

Original Research Article

Efficacy of Neem and Eucalyptus leaf powders ~~in for~~ the management of maize weevil, *Sitophiluszeamais* (Motschulsky) ~~author?~~ (Coleoptera: Curculionidae) in dried sweet potatoes

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ABSTRACT

Maize weevil (*Sitophiluszeamais*) is a polyphagous storage pest ~~in many for~~ crops of economic and food security importance. Its management currently relies ~~mainly~~ 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 of neem 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 powders were introduced as 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 showed significant ($P < 0.001$) increase in mortality and inhibition ~~of maize weevil~~, and a decrease in damage and weight loss ~~of sweet potato~~ compared to control. The combination showed superiority in all parameters measured.

Keywords; Efficacy, Neem, Eucalyptus, leaf powders, *Sitophiluszeamais*, 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 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 high valued crop in storage mostly due to storage pests like, larger grain borer, lesser grain borer, and *Sitophiluszeamais*. 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 powder pulverized within 2-3 month of storage due to pests (Agona *et al.*, 1999).

Maize weevil (*Sitophiluszeamais*)is apolyphagous chewing pest that has been reported as a serious pest-threat in maize storage including other crops (Barre & Jenber, 2022). Themaize weevil also infests other types of stored, products such as sweet potatoes, cassava, and various coarse, milled grains causing quantitative and qualitative losses up to 90% under serious infestation (Muzemu, Simbarashe & Chitamba, 2013). The management of storage pests has relied on synthetic insecticides in form 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 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 & Ogunbite, 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 accessible to a majority of farmers in Uganda (Erenso & Berhe, 2016; Trivedi *et al.*, 2018), Being cheap, safe and eco-friendly environmentally friendly nature make them the use in powder form of powders from the plants as protectants an appealing alternative in control of *S. itophiluszeamais* (Soujanya *et al.*, 2016) among smallholder farmers.

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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 (Korada *et al.*, 2010), rice (Devi *et al.*, 2014), and maize (Erenso & Berhe, 2016). Musundire *et al.* (2015) investigated the efficacy of *Eucalyptus grandis* and *Tagetes minuta* ground leaf powders as grain protectants against *Sitophilus zeamais* in stored maize ~~and recorded, their results showed that all powders~~ significantly minimized grain damage and infestation on 96 days of post treatment. The plant materials have been reported successful in management of storage pests. Although the effectiveness of seed oil and leaf extracts have been experimented as single applications, the potency of leaf powders of the two insecticidal plants has not been tested in stored dry sweet potatoes ~~so far.~~ Therefore, the present study ~~on testing 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 present 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.

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Methods and materials

3.1. Description of study location

The experiment was conducted at Busitema 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

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Preparation of plant powders

The leaves of ~~eucalyptus and neem~~ test plants ~~eucalyptus and neem~~ were obtained from Busitema University- Arapai campus, ~~they were and~~ washed ~~under in~~ running tap water to remove impurities and then dried under shade for 20 days at room temperature until crispy to conserve

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the active ingredients, 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 $30\pm 3^{\circ}\text{C}$ and relative humidity of $75\pm 3\%$. Weevil-infested potato chips were sourced from farmer stores within Arapai community and were put in culture 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 half months and the newly emerged adults were used for the experiment.

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3.6. Treatment of sweet Potato chips with plant powders and inoculation 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, 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 $30\pm 3^{\circ}\text{C}$ and humidity of $75\pm 5\%$ for 84 days (Muzemu et al., 2013).

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Description of experimental design and layout

The experiment was conducted in Completely Randomized design (CRD) was used in the experiment Design with. There were four treatments such as 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 and a untreated control with only 0.4g of sweet potatoes (sp). Each treatment was replicated three times. Thirty unsexed, 1 to 10 days old 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 covered with muslin cloth to prevent escape of insects while allowing in air and continued for. The experiment ran for 84 days during which data was collected.

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Comment [A17]: In CRD, $t \times (r-1)$ should be minimum 12 in order to get the good data. But in the present case comprise of 4 treatments and each replicated for thrice. Hence $t \times (r-1)$ is only 8. So confirm the reliability of data recorded once again.

