81.1	87.8	91.1	62.4b
Neem + Eucalyptus	23.3	57.8	96.7	97.8	98.9	74.9c
Mean	15.6a	44.1b	85.2c	91.1d	92.2d	65.6
Se	1.836					
LSD	5.255***					
CV (%)	6					

Lsd=least significant difference, CV=Coefficient of variation, same letters following meansdown the column and along the rows show no statistical difference and ***highly significant P<0.001

4.1.2. Newly emerged weevils and Inhibition Rate

The numbers of newly emerged maize weevils increased significantly P<0.001 with the highest increase being observed in the control (13.3) followed by eucalyptus leaf powder (5.3), neem leaf powder (4.3) and the least emergence was in the combination with 2.8 maize weevils. On the 35th day, 4 new weevils had emerged in the control whereas no new emergences were registered in neem leaf powder and eucalyptus leaf powder up to the 42nd day after treatment.,Nnew emergencies were observed in the combination for the first time in the 49th day after treatment. By Onthe 56th day, only 7.3 weevils had emerged in the combination, 9.7 in neem leaf powder, and 11.3 in eucalyptus leaf powder compared with 26.0 weevils in the control(Ttable 3).

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Table 3;Effect of plant powders on the numbers of emerged *Sitophilus zeamais*

Time interval (Days)	35	42	49	56	Mean
Treatments	No. emerged insects				
Control	4.0	6.7	16.7	26.0	13.3d
Eucalyptus	0.0	3.0	6.7	11.3	5.3c
Neem	0.0	1.7	5.7	9.7	4.3b

Neem + Eucalyptus	0.0	0.0	3.7	7.3	2.8a
Mean	1.0a	2.8b	8.2c	13.6d	6.4
SE	0.491				
LSD	1.418***				
CV (%)	13.3				

S.E-Standard error, LSD- Least Significant difference, CV-Coefficient of variation, *** Significance at P<0.001

It was observed that, all plant powders showed an inhibitory effect on *Sitophilus zeamis*growth. Significant differences P<0.001 among powders and the duration of exposure to treatments was recorded. Inhibition was highest in the combination (Neem + Eucalyptus) 87.4% followed by neem leaf powder (75.8%) and eucalyptus leaf powder (67.9%).Maximum inhibitory effect of upto 100% for combined use of Neem and eucalyptus leaf powders was sustained up to 49 days while single application of insecticidal powders only inhibited emergence of new insects up to 35 days after treatment. It was also observed that inhibition rate decreased with increase in days of exposure to powder treatments from 75.0% on the 35th day to 47.6% on the 56th day after treatment (**Table 4**)

Table 4;Inhibitory effect of plant powders on emergence of *Sitophilus zeamais*in dried sweet potato chips up to the 56th day of treatment duration

Time interval (Days)	35	42	49	56	Mean
Treatments	Inhibition rate				
Control	0.0	0.0	0.0	0.0	0.0a
Eucalyptus	100.0	55.6	60.1	56.1	67.9b
Neem	100.0	74.6	65.9	62.8	75.8c
Neem + Eucalyptus	100.0	100.0	77.9	71.5	87.4d
Mean	75.0c	57.5b	51.0a	47.6a	57.8
SE	2.811				
LSD	8.118***				
CV (%)	8.4				

LSD- least significant difference, SE- standard error, CV- coefficient of variation, *** Significance at P<0.001

Percentage Damageon sweet potato chips by *S. zeamais*

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Generally, mean percentage damage wasobserved to be lower (20%) when combined application of Neem and Eucalyptus was used and significantly (P<0.001) higher damage (60%) was observed in control buckets. The use of Neem and Eucalyptus separately showed low damage at 30% and 40, respectively. Similarly, there was significant variation in weight loss between treatments (p<.001). The highest weight loss was observed in the control bucket 34.42% and the least weight (3.18%) loss of stored potato chips was observed when Neem and Eucalyptus leaf powders were used in combination, followed by neem leaf powder (9.89%) and Eucalyptus powder (10.24%).

