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Effects of aqueous and oil leaf extracts of *Pterocarpus santalinoides* on the maize weevil, *Sitophilus zeamais* pest of stored maize grains

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The effects of aqueous and oil leaf extracts of *Pterocarpus santalinoides* at concentrations of 5, 10, 15 and 20%v/v, each as proctectant in the control of the maize weevil, *Sitophilus zeamais,* were compared with a conventional insecticide, pirimiphos-methyl at a rate of 0.5 ml / 50 g maize grains of Oba Super II variety in a Completely Randomized Design with four replicates. Parameters assessed, include adult mortality, rate of oviposition and adult emergence, grain damage and weight loss, and seed viability. The data were subjected to analysis of variance and means separated by using Duncan's Multiple Range Test. Mortality of adult *S. zeamais* increased with increased concentration of the extracts as well as with days of exposure. Emergence rate was significantly ($p<0.05$) reduced from 41.82% pt in the control values to 19.35 to 2.14% in *P. santalinoides* aqueous and 9.30 to 0.90% in *P. santalinoides* oil with pirimiphos methyl having the least number of emerged adults (0.60%). Damaged maize seeds varied from 12.32 to 1.98% in *P. santalinoides* aqueous extract and 4.86 to 0.61% in *P. santalinoides* oil extract while 0.59% was recorded in Pirimiphos methyl-treated seed grains. Grain weight loss significantly varied between treatments after two and a half months ($F_{11, 24}$= 1499.2, $p<0.0001$). Highest seed germination percentage (78.60%) was observed in seeds treated with 5%v/v *P. santalinoides* aqueous extract and the control, followed by 72.40% in *P. santalinoides* oil concentrations at 5, 10 and 15%v/v. The findings showed that almost all treatments except un-treated control decreased (weevil reproduction) grain weight loss and grain damage (holes on grains) in maize.

Key words: *Pterocarpus santalinoides*, pirimiphos-methyl, *sitophilus zeamais*, effects, grain damage and weight loss.

INTRODUCTION

Maize is a cereal crop of the grass family Poaceae. It is the most important cereal in the world after wheat and rice with regard to cultivation areas and total production (Awika, 2011; Mrkovacki et al., 2016). According to Abdulrahaman and Kolawole (2006), some of the local dishes prepared with maize include hot and cold pap, 'tuwo', donkunnu', 'maasa', 'couscous', 'Akple', 'Ukejuka', 'Gwate', 'Nakia', 'Dambualubosa', 'Abari', 'Egbo' and

'Donkwa'. Maize is also made into 'popcorn', 'Ajepasi', 'Aadun', 'Kokoro' and 'Elekute.

Apart from food, maize is also useful as medicines and as raw materials for industries. According to Oladejo and Adetunji (2012), levulinic acid, a chemical derived from maize, is used as ingredient in antifreeze and is capable of replacing the toxic petroleum-based ingredients normally used. Plastic and fabrics are made from corn stocks, ethanol obtained from maize can be used as a biomass fuel and stigmas from female corn-flowers, known as corn silk, can be used as herbal supplements (Oladejo and Adetunji, 2012). Also, the leaves of the maize plant serve as forage for livestock. Maize is used extensively as the main source of calories in animal feeding and feed formulation, and also in making silage after fermentation of corn stocks (Oladejo and Adetunji, 2012).

Despite the vast uses of maize grains and its products, there are problems to its sustainable production. One of the most important limitations to maize production is the effect of pests (both field and storage pests). Some of them include: the bacterium *Pantoea stewartii,* which causes Stewart's Bacterial Wilt,; the pathogenic fungus *Ustilago maydis* that causes smut on maize (Hoopen and Maïga, 2012).

Nevertheless, by far the most important pest of maize is the maize weevil, *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae). The insect is a major pest of stored maize grains in the tropics and temperate regions of the world (Adedire, 2001; Yeshaneh, 2015). Its infestation causes severe post-harvest losses of staple food crops in Nigeria leading to major economic losses (Oni and Ileke, 2008). Various strategies aimed at checking the menace of pest infestation, especially with the maize weevil, *S. zeamais* in stored grains have been employed. These strategies include physical, biological and chemical control among others.