Data Collection

Data ~~collected included; viz.,~~ ~~percentage~~ mortality of adult weevils (%), ~~and~~ ~~inhibition rate~~ ~~which~~ ~~relate to objective one of this study,~~ ~~and then~~ ~~percentage~~ potato chips damage of potato chips and ~~percentage~~ weight loss (%) were recorded, ~~which aided in measurement of the second objective.~~

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Adult ~~m~~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 ~~at on a seven~~ ~~(7)-days~~ interval (7, 14, 21, 28 and 35 days) and the ~~percentage~~ mortality was computed using the ~~following~~ 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 ~~at 7 days interval on a seven day interval,~~ ~~and~~ days of first emergence were also recorded between the 35th and 56th days. The inhibition rate was calculated from the ~~following~~ formula ~~as used by~~ (Ahad *et al.*, 2016) ~~below.~~

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

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 holes~~ ~~and chips with bore holes were~~ ~~considered as damage and~~ ~~chips were regarded as damaged and~~ their number was recorded ~~in~~ ~~for~~ each replication. The percentage damage was calculated using ~~the following~~ ~~a~~ formula ~~adopted from~~ (Adedire & Lajide, 1996).

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$$\text{Percentage potatoes chips damage} = \frac{G_1}{G_2} \times 100\%$$

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

Percentage ~~w~~Weight ~~l~~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 ~~from of~~ sweet potatoes, ~~and t~~he plant powders and leaving behind the sweet potato chips which were weighed ~~separately~~ using a digital scale ~~from or~~ each replication and ~~their weights recorded as the final weight~~ recorded. 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 ~~by from~~ (Loko *et al.*, (2018), ~~as~~;

$$\text{Percentage weight loss} = \frac{\text{Initial weight of chips} - \text{final weight of chips}}{\text{initial weight of chips}} \times 100\%$$

Data analysis

The ~~%per cent~~ 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 (Reference ?).

Results

Mortality of *S. ~~itophilus~~zeamais*

The analysis of variance showed that there was significant variation in mortality ($P < 0.001$) ~~in with respect to~~ all the treatments during the treatment period ~~and among treatment interaction with time~~ (table 2). When mortality of weevils was studied at 7, 14, 21, 28 and 35 days of exposure to treatments, results showed that there was increase in mortality with time for all treatments, the ~~greatest~~ highest mean mortality (92.2%) was achieved on the 35th day after treatment (DAT) however, there was no statistical difference in mean mortality between the 28th and 35th DAT day. The treatment interaction showed that the combination (Neem ~~and~~ 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 treated with neem leaf powder and eucalyptus leaf powders (table 3).~~

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

Source of variations	df	MS	d	MS			
					Mortality	Emerged	Inhibition
					(%)	insects	rate
							Damage
							Weight loss
					(%)		(%)
Treatment	2	10746.2**	2	269.4***	18567.9***	875.0**	564.2***
Time interval (Days)	4	9445.7***	3	386.4***	1786.1***	-	-
Treatment X Time	12	495.4***	9	27.1***	370.5***	-	-

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

Table 2: Effect of treatments on the mortality of *S. strophiluszeamais*

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

LSD=Least Significant Difference, CV=Coefficient of Variation, DAT= Days After Treatment Same letters following meansdown the column and along the rows show no statistical difference e and ***highly significant at 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 42 DATnd day after treatment, new emergencies were observed in the combination for the first time in the 49 DATth day after treatment. By the During 56 DATth 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(table 3).

