Extracts from *Hyptis suaveolens* (L.) Poit. and *Tephrosia vogelii* Hook.f leaves as maize grain protectants against Larger Grain Borer, *Prostephanus truncatus* (Horn)

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ABSTRACT

The Larger Grain Borer (LGB), *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), is an important pest of maize in Nigeria. Botanical pesticides contain secondary metabolites that are useful in pest control and thus aid in agricultural pest management. The study examined the bioactivities of ethanolic and aqueous extracts of leaves of each *Hyptis suaveolens* and *Tephrosia vogelii* on LGB in stored maize. The extracts of *H. suaveolens* and *T. vogelii* leaves were applied at the rates of (0.05, 0.1, 0.2, 0.3 and 0.5ml/10g of maize grains) at dosage level and (2.5, 5.0, 7.5, 10.0, and 15.0%) at concentration level and were replicated 3 and 5 times respectively. Results showed the potency of the tested botanicals to be dose dependent. The extracts of *H. suaveolens* and *T. vogelii* leaves were found to be toxic to *P. truncatus*. The two extracts were observed to be toxic to *P. truncatus*, increased mortality, improved repellence, inhibited reproduction, caused grain damage and weight loss on stored maize at the highest dose and concentration. The results suggest that leaf extracts of *H. suaveolens* and *T. vogelii* were effective as toxicants and grain protectants against Larger Grain Borer and can be used in Integrated Pest Management (IPM) practices.

Keywords: Damage, *H*yptis *suaveolens,* Maize, Mortality, *Prostephanus truncatus*,

INTRODUCTION

The Larger Grain Borer (LGB), *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) is an important storage pest of maize and dried cassava roots in the tropics. It is a pest of phytosanitary importance in many countries of the world (Myres and Hagstrum, 2012). It spreads fast in most countries of Africa, Americas and Asia, although it is believed to have originated from Central America from where it spreads to Africa and other continents about forty years ago (Hodges, 2002; EPPO, 2020). It lives, feeds, reproduces and survives on other stored grains and their flours which serve as secondary hosts and improve its progression as vehicle grains (Athanassiou *et al*., 2017). The infested maize, cassava, non-maize grains and their flours suffer serious losses by the feeding activity of LGB (Athanassiou *et al*., 2017; Kavallieratos *et al*., 2017).

There are different strategies for management of *P. truncatus* in storage. In the past few decades, the application

of synthetic pesticides to control pests of durable stored food products has been the standard practice. In some countries, a common control measure for infestation of *P. truncatus* is to treat grain with a dust formulation containing a mixture of an organophosphate (OP) and a pyrethroid insecticide (Golob, 2002; Athanassiou *et al*., 2007). However, natural and synthetic insecticides which include diatomaceous earths and organophosphate respectively are not effective on LGB (Golob, 2002; Kavallieratos *et al*., 2020). The use of botanicals for the control of insect pests on several stored produce has been effective (Athanassiou *et al*., 2007; Ojo *et al*., 2016) and has helped in addressing challenges associated with synthetic insecticides. Past studies showed that numerous botanicals like wormseed - *Dysphania ambrosioides*, soro plant or anamu - *Petiveria alliaceae*, horsemint – *Mentha longifolia*, candel wood – *Zanthoxylum zanthoxyloides*, anise, *Pimpinella anisum*, industrial hemp – *Cannabis sativa*, among others (Tapondjou, 2002; Omoloye and Awolaja, 2008; Ojo *et al*., 2016; Kavallieratos *et al*., 2020) have been effective in controlling many stored product pests.

The use of synthetic insecticides poses health hazards to animals, causes environmental pollution, resistance development by insects and pest resurgence, these necessitated for the adoption of effective, affordable and eco-friendly control methods (Rajendran and Sriranjini, 2008; Ojo *et al*., 2016). Botanical pesticides possess different active constituents and modes of action are target-specific, relatively safe, affordable and readily available. Hence, the readily available botanical pesticide technology for pest management in smallholder agriculture is a viable alternative option to synthetic insecticides. Most farmers in the tropics and in province where this study was carried out encountered challenges in controlling LGB attacking their storage produce being agrarian communities. There is vast availability of *Hyptis suaveolens* and *Tephrosia vogelii* which farmers have not harnessed to mitigate storage pests. This study was carried out to demonstrate and validate the potency of these botanicals to transfer the knowledge to the teeming peasant farmers in Nigeria.

MATERIALS AND METHODS

Insect rearing and collection of clean maize grains

Two hundred and fifty unsexed adults *P. truncatus* were introduced into glass jars with mesh lid containing 1 kilogram of maize grain samples and kept at ambient temperature of 27 ± 3°C and relative humidity of 65 ± 5%. in the laboratory. The insects were left on the grains to feed and lay eggs for 14 days and thereafter removed. The jars were left undisturbed until emergent of new progenies. The emergents were used as insect stock culture for bioassay in the study. The clean uninfested maize grains - variety DMR-ESR purchased from Premier Seed Company® in Ilorin, Kwara State, Nigeria, was used in this study. The grains were cold-shocked at 10°C for 12 days to kill all incipient infestations on the grains.