However, because of serious health and environmental concerns as well as genetic resistance by insect species, pest resurgence and residual toxicity related to the use of these chemicals, most societies have questioned their use and are in search of more favourable/acceptable pest control methods (Adedire, 2002; Adedire et al*.,* 2011; Ekeh et al., 2013). The main advantage of botanical pesticides centers majorly on their eco- friendliness, easily bio-degradable and plant-derived natural products that are toxic to pests and they could be produced from locally available organic materials.

Currently, attention is being given to the use of edible plant materials as grain protectants (Ivbijaro and Agbaje, 1986; Adedire and Lajide, 2003; Akinkurolere et al*.,* 2006; 2009 Adedire et al*.,* 2011). Farmers, especially the peasant ones in developing countries had over the years been using selected indigenous plants materials believed to possess insecticidal properties as crop protectants by mixing them with the stored grains (Edelduok et al., 2015). And one of the plants employed is *Pterocarpus santalinoides*, (French: Ouokisse; Hausa: Gyadar kurmi, Gunduru; Igbo: Nturukpa; Yoruba: Gbengbe) a tree in the family fabaceae*.* The tender leaves of the plant are used as vegetables in soup making while the stem bark is used in making "pepper soup" (Okwu and Ekeke, 2003).

The aqueous extract of the stem bark of *P. santalinoides*, has been established to have effects on *Pseudomonas aeruginosa* which is responsible for such infections as pneumonia, urinary tract infections (UTIs) and bacteraemia (Eze et al., 2012). According to Anowi et al. (2012b), the methanolic extract of leaves of *P. santalinoides* possesses analgesic activity and Okpo et al. (2011) reported the anti-diarrhea property of aqueous extract of the leaves of the plant while Otitoju et al*.* (2014b) observed that the leaves of *P. santalinoides* are used in preparing soups like ogbono and egwusi (melon soup). Also, Adeleke et al. (2009) reported the larvicidal properties of the seed oil of *P. santalinoides.* But there has been paucity of information on the effects of aqueous and oil leaf extracts of *P. santalinoides on* maize weevil, *S. zeamais.*

Hence, the need to study this plant`s oil and aqueous leaf extracts on maize weevil, *S. zeamais* was borne due to its ready availability and non-toxicity to humans, local farmers use of the seed extracts, leaf extracts and stem-bark extracts as grain protectant. However, whether or not this has been effective is subject to investigation. Therefore, the present study investigated the *P*. *santalinoides* effectiveness by using its aqueous and oil leaf extracts on the maize weevil. *S. zeamais* access the rate of mortality, oviposition, rate of adult emergence, grain damage, weight loss and seed viability of *S. zeamais* with application of varied concentrations of aqueous, and oil leaf extracts of *P. santalinoides,* also compare its effectiveness with that of a synthetic pesticide (*Pirimiphos methyl*).

MATERIALS AND METHODS

Study location

All experiments were conducted at the Entomology Research

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Laboratory, Department of Zoology and Environmental Biology, University of Nigeria, Nsukka under ambient temperature of 27±2°C and 65±5% relative humidity.

Stock culture of weevils

Weevils were purchased from traders' granary stores in town (Ogige market) as initial stock. They were first mass reared in a separate container (tins, cans covered with muslin cloth at the top). 500 unsexed adult *S. zeamais* weevils were introduced into the maize seeds and the container kept in ideal conditions for reproduction to take place. Jars were placed on a table whose stands were dipped in plastic bowls containing oil to prevent ants from contaminating the culture. Newly emerged weevils were used for the rest of the study (Ojo and Ogunleye, 2013).

Procurement of maize grains

The Oba Super II variety of maize grains was used for this research. One kilogram of the uninfested grains was bought from Ogige Market, Nsukka L.G.A Enugu state and identified at the department of Crop Science, University of Nigeria, Nsukka. The grains were still handpicked to make sure only clean unhampered grains were picked, thereafter the clean seeds were left under the sun in order to eliminate any resident insect pest. The grains were then sieved with a 2 mm- mesh size sieve to remove any dead insect and frass. The maize seeds were then packaged in an air-tight container and kept in a refrigerator, pending usage.

Procurement of *Pterocarpus santalinoides* leaves

The plant material used were leaves of *P. santalinoides* which were collected from a farm in Ugboezeji Abakpa Nike, Enugu, Enugu State, Nigeria and identified to species level at the Department of Plant Science and Biotechnology. The plant materials were dried under room atmosphere for three weeks until a constant weight was maintained. 2 kg of the leaves were then ground into very fine powder using an electric blender and kept in plastic containers with tight lids and stored in a refrigerator at 4±2°C till the time for Soxhlet extraction (Mulungu et al., 2010; Ileke and Oni, 2011). *P. methyl* was bought from Lavans Group Limited, Enugu, Enugu State.