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Table 3. Effect of plant powders on ~~the numbers emergence of emerged~~ *S. ~~itophilus~~ zeamais* ~~emergence~~

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 $P < 0.001$

Comment [A28]: Modify this table like Table 2

It was observed that, all plant powders showed an inhibitory effect on *S. ~~itophilus~~ zeamais* 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 Complete~~ inhibitory effect ~~recorded while of upto 100% for combined the~~ use of Neem and eucalyptus leaf powders ~~together and this~~ was sustained up to 49 ~~DAT days while~~. Whereas, individual ~~single~~ application of insecticidal powders ~~only~~ inhibited ~~the weevil~~ emergence ~~of new insects~~ up to 35 ~~DAT days after treatment~~. It was also observed that inhibition rate decreased with increase in days of exposure to ~~botanical~~ powder treatments from 75.0% (~~on on the 35 DATth day~~) to 47.6% (~~on the 56 DATth day after treatment~~) (table 4)

Table 4. ~~Inhibitory effect of plant powders on emergence of~~ *S. ~~itophilus~~ 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
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LSD- least significant difference, SE- standard error, CV- coefficient of variation, *** Significance at P<0.001

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Percentage Damage on sweet potato chips by *S. zeamais*

Generally, mean percentage damage was observed to be significantly lowest (20%) in when combined application of Neem and Eucalyptus powder treatment was used and significantly (P<0.001) when compared to 60% of highest damage (60%) was observed in control buckets. Whereas, the individual use of application of Neem and Eucalyptus powder gave separately showed lower damages of 30% and 40%, respectively. Similarly, there was significant variation in weight loss between among 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%). (Fig 1)

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Comment [A31]: The pattern of drawing this figure is not correct. This shows that mean is also a treatment. In order to have better understanding, Mean values should be shown as separate line for both parameters.

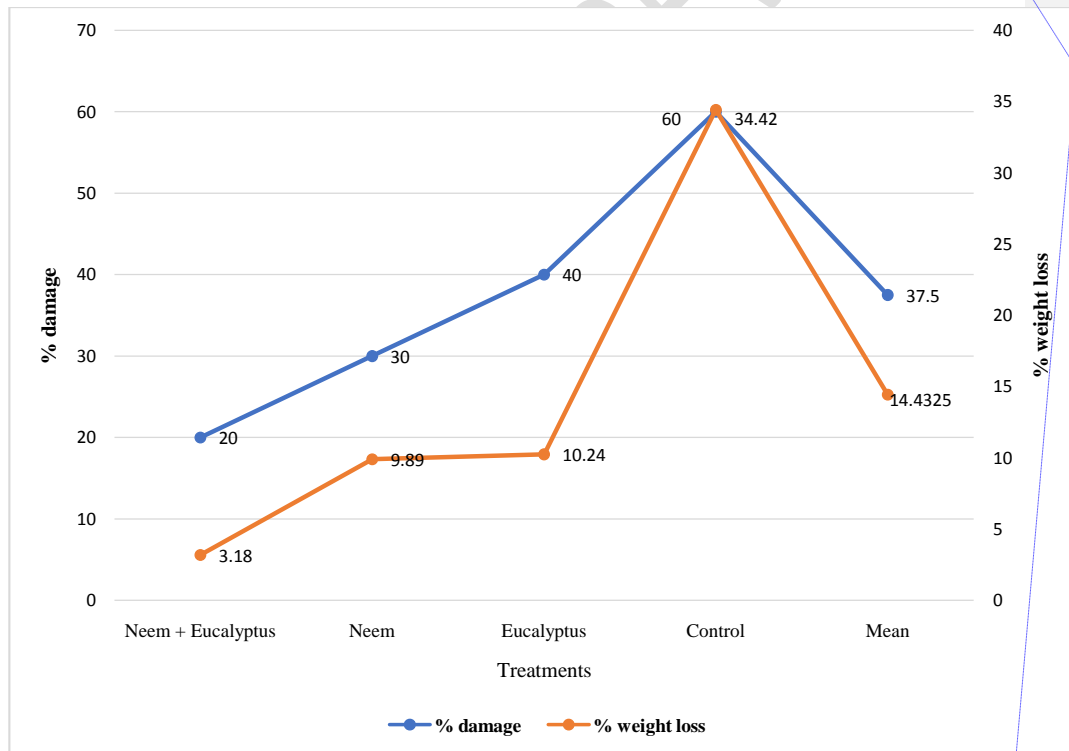


Figure 1. Variations in damage and weight loss among the different treatments due to *S. zeamais* on dried sweet potato chips under storage