Collection and preparation of plant materials

Hyptis suaveolens and *Tephrosia vogelii* leaves were collected from Malete, Kwara State, Nigeria. They were taken to a Botanist in the Department of Biosciences and Biotechnology, Kwara State University, Malete, to validate their identification. The collected samples were rinsed with clean water and air dried separately in the laboratory for three (3) weeks. The dried leaves of each plant were ground into powder using universal grinder (model Retsch MM301), weighed and kept separately in an airtight polyethylene bag. The powder was used for extraction and the bioassays.

Preparation of aqueous and ethanolic extracts of the two plants

The two solvents used for the extraction were ethanol and water. Two hundred gram (200 g) of each pulverized plant powder was soaked in 400 ml of ethanol, stored under dark conditions at room temperature for 24 hours with periodic stirring. The solution was filtered using muslin cloth, then filtered twice using Whatman No.1 filter paper and non-absorbent cotton wool. Ethanolic extracts in the filtrate were concentrated in a vacuum using a rotary evaporator at a temperature of 40°C at 120 tr/min. The procedure was done for aqueous extracts of the botanicals except that the extracts were concentrated by freeze drying using the vacuum freeze dryer and distilled water was used for the extraction process. The extracts were stored at 4°C until needed for the bioassays.

Five different concentrations, namely, 2.5%, 5%, 7.5%, 10% and 15% of each ethanolic and aqueous extracts of Hyptis and Tephrosia were prepared by dissolving the stock solution in the acetone. The 2.5%, 5%, 7.5%, 10% and 15% concentration of each plant extracts was prepared by diluting 25 ml of the extract into 975 ml of acetone; 50 ml of the extract into 950 ml of acetone; 75 ml of the extract into 925 ml of acetone; 100 ml of the extract into 900 ml of acetone and 150 ml of the extract into 850 ml of acetone respectively. The prepared concentrations of the extracts were used in the bioassay.

Evaluation of phytochemical constituents of plant materials

Phytochemical screening was carried out qualitatively to ascertain the presence of phytochemicals like phenols, tannins, saponins, triterpenes, flavonoids, alkaloids and steroids in the extracts of *H. suaveolens* and *T. vogelii*. The activity was conducted following the modified procedures of Ajiboye *et al.* (2015).

Contact toxicity assay by topical application

Bioassays were conducted to determine the toxicity of the extracts by topical application. Aliquot of 1 µL of each concentration of extract was applied topically on the dorsal surface of the thorax of each beetle with the aid of micropipette, while the control received 1 µL of acetone. In order to carry out this bioassay, Prostephanus were put inside petri dishes and inactivated by keeping them briefly in the refrigerator for three minutes for easy conduct of topical application of the extracts. Each group of ten treated insect individuals was transferred into 10cm petri dishes. This experiment was replicated four times and

arranged in a Completely Randomized Design (CRD). Insect mortality was recorded at 1, 2, 3, 7, 14 and 21 days after treatment. Abbott's formula (Abbott, 1925) was used to correct for mortality. Corrected mortality values were computed as:

$$Pt = [(Po - Pc) / (100 - Pc)] \times 100$$

Where, Pt = corrected mortality
Po = observed mortality
Pc = control mortality

Repellent activity bioassay

The repellency was tested according to modified method of Hamouda *et al*. (2014). Half filter paper discs (Whatman number 40, 9 cm diam.) were prepared and a volume of 100 µL of each plant extract concentration was applied separately to one-half of the filter paper as uniformly as possible with a micropipette. The other half (control) was treated with 100 µL of different solvents - ethanol and distilled water, for ethanolic and aqueous extract respectively. Thereafter, both the treated and the control halves were air dried at room temperature in the laboratory for 10 minutes. Each treated half disc was fitted back to a control half disc with adhesive tape and placed in a petri dish. Twenty adult insects were released in the middle of each filter paper circle. Each concentration was replicated four times. Insects that settled on each half of the filter paper disc were counted after 2 hours. The average of the counts was converted to percentage repellency (PR) using the formula of McDonald *et al*. (1970) as follows:

$$PR = [(Nc - Nt) / (Nc + Nt)] \times 100$$

Where Nt = number of insect present on the treated half disc
Nc = Number of insects present on the untreated half disc

Efficacy of extracts on mortality of *P. truncatus* and adult emergence of *P. truncatus*