Extraction of the plant material

Aqueous

800 g of the ground plant material was soaked in 5500 ml of water and left for 24 h. The solution was filtered with a muslin cloth of 1.5 mm mesh size. The filtrate was then poured into an evaporation dish and dried under fan at room temperature.

Oil

The soxhlet extraction method was used for the extraction of oil from the plant material. The soxhlet extractor was set up with pre-weighed soxhlet flask and the extraction procedure followed. 400 g of powdered plant material was put into the thimble and the material was continuously shaked for 6 h using 800 ml distilled N- hexane (40 to 60°C) and thereafter left to cool and concentrate at room temperature for 24 h using cold pressing through decanting method at 130 rpm (Ekeh et al., 2013b). At the end of the extraction, the thimble was removed and the solvent distilled off and filtered using whatman filter paper. Crude extract of *P. santalinoides* were later diluted with N-hexane to obtain five different concentrations of 10, 20, 30,40, and 50% v/v with a control (0 %v/v) containing only N-hexane. The oil was transferred to glass jar with cover and kept in a refrigerator until needed.

Phytochemical test of the plant material

The qualitative phytochemical composition of the leaves of *P. santalinoides was* studied following the method of Ndukwe and Ikpeama (2013) and Otitoju et al. (2014b).

Experimental design

50 g of clean maize grains contained in 200 ml plastic plate of about 0.075 m diameter were added five pairs of a day old male and female adult *Sitophilus zeamais* which were obtained from a stock culture. Each of the two treatments of aqueous and oil extracts of the plant material was added to the different plates (12 plates for the aqueous treatment and 12 plates for the oil treatment) at the rates of 10, 20, 30, 40 for the aqueous and oil extracts, and each concentration was replicated three times. A total of 26 plates were used. The experimental control for each of the treatments was set up with maize grains and *S. zeamais* but no plant or oil extract. Each of the plate was covered with muslin cloth of about 0.2mm mesh size to permit air passage and prevent escape of the insects. The set up was allowed for six weeks at temperature of about 30±3°C with daily monitoring. Dead insects in each plate were removed and counted. Oviposition of eggs in the maize grains by *S. zeamais* was also monitored daily and natality was recorded as adult emergence, also number of holes and seed damage was recorded.

Evaluation of extracts for contact toxicity for determination of LC_{50}

Twelve day-old *S. zeamais* were placed per petri-dish and were individually picked and treated by applying 1-2µl drops of each concentration of both extracts on their ventral sides from a micro syringe. The contents of the petri-dishes were provided with maize grains and insects were observed at 24 h. Insects that do not respond to probing with a seeker were considered dead. The concentrations were converted into logarithmic values while mortality values were converted to probits. Probit values were plotted against logarithmic values and a regression line (of best fit) was drawn. The logarithmic dose at the median point when changed to antilogarithm was taken as the effective LC_{50} for each extract (Finney, 1971).

Effects of plant extracts and P. methyl on the mortality of *S. zeamais*

50 g of maize grains were weighed into jars. Using a micro-syringe, 0.5 ml of the concentrations (10, 20, 30 and 40% v/v) of each of the extracts and *P.methyl* was applied to the grains and shaken to allow for coverage. Grains in the control jar were treated with ethanol only. The grains were infested with ten (1 male: 1 female) adult s. *zeamais* per jar and jars covered with a lid of fine mesh to allow for aeration. Mortality was recorded at 24, 48, 72

and 96 h after infestation, with insects considered dead if they did not move when probed with a camel hairbrush. Dead adults were removed at each assessment, counted and recorded. Data on percentage mortality were corrected using Abbott's (1925) formula:

$P_T = P_O - P_C / 100 - P_C$; where P_T = corrected mortality (%), P_O = observed mortality (%), Pc = control mortality (%).