Discussion

~~-----~~The experimental results showed significant differences in mortality at $p < 0.001$ for all treatments and with storage duration and their interaction. The that the highest mortality of maize weevils in treatment 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 the delayed mortality of *S. zeamais* death was delayed by themight be due to their slow action of powders (NRC, 1992), also there was no statistical difference in mortality between 28th and 35 day, this indicates that though mortality in the 35th day is higher, a similar effect could be achieved in the 28th day post treatment, as noted in Maize storage by (Mbewe, 2016). The

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The findings in the current study align with those of earlier studies of Erenso & Berhe, (2016) who tested the effect of neem leaf and seed powder against maize weevil, they and reported mortality of 61.13, 68.76 and 77.75% within 10, 30 and 45 days, respectively. Also in a study conducted by (Shiberu and Mulugeta, (2017) on the determination of appropriate doses of botanicals against maize weevil had revealed 100% mortality was reported when applying 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 present findings in this study showed 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).

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All plant powders showed inhibitory effect to *S. zeamais* 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 as: 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 present in neem and eucalyptus, respectively. These active ingredients could have delayed or 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, the high delay in emergence of neonates in the combination (neem + eucalyptus) could be due to the synergistic

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effects of the powders. Our study confirmed those of Soujanya *et al.* (2016) who reported botanical pesticides inhibit development of immature neonates of storage pests of agricultural produce.

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Comment [A36]: Mention some more earlier studies/ reports to support your point

We observed that all the plant powders significantly reduced damage on dried sweet potato chips due to *S. 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 acting as fumigants (Muzemu *et al.*, 2013) and inhibitory effects of the powders against *S. 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 in the control of maize weevil when *Imperata cylindrica* powder was used in stored maize.

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Weight loss was recorded in all treatments, however, maximum loss in weight of sweet potato chips due to *S. zeamais* damage was recorded in the untreated (control) bucket followed by and the order of weight loss was: control > eucalyptus > neem and combination (neem + eucalyptus) and were significantly different $P < 0.001$ for all treatments. The reduced weight loss is 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. Similar findings were reported by (Musundire *et al.*, 2015) on maize weevils under storage conditions. The lower 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 could be attributed 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 show increased efficacy in 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

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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, 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.

References

Abong', G-O., Ndanyi, V-C-M., Kaaya, A., Shibairo, S., Okoth, M-W., Lamuka, P-O., Odongo, N-O., Wanjekeche, E., Mulindwa, J., & Sopade, P. (2016). A review of production, post-harvest handling and marketing of sweetpotatoes in Kenya and Uganda. Current Research in Nutrition and Food Science, 2016;4(3);162–181.
<https://doi.org/10.12944/CRNFSJ.4.3.03>

Adedire CO, Lajide L. (1999). Toxicity and oviposition deterrence of some plant extracts on cowpea storage bruchid. Callosobruchus maculatus Fabricius. Plant Disease Prot. 1999;106-(6);647– 653.

Agona, J-A., Nahdy, D-P., Giga, D-P., & Rees, D. (1999). A visual scale of loss assessment for dried sweet potato chips due to Araecerus fasciculatus Degeer (Coleoptera: Anthribidae) infestation on-farm. Uganda Journal of Agricultural Sciences; 1999;4(1); 1–5.

Ahad, A., Hossain Bhuyain, M-M., Hoque, M., & Hoque, F. (2016). Eco-friendly Management of Lesser Grain Borer, Rhizoperthadominica f. (bostrichidae: coleoptera) on Wheat in Storage. American Journal of Life Science Researches; 2016;4(4); 145–151.
<https://doi.org/10.21859/ajlsr-040407>

Akinneye, J-O., & Ogunbite, O-C. (2013). Insecticidal activities of some medicinal plants against Sitophilus zeamais (Motschulsky) (Coleoptera: Curculionidae) on stored maize.

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~~Archives of Phytopathology and Plant Protection~~, 2013;46(10); 1206–1213.

<https://doi.org/10.1080/03235408.2013.763614>

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Apoolo, S., Angor, N., ~~Development, W., &Goals, S.-D. (2010).~~ Making Sweet Potato Chips and Flour. 2010;1–4.