In order to evaluate the effects of extracts of *H. suaveolens* and *T. vogelii* on mortality and F1 emergence of *P. truncatus* adults, five different application rates (0.05; 0.1; 0.2; 0.3; 0.5 ml) of the extracts were used. The extracts were mixed thoroughly with 10g maize to ensure uniformity before the introduction of insects. Five pairs of adults *P. truncatus* were introduced in each treatment, each treatment and control were replicated three times and arranged in Completely Randomized Design (CRD). Mortality of the insects was recorded 1 day, 2 days, 3 days and 7 days after treatment application. All insects were removed after 14 days post treatment and left undisturbed until F1 emergence starting the sixth week post treatment. The emerged adults were thereafter counted and recorded. The reproduction inhibition rate was calculated following Tapondjou *et al*. (2002) as:

Reproduction inhibition rate
= Ca-Ta/Ca x 100

Where;
Ca= number of newly emerged adult insects in the untreated control
Ta= number of newly emerged adult insects in the treated grains.

Effects of extracts on grain damage and weight loss of maize

In order to assess the level of damage *P. truncatus* inflicted on maize grains treated with the extracts of *H. suaveolens* and *T. vogelii*, two parameters used include percent grain damage and seed weight loss. Application rates of 0; 0.05; 0.1; 0.2; 0.3 and 0.5 ml on 10g maize was used for the evaluation for each ethanolic and aqueous extracts of the two botanicals. The extracts were mixed thoroughly with 10g maize to ensure uniformity before the introduction of insects. Each treatment and control were replicated three times and arranged in Completely Randomized Design (CRD). Five pairs of adults of *P. truncatus* were thereafter introduced into each treatment and monitored for ten weeks in the laboratory. Damage assessment was measured using percentage grain damage and grain weight loss. The percentage damage and weight loss of maize were measured after ten weeks by counting the damaged and undamaged seeds and was calculated using the formula of Compton and Sherington, (1999):

$$\%\text{damage} = Nd/Nu + Nd \times 100$$

Where Nd= Number of damaged seeds

Nu= Number of undamaged seeds

$$\%\ \text{Weight loss} = PW1 - PW2/PW1 \times 100$$

Where, PW1= initial weight of sample before infestation

PW2= final weight of sample after infestation

Data Analysis

To determine mean Lethal Concentration (LC_{50}) values, the data were analyzed using the Probit procedures with IBM SPSS Statistics 21 for Windows®. Data expressed in percentages were arcsine-transformed to normalize the variance. Data collected were thereafter subjected to Analysis of Variance (ANOVA) using DSAASTAT (Onofri, 2007) and treatment means separated using Tukey Honestly Significant Difference (HSD) test at 5 % level of probability.

RESULTS

Evaluation of phytochemical constituents of plant materials

Qualitative phytochemical screening of solvent extracts showed that the secondary metabolites in the aqueous and ethanolic extracts of *H. suaveolens* and *T. vogelii* were similar with the exception of alkaloids and tannins which were not present in both aqueous and ethanolic extracts of *T. vogelii*. (Table 1).

Table 1: Qualitative phytochemical screening of the aqueous and ethanolic extracts of leaves of *H. suaveolens* and *T. vogelii*

Phytochemicals	Aq. *H. suaveolens*	Eth. *H. suaveolens*	Aq. *T. vogelii*	Eth. *T. vogelii*
Flavonoids	++	++	++	++
Poly phenol	++	++	++	++
Glycoside	++	++	++	++
Terpenoids	++	++	++	++
Tannins	++	++	-	-
Steroid	++	++	++	++
Saponin	+	-	++	++
Alkaloids	++	++	-	-

Note: Present: ++; Weakly Present: +; Absent: -.Aq. – Aqueous; Eth. - Ethanol

Contact toxicity by topical application

The topical effect of aqueous and ethanolic extracts *H. suaveolens* and *T. vogelii* showed that the percentage weevil mortality varied with the period of exposure, plant materials used and the concentration of the extracts (Table 2). There were significant differences ($P < 0.05$) in the percent mortality recorded after seven (7) day of exposure. All the extracts were able to cause weevil mortality over the period of the experiment but at different levels. Ethanolic extract of *T. vogelii* was the most toxic and produced the best effect with LC_{50} of 11.12 % at 7th day of exposure (Table 3) with the highest percentage of mortality (15 % conc -74 %) and lowest mortality (0.05 w/v- 24 %) at 7th day (Table 2). The two *H. suaveolens* extracts (aqueous and ethanol) were the least toxic to the insect pests, each killing highest of (15 % conc – 58 %) and (15 % conc- 64 %) respectively at day 7 and lowest (2.5 % conc - 4.00 %) at day 1 and 2 and (2.5 % conc- 4.00 %) at day 2 respectively. Moreover, it should be noted that at all levels of concentrations, the effect of these extracts was significantly ($P < 0.05$) different from the controls. These results showed that ethanolic extract of *T. vogelii* exhibited the highest mortality and was more persistent than others.