Effects of plant extracts and P. methyl on emergence of S. zeamais, grain damage, weight loss and seed viability

After 10 days, all adult weevils were removed and the jars left undisturbed and monitored (two and half months) until the emergence of F_1 progeny. Data on F_1 adult emergence were assessed from the commencement of adult emergence with emerged adults removed, counted and recorded. The grains were later sieved to remove the dust produced from adult feeding and re-weighed by using a Mettler Weighing balance and the percentage loss in weight determined as follows:

$$\text{Per (\%) weight loss} = \frac{\text{initialwt} - \text{finalwt}}{\text{final weight}} \times 100$$

The number of grains perforated in each of the treated and control jars were counted and percentage seed damage was determined as:

$$\text{\% seed damage} = \frac{\text{Number of perforated grains}}{\text{Total number of grains counted}} \times 100$$

In order to assess the viability of seeds, germination test was conducted using twenty seeds from each jar. The seeds were placed on moist filter paper in plastic Petri dishes kept in an incubator at 25°C and the number of germinated seed was counted and recorded, and percentage seed viability was calculated as:

$$\text{\% viability} = \frac{\text{Number of germinated seed}}{\text{Number of seed sown}} \times 100$$

Statistical analysis

All percentage data were angular transformed prior to statistical analysis, in order to equalize variances. All data were analysed and significant differences were compared at 0.05 significant level using Duncan's Multiple Range Test (DMRT) (Zar, 1984).

RESULTS

Contact toxicity of plant extracts on *S. zeamais*

Contact effect of aqueous extracts of *P. santalinoides* and its oil extract on *S. zeamais* at various concentrations showed an increase in mortality in both extracts from 39.4 to 78.4% in *P. santalinoides* aqueous and to 100% in *P. santalinoides* oil. The lethal concentration (LC_{50}) of P. *santalinoides* aqueous extract was 19.95% while that of *P. santalinoides* oil was 13.18% (Figures 1 and 2).

Effects of plant extracts and *P. methyl* on the mortality of *S. zeamais*

Mortality of adult *S. zeamais* exposed to different rates of extracts of *P. santalinoides* aqueous extract, *P. santalinoides* oil and the conventional insecticide (*P. methyl*) was compared in Table 1. Adult mortality increased with increase in concentration and with days of exposure to both extracts and in *P. methyl*. There was no significant difference ($p < 0.05$) between *P. santalinoides* oil at 20%v/v and *P. methyl* at 72 and 96 h post-treatment. *P. santalinoides* oil at 20%v/v also caused 100% mortality to adult *S. zeamais* even though the synthetic insecticide caused 100% mortality 24 h earlier. All rates of application of both extracts and *P. methyl* were significantly ($p < 0.05$) different from the control in all the days of the trials (Tables 2 and 3).

Effects of plant extracts and *P. methyl* on emergence of *S. zeamais*, grain damage, weight loss and seed viability

The effect of *P. methyl* and different concentrations of extracts of *P. santalinoides* (aqueous and *P. santalinoides* oil) is shown in Table 4. Mean number of emerged F_1 adults decreased with increasing concentrations of both extracts. Emergence was significantly ($p<0.05$) reduced from 41.82 in the control values to 19.35 to 2.14 in *P. santalinoides* aqueous and 9.30 to 0.90 in *P. santalinoides* oil with *P. methyl* having the least number of emerged adults (0.60). However, treatment with *P. methyl* did not significantly ($p > 0.05$) reduce emergence than those with *P. santalinoides* oil at 15, 20 and 20%v/v at *P. santalinoides* aqueous extract. All treatments were significantly better ($p < 0.05$) than the control in reducing adult emergence (Table 4). Damaged maize seeds in treatments of various concentrations of the extracts varied from 12.32 to 1.98% in *P. santalinoides* aqueous and 4.86 to 0.61% in *P. santalinoides* oil while 0.59% was recorded in treatment with *P. methyl*. All treatments proved superior to control, (28.25%) with *P. methyl* and 20 %v/v with *P. santalinoides* oil outstanding (Table 5). The percentage loss in weight of grains due to damage varied among treatments from 0.04% in *pirimiphos - methyl* to 4.57% in the control. 20 % v/v of *P. santalinoides* oil and *pirimiphos –methyl* were significantly ($p<0.05$) better than the other treatments in reducing weight loss (Table 3). Highest germination percentage (78.60) was observed in