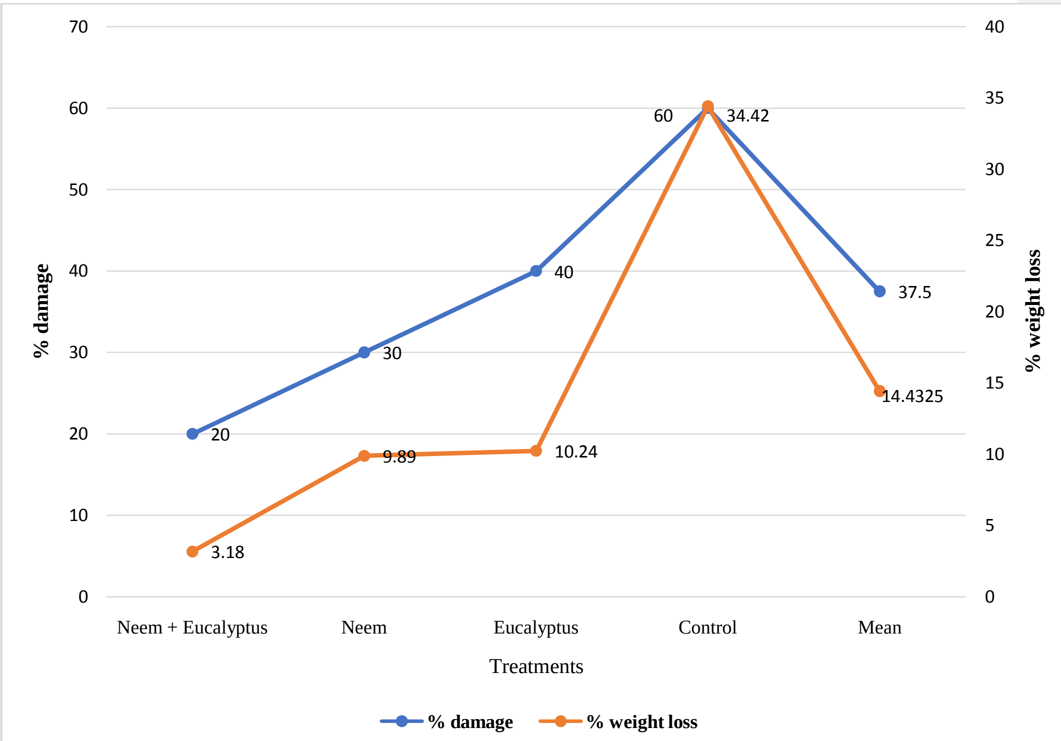

Figure 1;Variations in damage and weight loss among the different treatments due to *Sitophilus zeamais*on dried sweet potato chips under storage

Discussion

Results showed significant differences in mortality at p<0.001 for all treatments and with storage duration and their interaction. The combination caused the highest mortality, followed by single applications of neem and eucalyptus leaf powders and the control had the least mortality. The increased mortality in the combination could be due to the additive or synergist effect of the powders in acting as fumigants. The progressive mortality observed in this study is associated with the slow action of active ingredients (azadirachtin and eucalyptol) in the powders and so *Sitophilus zeamais* death was delayed by the slow action of powders (NRC, 1992). Besides, , also there was no statistical difference in mortality between 28th and 35 day indicating, this indicates that though mortality in the 35th day is higher, a similar effect could be achieved in the

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28th day post treatment, as noted in Maize storage by (Mbewe, 2016). The findings in the current study align with those of Erenso & Berhe, (2016)who tested the effect of neem leaf and seed powder against maize weevil reporting a , they reported mortality rate of 61.13, 68.76 and 77.75% within 10, 30 and 45 days, respectively. Also Additionally,in a study conducted by (Shiberu and Mulugeta., 2017) on the determination of appropriate dozes of botanicals against maize weevil, 100% mortality was reported due to 5g of neem leaf powder on 100g of maize grain. Though the mortality in the current study is lower than that of Shiberu. and Mulugeta., (2017), the findings in this study show potency of the leaf powders in causing mortality of *S. zeamais* in stored sweet potato chips, however, the efficacy of leaf powders can be influenced by dosage, size of chips and storage conditions and the extent of contact between the insecticide and the pest (Mbah & Okoronkwo, 2008)

All plant powders showed inhibitory effect to *Sitophilus zeamis* with a highly significant difference among the powders and powder interaction with time at P<0.001, the inhibitory ability of powders was in the order; combination (neem + eucalyptus) > neem leaf powder > eucalyptus leaf powder. The results obtained in this study are attributed greatly to the inhibitory activity of azadirachtin and eucalyptol in neem and eucalyptus, respectively. , tThese active ingredients could have delayed or inhibitedor inhibited oviposition, feeding, growth and development of the insects by blocking the ecdysone hormones which control those vital insect physiological processes thereby reducing the number of neonates compared to the control.,tThe high delay in emergence of neonates in the combination (neem + eucalyptus) could be due to the synergistic effects of the powders.Our studyconfirmcongruentthose of withSoujanya *et al*. (2016) who reported that botanical pesticides inhibit the development of immature neonates of storage pests of inagricultural produce.

We observed that all the plant powders significantly reduced damage on dried sweet potato chips due to *Sitophilus zeamais*in comparison to the untreated control.Generally, the lower damage values recorded with the powders are attributed to the toxicity by the insecticidal plant powders by whichacting actas fumigants (Muzemu et al., 2013) and inhibitory effects of the powders against *Sitophilus zeamais.* The significantly lower damage due to combined application of Neem and Eucalyptus is attributed to synergistic effect of the powders in causing deterrence to the weevils feeding(Akinneye & Ogungbite, 2013). The results of this current study are in line with those of Ehisianya (2019) who reported 68% damage of maize weevil in the control of maize weevilwhen *Imperata cylindrica* powder was used in stored maize.

Produce weight loss was recorded in all treatments, however, high loss in weight of sweet potato chips due to *S. zeamais* damage was recorded in the untreated (control) bucket and the order of weight loss was; control > eucalyptus > neem > combination (neem + eucalyptus) and were significantly different $P < 0.001$ for all the treatments. The reduced weight loss realized with the powder treated sweet potato chips is as a result of reduced damage which could be due to feeding deterrence of the adults and larvae of the weevils. These similar findings were reported by (Musundire *et al*., 2015) on maize weevils under storage conditions. The low damage observed in the treated sweet potato chips could be attributed to the dehydration effect of botanical powders as well as reduced humidity in storage buckets that affected weevil survival, egg deposition and activity (Mbewe, 2016). This point to the potential of botanical pesticides in influencing ecosystems services provisioning for effective storage of agricultural produce.

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Conclusion

The plant leaf powders in the current study have shown effectiveness as management options for *S.zeamais* in stored sweet potato chips. This is shown by the increased mortality of the weevil, slow population build-up in the experimental buckets and reduced damage and weight loss on sweet potato chips. The combined application of Neem and Eucalyptus leaf powders showed increased efficacy in the management of the storage pest as compared to singular application, implying best results from the two botanical plants are realised when they are applied together rather than as sole application. The results also showed that the inhibitory effect of plant leaf powders decreases with time of application, similarly, weight loss associated with damage by the weevil tends to increase with time of application of the leaf powders.~~, t~~Therefore, reapplication of leaf powders can be better strategy to enhance long term effect of the leaf powders in management of storage pests.

Data availability statement

The data that support the findings of this study are available from the corresponding author [DO] upon reasonable request.

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