Repellent activity bioassay

The percent repellence (PR) values obtained from the choice bioassay experimental set up showed that repellence was significantly influenced ($P < 0.05$) by plant species, concentration of extract applied, and types of solvent used in extraction (Table 4). The PR values for the two tested plants increased

with concentration of extract applied and types of solvent used in extraction. The results further showed significant differences in PR values between the two plant extracts at all rates except aqueous *H. suaveolens* at 2.5 % (w/v) after 2 h exposure. At the highest concentration (15 % w/v) evaluated, ethanolic *T. vogelii* (PR value: 95%) was more repellent (although not statistically different – $P > 0.05$) than ethanolic *H. suaveolens* (PR value: 80 %) against adult *P. truncatus* 2 hours after treatment application.

Efficacy of extracts on mortality

The aqueous and ethanolic extracts of *H. suaveolens* and *T. vogelii* significantly enhanced mortality of adult larger grain borer (Table 5). Mortality in the control experiment was significantly lower ($P < 0.05$) than the mortalities recorded in both aqueous and ethanolic extracts of *H. suaveolens* and *T. vogelii*. Mortality increased with ascending dosage levels and time post-exposure for extracts. At the same dosage and time of exposure, ethanol extract of *T. vogelii* caused highest mortality of 70.00 % at day 7 and ethanol extracts of *H. suaveolens* of 56.67 % while lowest mortality at 0.00 % at day 1 for two ethanolic extracts. At the low dosages of 0.05 ml/10 g of maize, aqueous extracts of *H. suaveolens* and *T. vogelii* caused 0.00 % mortality of day 1, 2 and 3 after exposure. Highest mortality was obtained with ethanol *T. vogelii* at the highest tested dosage of 0.5ml/10 g 7 days after treatment and with LD_{50} of 0.33ml/10g of maize (Table 6).

Effects of extracts on grain damage and weight loss of maize

The grain damage and weight loss caused by the feeding activities of larger grain borer on maize was significantly higher ($P < 0.05$) in the untreated control than grains treated with aqueous and ethanolic extracts of *H. suaveolens* and *T. vogelii* (Tables 7). The extracts confer protection on the grains against *P. truncatus* in comparison to the untreated grains (47.10 % seed damage and 10.57

Table 2: Percentage topical application treated with different concentrations of extracts of *H. suaveolens* and *T. vogelii*

Percentage topical application					
		Duration of exposure (Days)			
Treatment	Concentration (%)	1	2	3	7
Control		0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	2.00±1.79^{a}
Aq. *H. suaveolens*	2.5	4.00±2.19^{b}	6.00±2.19^{b}	8.00±1.79^{b}	30.00±2.83^{bc}
	5.0	4.00±2.19^{b}	6.00±3.59^{b}	8.00±4.39^{b}	34.00±4.59^{bc}
	7.5	4.00±2.19^{b}	6.00±2.19^{b}	6.00±3.35^{b}	37.50±4.57^{bc}
	10.0	6.00±2.19^{b}	10.00±2.83^{bc}	18.00±3.35^{c}	50.00±3.59^{c}
	15.0	6.00±2.19^{b}	10.00±2.83^{bc}	16.00±3.58^{c}	58.00±3.35^{c}
Eth. *H. suaveolens*	2.5	4.00±2.19^{b}	4.00±2.19^{b}	6.00±2.19^{b}	24.00±2.19^{b}
	5.0	4.00±2.19^{b}	6.00±2.19^{b}	10.00±4.01^{b}	30.00±2.83^{bc}
	7.5	6.00±2.19^{b}	6.00±2.19^{b}	14.00±3.59^{bc}	40.00±2.83^{bc}
	10.0	6.00±2.19^{b}	12.00±3.35^{c}	20.00±4.91^{c}	56.00±4.57^{c}
	15.0	8.00±1.79^{b}	8.00±1.79^{bc}	22.00±3.35^{cd}	64.00±1.79^{cd}
Aq. *T. vogelii*	2.5	4.00±2.19^{b}	6.00±2.19^{b}	8.00±2.19^{b}	24.00±2.83^{b}
	5.0	4.00±2.19^{b}	6.00±1.79^{b}	10.00±2.19^{b}	32.00±2.83^{bc}
	7.5	4.00±2.19^{b}	6.00±2.83^{b}	6.00±1.79^{b}	40.00±2.19^{bc}
	10.0	6.00±2.19^{b}	8.00±2.19^{bc}	16.00±1.79^{c}	50.00±3.34^{c}
	15.0	6.00±2.19^{b}	10.00±2.19^{bc}	22.00±2.19^{cd}	66.00±2.82^{cd}
Eth. *T. vogelii*	2.5	4.00±2.19^{b}	4.00±1.79^{b}	8.00±1.79^{b}	24.00±2.19^{b}
	5.0	4.00±2.19^{b}	2.00±1.79^{b}	4.00±2.19^{ab}	28.00±3.34^{b}
	7.5	6.00±2.19^{b}	2.00±1.79^{a}	4.00±2.19^{ab}	32.00±3.34^{bc}
	10.0	6.00±2.19^{b}	4.00±2.19^{b}	6.00±2.19^{b}	46.00±3.59^{c}
	15.0	8.00±1.79^{b}	6.00±2.19^{b}	8.00±1.79^{b}	74.00±2.19^{d}