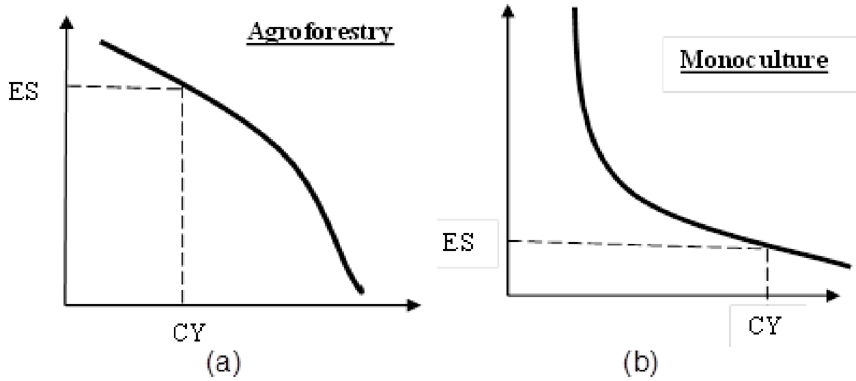

Figure 1. (a) Agroforestry and (b) Monoculture practices (ES = Ecosystem Services, CY = Crop Yields). Source: Adapted from Elmqvist et al. (2011).

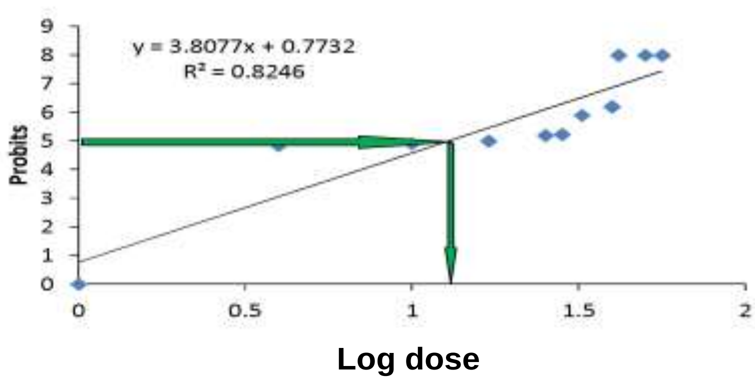

Figure 2. Determination of LC_{50} of oil extract of *Pteracarpus santalinoides* leaves on *S. zeamais.*

Table 1. Percentage proximate composition of stored maize grain.

Nutrient	(%) proximate composition
Moisture	11.60±0.23
Ash	2.95±0.15
Crude fibre	2.50±0.11
Protein	9.35±0.25
Fat	3.95±0.18
Carbohydrate	69.60±0.10

Source: Enyishi *e*t al. (2014).

seeds treated with 5%v/v *P. santalinoides* aqueous extract and the control, followed by 72.40% in *P. santalinoides* oil concentrations at 5, 10 and 15 %v/v. Other treatments gave the least germination of 70.25%. There were no significant differences ($p > 0.05$) in seed germination among the treatments and the control.

Table 2. Phytochemical composition of *Pterocarpus santalinoides.*

Phytochemical	Relative presence
Tannins	++
Flavonoids	+++
Oxalate	++++
Steroids	+
Glycosides	-
Phenols	++
Alkaloids	++++
Anthocyanin	+
Carotenoids	+
Saponins	++++

Key: Not present; +, present in very small concentration; ++, present in moderate concentration; +++, present in high concentration; ++++, present in very high concentration.
Source: Ndukwe and Ikpeama (2013) and Otitoju et al. (2014b).

Table 3. Effects of plant extracts and *P. methyl* on mortality of *S. zeamais.*

Insecticidal materials	Conc. %v/v	Percentage mortality over 4 days post treatment			
		24 h	48 h	72 h	96 h
Pterocarpus santalinoides (aqueous)	5	10.4^{g}±2.03	16.6^{f}±2.05	19.0^{de}±3.02	26.5^{d}±3.51
	10	14.0^{fg}±2.34	19.2^{ef}±1.66	23.0^{cd}±1.92	34.0^{d}±2.59
	15	19.0^{ef}±0.00	29.5^{d}±1.51	40.5^{c}±2.83	46.5^{c}±2.89
	20	24.6^{ef}±1.66	36.5^{d}±1.51	46.5^{c}±2.82	54.5^{c}±2.76
Pterocarpus santalinoides (oil)	5	18.0^{ef}±3.02	29.0^{de}±3.02	39.0^{c}±4.14	54.0^{c}±4.39
	10	40.4^{d}±1.51	38.5^{d}±1.51	58.0^{d}±2.41	78.0^{b}±3.17
	15	49.3^{c}±1.44	49.5^{c}±1.44	67.0^{b}±2.59	89.5^{ab}±3.40
	20	68.0^{b}±0.00	74.0^{b}±5.18	96.0^{a}±5.32	100.0^{a}±0.00
Pirimiphos methyl (control)	0.05	89.5^{ab}±3.40	95.00^{ab}±3.02	100.0^{a}±0.00	100.0^{a}±0.00
	0.000	75.0^{a}±1.92	97.5^{a}±4.61	100.0^{a}±0.00	100.0^{a}±0.00

Means followed by common letters in the same column are not significantly different at 5% level.