Formatted: Font: Not Italic, No underline, Font color: Auto

Barre, J., &Jenber, A.-J. (2022). Evaluation of selected botanicals for the management of maize weevil (*Sitophilus zeamais*) on maize (*Zeamays* L.) grain under laboratory condition in Gabilay District, Somaliland. ~~Heliyon~~, 2012;8(12),

Formatted: Font: Not Italic, No underline, Font color: Auto

e11859.<https://doi.org/10.1016/j.heliyon.2022.e11859>

Formatted: No underline, Font color: Auto, Highlight

Belmain, S.-R., Tembo, Y., Mkindi, A.-G., Arnold, S.-E.-J., &Stevenson, P.-C. (2022). Elements of agroecological pest and disease management. ~~Elementa~~, 2022;10(1); 1–14.

Formatted: Font: Not Italic, No underline, Font color: Auto

<https://doi.org/10.1525/elementa.2021.00099>

Formatted: Font: Not Italic, No underline, Font color: Auto

Chayengia, B., Patgiri, P., Rahman, Z., &Sarma, S. (2010). Efficacy of different plant products against *Sitophilus oryzae* (Linn.) (coleoptera: Curculionidae) infestation on stored rice.

Formatted: Font: Italic, No underline, Font color: Auto

~~Journal of Biopesticides~~, 2010;3(3); 604–609.

Formatted: Font: Italic, No underline, Font color: Auto

~~citations, suggested. (1992). The national academies press.~~ <https://doi.org/10.17226/1924>

Formatted: Font: Not Italic, No underline, Font color: Auto

Devi, M.-B., Devi, N.-V., & Singh, S.-N. (2014). Effects of Six Botanical Plant Powder Extracts on the Control of Rice Weevil, *Sitophilus Oryzae* L. in Stored Rice Grains. ~~International Journal of Agriculture Innovations and Res.eareh~~, 2014;2(5); 683–686.

Formatted: Font: Not Italic, No underline, Font color: Auto

~~edgar Tinyro; Sarah Mayanja. (2018). State Of Knowledge Report : Sweet Potato - Uganda,~~

Formatted: Font: Not Italic, No underline, Font color: Auto

~~Ehisiyanya, I. et al. (2019). Assessment of Plant Powders As Protectants of Stored Maize Grains.~~ 50(1), 37–45.

Formatted: Font: Not Italic, No underline, Font color: Auto

Epeju, W.-F., &Rukundo, P.-M. (2017). Food Security and Income through Sweet Potato Production in Teso, Uganda. ~~Sustainable Agriculture Research~~, 2017; 7(1), 146.

Formatted: Font: Italic, No underline, Font color: Auto

<https://doi.org/10.5539/sar.v7n1p146>

Formatted: Font: Not Italic, No underline, Font color: Auto

Erenso, T.-F., &Berhe, D.-H. (2016). Effect of Neem leaf and seed powders against adult maize weevil (*Sitophiluszeamais*Motschulsky) mortality. ~~International Journal of Agricultural Research~~, 2016; 11(2); 90–94. <https://doi.org/10.3923/ijar.2016.90.94>

Formatted: Font: Not Italic, No underline, Font color: Auto

Formatted: No underline, Font color: Auto, Highlight

Ileke, K.-D., Idoko, J.-E., Ojo, D.-O., &Adesina, B.-C. (2020). Evaluation of botanical powders and extracts from Nigerian plants as protectants of maize grains against maize weevil,

Formatted

Formatted

Formatted: Highlight

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Sitophiluszeamais (Motschulsky) [Coleoptera: Curculionidae]. ~~Biocatalysis and Agricultural Biotechnology~~, 2020;27; 101702. <https://doi.org/10.1016/j.bcab.2020.101702>

Koradaa, R.-R., Naskara, S.-K., &Edison, S. (2010). Insect pests and their management in yam production and storage: A world review. ~~International Journal of Pest Mgmt.anagement~~,

Formatted

[2010](https://doi.org/10.1080/09670874.2010.500406);56(4), 337–349. <https://doi.org/10.1080/09670874.2010.500406>