Each value is the mean ± standard error of five replicates, each replicate with 10 adults. Mean followed by the same letters within the same column are not significantly ($P \leq 0.05$) different from each other using Tukey HSD Test. Key: Aq. = Aqueous, Eth. = Ethanol

% weight loss). The higher the dose the lower the seed damage and weight loss. The ethanolic *T. vogelii* treated grain recorded lowest seed weight loss and damage at highest dosage level of 0.5 ml - 0.84 % and 2.95 % respectively.

Effects of *H. suaveolens* and *T. vogelii* extracts on emergence of F1 progeny of *P. truncatus* on maize

There was a significant reduction ($p < 0.05$) in emergence of F1 progeny in the grains treated with aqueous and ethanolic extracts of *H. suaveolens* and *T. vogelii* compared to untreated control (Table 8). Percentage reduction in progeny emergence as influenced by the different extracts treatments was significantly different and there was also significant reduction in progeny emergence as the extract dosage increased. Results have shown a clear dose-dependent reduction in the adult of *P. truncatus* F1 progeny at concentration between 0.05 to 0.5ml/10g grain of *T. vogelii* and *H. suaveolens* leaves extracts (aqueous and ethanol). The lowest percentage F1 progeny of 3.00 was obtained in grains treated with 0.5 ml ethanolic extract of *T. vogelii* while the highest percentage F1 progeny (79.67) was obtained on untreated grains. The reproduction inhibition rate was highest at 0.5 ml application rate of the two extracts.

There was strong relationship between LGB mortality, F1 emergence, weight loss and seed damage in this experiment based on the simple linear correlation analysis (Table 9). Percentage mortality had strong negative correlation with F1 emergence ($r = - 0.8203$), weight loss ($r= - 0.6713$) and seed damage ($r = - 0.8637$) but had a strong positive correlation between F1 emergence, weight loss and seed damage. An increase in mortality leads to decrease in F1 emergence, weight loss and seed damage of the grains.

Table 3: LC_{50} at 7^{th} day after topical application of different concentrations of extracts of *suaveolens* and *T. vogelii* on *P. truncatus*.

Treatment	LC_{50}	95% CL	S. E.
Aq. *H. suaveolens*	11.72	5.31-13.86	0.218
Eth. *H. suaveolens*	10.80	11.30-20.19	0.227
Aq. *T. vogelii*	10.40	9.79-18.62	0.225
Eth. *T. vogelii*	11.12	11.73-20.71	0.229

Key: Aq. = Aqueous, Eth. = Ethanol

DISCUSSION

The use of synthetic insecticides to mitigate damage caused by insect pests of stored produce has been effective but its usefulness is confronted with negative effects on the environment, health and safety of the users. This has led to the use of plant material as an ecofriendly, safe, effective and sustainable method. The findings from this study showed the potency of extracts of *H. suaveolens* and *T. vogelii* as protectants against Larger Grain Borer infestation.

The insecticidal efficacy of *H. suaveolens* and *T. vogelii* extracts on LGB adults was influenced by plant species, dose of the extracts, solvent type used in the extraction and exposure time of the extracts. The increased efficacy with exposure time could be attributed to cumulative toxicity against adult beetles. The efficacies of *H. suaveolens* and *T. vogelii* extracts on LGB could be attributed to the presence of phytochemicals like flavonoid, glycoside, terpenoid, tannin, polyphenol and saponin. All the extracts of *H. suaveolens* and *T. vogelii* were able to cause weevil mortality, significant reduction in emergence of F1 progenies in comparison to the untreated control. The recorded reduction in F1 progeny could be due to the observed adult mortality and potential anti-oviposition, ovicidal and/or larvicidal effects caused by the two plant extracts. The presence of insecticidal properties in *T. vogelii* has been reported previously even when dried *T. vogelii* had been stored for 22 years (Lambert *et al*., 1993). Various bio-active isoflavonoids isolated from *T. vogelii* are responsible for the insecticidal properties observed in this study

Table 4: Percentage repellency of different concentrations of *H. suaveolens* and *T. vogelii* extracts against *P. truncatus*

Percentage Repellency			
		Repellency after 2hrs of exposure	
Treatment	Concentration (%)		Repellency class
Aq. *H. suaveolens*	2.5	32.50±2.17^{a}	
	5.0	42.50±4.15^{ab}	
	7.5	50.00±0.00^{abc}	
	10.0	45.00±2.50^{bcd}	
	15.0	55.00±2.50^{cde}	
Mean		45.00±2.26	Class III
Eth. *H. suaveolens*	2.5	40.00±0.00^{defg}	
	5.0	52.50±4.15^{defg}	
	7.5	60.00±3.54^{defg}	
	10.0	65.00±2.50^{defg}	
	15.0	80.00±3.54^{defg}	
Mean		59.50±2.75	Class III
Aq. *T. vogelii*	2.5	35.00±2.50^{cde}	
	5.0	50.00±3.54^{cde}	
	7.5	55.00±2.50^{cde}	
	10.0	57.50±2.17^{cdef}	
	15.0	62.50±2.17^{defg}	
Mean		52.00±2.58	Class III
Eth. *T. vogelii*	2.5	47.50±2.17^{defg}	
	5.0	60.00±3.74^{defg}	
	7.5	62.50±2.17^{efg}	
	10.0	87.50±2.17^{fg}	
	15.0	95.00±2.5^{g}	
Mean		70.50±2.55	Class IV

Each value is the mean ± standard error of four replicates, each replicate with 20 adults. Mean followed by the same letters within the same column are not significantly ($P \leq 0.05$) different from each other using Tukey HSD Test.

Key: Aq. = Aqueous, Eth. = Ethanol

Table 5: Effects of extracts of *H. suaveolens* and *T. vogelii* on adult *P. truncatus* mortality

		Mortality			
		Duration of exposure (Days)			
Treatment	Dosage(ml)	1	2	3	7
Control		0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{ab}	0.00±0.00^{ab}
Aq. *H. suaveolens*	0.05	0.00±0.00^{a}	0.00±0.00^{a}	3.33±2.72^{ab}	13.33±2.72^{bc}
	0.1	0.00±0.00^{a}	3.33±2.72^{ab}	6.67±2.72^{ab}	16.67±2.72^{bc}
	0.2	3.33±2.72^{a}	6.67±2.72^{ab}	10.00±0.00^{bc}	20.00±0.00^{cd}
	0.3	0.00±0.00^{a}	6.67±2.72^{ab}	13.33±2.72^{bc}	26.67±0.00^{cd}
	0.5	0.00±0.00^{a}	6.67±2.72^{c}	23.33±2.72^{ab}	46.67±2.72^{d}
Eth. *H. suaveolens*	0.05	0.00±0.00^{a}	0.00±0.00^{a}	6.67±2.72^{b}	10.00±0.00^{cd}
	0.1	0.00±0.00^{a}	0.00±0.00^{ab}	10.00±0.00^{cd}	16.67±2.72^{cd}
	0.2	0.00±0.00^{a}	10.00±0.00^{ab}	20.00±0.00^{cd}	30.00±0.00^{cd}
	0.3	3.30±2.72^{ab}	16.67±2.72^{bc}	26.67±2.72^{cd}	40.00±0.00^{d}
	0.5	3.30±2.72^{ab}	20.00±0.00^{bc}	33.33±2.72^{e}	56.67±2.72^{de}
Aq. *T. vogelii*	0.05	0.00±0.00^{a}	0.00±0.00^{a}	6.67±2.72^{cd}	13.33±2.72^{cd}
	0.1	0.00±0.00^{a}	3.33±2.72^{b}	13.33±2.72^{cd}	23.33±2.72^{cd}
	0.2	0.00±0.00^{a}	6.67±2.72^{bc}	16.67±2.72^{cd}	30.00±0.00^{cd}
	0.3	0.00±0.00^{a}	6.67±2.72^{bc}	23.33±2.72^{cd}	33.33±2.72^{cd}
	0.5	0.00±0.00^{a}	10.00±0.00^{cd}	30.00±0.00^{cd}	43.33±2.72^{d}
Eth. *T. vogelii*	0.05	0.00±0.00^{a}	3.33±2.72^{bc}	6.67±2.72^{cd}	16.67±0.00^{cd}
	0.1	0.00±0.00^{ab}	3.33±2.72^{bc}	13.33±2.72^{cd}	23.33±0.00^{cd}
	0.2	0.00±0.00^{ab}	6.67±2.72^{cd}	16.67±2.72^{cd}	30.00±0.00^{cd}
	0.3	3.30±2.72^{bc}	13.33±2.72^{cd}	23.33±2.72^{d}	40.00±0.00^{d}
	0.5	6.70±2.72^{bc}	16.67±2.72^{cd}	33.33±2.72^{d}	70.00±4.72^{e}

Each value is the mean ± standard error of three replicates, each replicate with 10 adults. Mean followed by the same letters within the same column are not significantly ($p \leq 0.05$) different from each other using Tukey HSD Test.
Key: Aq. = Aqueous, Eth. = Ethanol