Formatted: Font: Not Italic, No underline, Font color: Auto

Loko, Y.-L.-E., Gnaho, A.-C., Toffa, J., Orobiyi, A., Dansi, A., & Tamo, M. (2018). Management of *Dinoderus porcellus* L. (Coleoptera: Bostrichidae) infesting yam chips using varietal resistance and botanical powders of three medicinal plants. *African Journal of Agricultural Research*, 2018;13(40), 2118–2133. <https://doi.org/10.5897/ajar2018.13418>

Formatted

Mandudzi, E., & Edziwa, X. (2016). Eucalyptus Leaf Powder is Effective in Maize Weevil Control. *2016*; 6(2), 93–98. <https://doi.org/10.5923/j.ijaf.20160602.06>

Formatted

Mbah, O.-I., & Okoronkwo, M.-O. (2008). An assessment of two plant products efficacy for the control of the maize weevil (*Sitophilus zeamais* Motschulsky) in stored maize. 3(July), 2008; 494–498.

Formatted

Mbewe, M. (2016). Effectiveness of botanical control of *Sitophilus zeamais* (maize weevils) in stored maize grain (*Tephrosia candida*, *Lantana camara* and *Eucalyptus tereticornis*). *The International Journal of Multi-Disciplinary Research*, 2016; 1–16.

Formatted

Musundire, R., Mazodze, F., Macheke, L., Ngadze, R.-T., Mubaiwa, J., & Manditsera, F. (2015). *Eucalyptus grandis* and *Tagetes minuta* leaf powders effectively protect stored maize against *Sitophilus zeamais* without affecting grain organoleptic properties. *African Journal of Agricultural Research*, 2015; 10(2), 49–57. <https://doi.org/10.5897/ajar2014.8711>

Formatted

Muzemu, Simbarashe. Chitamba, J. & M. B. (2013). Evaluation of *Eucalyptus tereticornis*, *Tagetes minuta* and *Carica papaya* as stored maize grain protectants against *Sitophilus zeamais* (Motsch.) (Coleoptera: Curculionidae). *Agriculture, Forestry and Fisheries*, 2013;2(5), 196. <https://doi.org/10.11648/j.aff.20130205.13>

Formatted

Namanda, S., Gibson, R., & Sindi, K. (2011). Sweetpotato seed systems in Uganda, Tanzania, and Rwanda. *Journal of Sustainable Agriculture*, 2011;35(8), 870–884. <https://doi.org/10.1080/10440046.2011.590572>

Formatted

Ojo, J.-A., & Omoloye, A.-A. (2016). Development and life history of *Sitophilus zeamais* (Coleoptera: Curculionidae) on Cereal Crops. *Advances in Agriculture*, 2016. <https://doi.org/10.1155/2016/7836379>

Formatted

Shiberu, T. (2017). Determination of the appropriate doses of promising botanical powders against Maize weevil, *Sitophilus zeamais* Mots (Coleoptera: Curculionidae) on maize grain. *Agricultural Research & Technology: Open Access Journal*, 2017;6(5), 49–53. <https://doi.org/10.19080/artoaj.2017.06.555698>

Formatted

Soujanya, P.-L., Sekhar, J.-C., Kumar, P., Sunil, N., Prasad, C.-V., & Mallavadhani, U.-V. (2016).

Potentiality of botanical agents for the management of post harvest insects of maize: a review. [Journal of Food Science and Technology](#), 2016;53(5), 2169–2184.
<https://doi.org/10.1007/s13197-015-2161-0>

Formatted: Font: Not Italic, No underline, Font color: Auto

Formatted: No underline, Font color: Auto

UN [\[United Nations\]](#), (2022). The Sustainable Development Goals Report 2019. *United Nations Publication Issued by the Department of Economic and Social Affairs*, 2022;64. [Available:](#)
<https://unstats.un.org/sdgs/report/2022/%0Ahttps://www.un->
[library.org/content/books/9789210018098%0Ahttps://www.un-](https://www.un-)
[library.org/content/books/9789210478878](https://www.un-)

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