Table 6: LD_{50} at 7th day of *P. truncatus* mortality after treatment with different dosages of extracts of *H. suaveolens* and *T. vogelii.*

Treatment	LD_{50}	95% CL	S.E.
Aq. *H. suaveolens*	0.75	0.06-0.14	0.185
Eth. *H. suaveolens*	0.62	0.11-0.18	0.190
Aq. *T. vogelii*	0.35	0.05-0.12	0.179
Eth. *T. vogelii*	0.33	0.10-0.17	0.179

Key: Aq. = Aqueous, Eth. = Ethanol

(Ibrahim *et al*., 2000). *H. suaveolens* have been reported to have insecticidal, antioviposition and growth regulating effects against field and storage insect pests (Facknath, 1994; Stoll, 2000).

The reduction of F1 progeny emergence in the treated grains might be due to the increased adult mortality of the two tested plants extracts on LGB. The lower the dose of the extract the lower the mortality, the higher the emergence of F1 progenies. The lower the dose of the extract, the lower the seed damage and grain weight loss. The high mortality effect of these extracts may be due to inability of some of the beetles to feed on the treated grains which had been coated with the extracts thereby leading to starvation (Ashamo *et al*. 2013). The insect mortality may be due to blocking of spiracles of the insect by application of the extracts and death caused by asphyxia (Fernando and Karunaratne, 2012). Plant product may also penetrate the insect body through the respiratory system (Kedia *et al.,* 2015). *Tephrosia vogelii* is traditionally used for its ichthyotoxic, insecticidal and food parasiticidal properties (Ibrahim *et al*., 2000). Leaf extracts of *H. suaveolens* reduced the population of *Spodoptera litura* and *Aphis craccivora* on groundnut (Jayakumar *et al*., 2004).

The extracts from the leaves of *H. suaveolens* and *T. vogelii* prevented grain damage and weight loss. The higher dosage of the extracts of *H. suaveolens* and *T. vogelii* have resulted in the low grain damage when compared to the untreated control. Since grain damage and weight loss are related, the higher the grain damage, the higher the grain loss and verse vice. This is because, as the number of live weevils reduces in the grains in storage, the amount of damage caused to the grains is also reduced as there is less feeding, hence the lower weight loss observed. Similar findings were reported by Mukanga *et al*. (2010) who illustrated that leaf powders of five botanicals (Eucalyptus, Guava, Neem, *Tephrosia*, and Water hyacinth) reduce weight loss and clearly suppressed the emergence of *P. truncatus* populations in dried cassava chips. Much of the antifeeding effects of test botanicals could be attributed to their bioactive principles (Abdelgaleil and Nakatani, 2003)

There was least emergence of F1 progeny in the grains treated with highest dosage level of *T. vogelii* ethanolic extracts as compared to aqueous *H. suaveolens* extract and the control. This may be due to the volatile phytochemicals present in the extracts causing the insects to have the inability to lay large quantity of eggs and those with higher dosage level inhibiting oviposition. The present results agree with the findings of other authors. Adedire *et al*. (2011) reported the effectiveness of different botanicals at higher dosage to various insect pests. Few eggs laid by the beetle were unable to thrive in the grains and this may affect the progeny production (Ileke and Olotuah 2012).

Chebet *et al*. (2013) reported that the maize grain treated with *L. camara T. vogelii and A. indica* powder recorded 71.6%, 69.7% and 85.6% F1 progeny reduction respectively. However, the efficacy of the plant products is significantly suppressing emergence has largely been attributed to ovicidal properties, which prevent eggs from hatching into larvae (Jadhav and Jadhav, 1984; Ojo *et al*., 2016). The findings in this study agree with the result of Jayakumar *et al*. (2005) who recorded

high adult mortality, reduction in number of eggs laid and reduction in number of F1 progenies of *Callosobruchus maculatus* when exposed to various solvent extracts of *H. suaveolens*.

Leaves' extracts of *H. suaveolens* and *T. vogelii* have repellent effects on *P. truncatus*. The observed repellent activity could partly be attributed to the presence of volatile constituents such as terpenoids, flavonoids and polyphenol in the two plants extracts. The toxic and repellent action

Table 7: Effects of extracts of *H. suaveolens* and *T. vogelii* on seed damage and weight loss of maize.

		Percentage seed damage/weight loss	
		Seed damage	Weight loss
Treatment	Dosage(ml)		
Control		47.10±4.63^{a}	10.57±0.28^{a}
Aq. *H. suaveolens*	0.05	31.57±1.14^{b}	3.47±0.20^{b}
	0.1	24.17±1.69^{bc}	3.20±0.00^{b}
	0.2	21.33±2.79^{bc}	3.40±0.17^{b}
	0.3	20.73±2.07^{bc}	3.20±0.09^{b}
	0.5	18.73±2.45^{c}	2.80±0.26^{b}
Eth. *H. suaveolens*	0.05	30.80±2.43^{b}	3.43±0.21^{b}
	0.1	18.33±1.15^{c}	3.40±0.24^{b}
	0.2	18.43±0.94^{c}	3.08±0.72^{b}
	0.3	17.50±3.20^{c}	2.93±0.27^{b}
	0.5	15.77±0.63^{c}	1.83±0.25^{c}
Aq. *T. vogelii*	0.05	29.43±1.98^{b}	3.10±0.31^{b}
	0.1	23.63±1.04^{bc}	3.17±0.14^{b}
	0.2	18.73±1.09^{c}	3.13±0.20^{b}
	0.3	15.67±0.65^{c}	2.10±0.14^{b}
	0.5	10.13±2.15^{d}	1.73±0.14^{c}
Eth. *T. vogelii*	0.05	28.07±2.00^{b}	3.67±0.45^{b}
	0.1	22.73±2.70^{bc}	2.50±0.72^{b}
	0.2	18.13±1.08^{c}	2.41±0.72^{b}
	0.3	15.10±0.82^{c}	1.90±0.27^{c}
	0.5	2.95±1.50^{d}	0.84±0.27^{d}

Each value is the mean ± standard error of three replicates, each replicate with 10 adults. Mean followed by the same letters within the same column are not significantly ($P \leq 0.05$) different from each other using Tukey HSD Test.
Key: Aq. = Aqueous, Eth. = Ethanol

Table 8: F1 Progeny emergence of *P. truncatus* on maize treated with different dosage levels of extracts of *H. suaveolens* and *T. vogelii*

Percentage F1 Progeny Emergence			
		F1 Emergence	Reproduction inhibition rate %
Treatment	Dosage(ml)		
Control		79.67±0.94[a]	-
Aq. *H. suaveolens*	0.05	35.67±1.97[b]	55
	0.1	30.67±2.33[b]	62
	0.2	19.33±1.25[bc]	76
	0.3	10.67±1.70[c]	87
	0.5	9.67±0.72[c]	88
Eth. *H. suaveolens*	0.05	31.00±2.06[b]	61
	0.1	28.00±0.98[b]	65
	0.2	19.33±1.25[bc]	76
	0.3	7.00±0.72[cd]	91
	0.5	4.67±0.98[d]	94
Aq. *T. vogelii*	0.05	34.33±1.66[b]	57
	0.1	29.67±1.97[b]	63
	0.2	19.67±1.42[bc]	75
	0.3	13.67±1.79[c]	83
	0.5	10.33±0.72[c]	87
Eth. *T. vogelii*	0.05	35.33±1.91[b]	56
	0.1	27.67±0.47[b]	65
	0.2	14.67±0.47[c]	82
	0.3	8.67±0.82[c]	89
	0.5	3.00±0.27[d]	96

Each value is the mean ± standard error of three replicates, each replicate with 10 adults. Mean followed by the same letters within the same column are not significantly ($P \leq 0.05$) different from each other using Tukey HSD Test.
Key: Aq. = Aqueous, Eth. = Ethanol

Table 9: Simple correlation variables of maize grains infested by *P. truncatus* as influenced by different extracts.

	Mortality	Seed damage	Weight loss	F1 emergence
Mortality	1			
Seed damage	-0.86368	1		
Weight loss	-0.67131	0.85161	1	
F1 emergence	-0.82028	0.91291	0.89325	1

T. vogelii and *H. suaveolens* showed their potencies as grain protectants among the traditional resource-poor farming communities in sub-Saharan Africa. The strong repellent effect of these leaves' extracts may have been largely influenced by olfactory and gustatory sensation (Schmutterer, 1990) of the test insects. Properties like the repellent odour may cause an insect to be restless (Ogendo *et al*., 2003), making insect to turn away and moved towards the untreated portions of grains. The choice for the untreated portions could be as a result of the presence of repellent chemicals inherent in the botanicals (Jilani *et al*., 1988). Insect repellents are secondary metabolites which have been identified to be alkaloids, phenolics, flavonoids and terpenes (Dales, 1996).

CONCLUSION

The findings from this study shows that botanicals are effective and potent as grain protectants against *P. truncatus*. The aqueous and ethanolic extracts each obtained from leaves of *H. suaveolens* and *T. vogelii* were found to be effective in mitigating Larger Grain Borer on stored maize. The protection of grain in bioassays tested was dose dependent, with higher doses offering better protection. However, *H. suaveolens* and *T. vogelii* are effective and readily available to farmers in the rural areas and they can be used for short- and long-term storage of maize grains, therefore there is need to sensitize the farmers on the potency of these botanicals to control LGB so as to improve their livelihood and enhance food security.

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