Table 4. Effects of plant extracts and *Pirimiphos methyl* on emergence of *S. zeamais* and grain damage.

Insecticidal material	% Conc. v/v	Meannumberof emerged adult (±S.E)	Percentage seed damage (±S.E)
P.santolinoides (aqueous)	5	19.35±0.15^{b}	12.32±0.04^{b}
	10	17.52±0.21^{c}	11.71±0.01^{c}
	15	8.19±0.15^{e}	4.31±0.04^{e}
	20	2.14±0.15^{g}	1.98±0.03^{g}
P.santolinoides (oil)	5	9.30±0.15^{d}	4.86±0.02^{d}
	10	6.40±0.15^{f}	2.20±0.03^{f}
	15	1.93±0.15^{g}	1.65±0.02^{h}
	20	0.90±0.15^{h}	0.61±0.01^{i}
Pirimiphos methyl (control)	0.5	0.60±0.15^{h}	0.59±0.01^{i}
	0.00	41.82±0.15^{a}	28.25±0.03^{a}

Means followed by common letters in the same column are not significantly different at 5% level.

Table 5. Effects of plant extracts and *P. methyl* on percentage weight loss and germination of maize seeds.

Insecticidal	Conc. %v/v	% weight loss (±SE)	% seed germination (±SE)
P. santalinoides (aqueous)	10	3.20^{b}± 0.06	78.65±2.64
	20	2.26^{c}± 0.03	75.14±1.25
	30	2.21^{cd}± 0.08	73.36±2.39
	40	1.42^{e}± 0.10	72.16±2.39
P. santalinoides (oil)	10	2.99^{c}± 0.05	72.40±5.18
	20	2.74^{d}± 0.10	71.40±1.44
	30	1.66^{e}± 0.16	71.40±1.44
	40	0.08^{f}± 0.01	70.00±4.08
Pirimiphos-methyl	0.5 ml	0.04^{g}±0.01	70.25±3.15
Control (solvent)	0.000	4.57^{a}±0.01	79.75±3 .68

LSD (0.05); 0.12; 0.2. Means followed by common letters in the same column are not significantly different at 5% level.

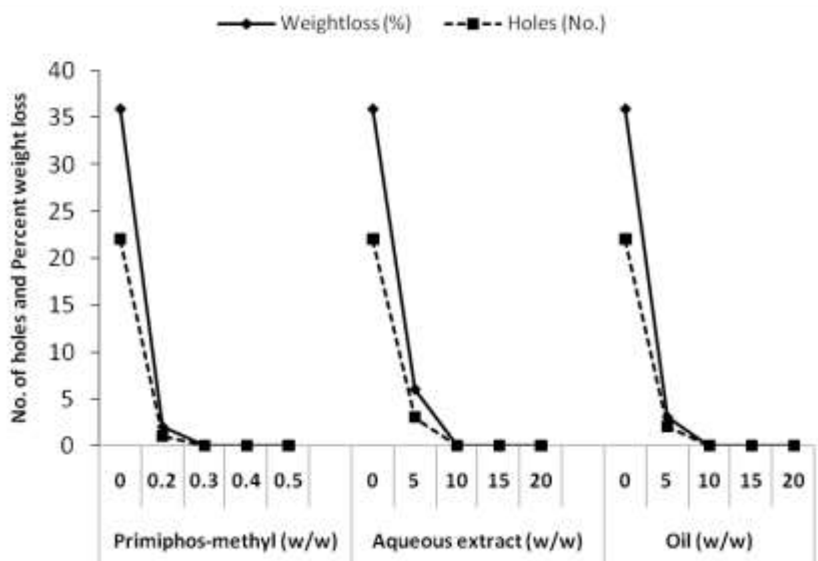

Figure 3. Number of holes and percentage weight loss.

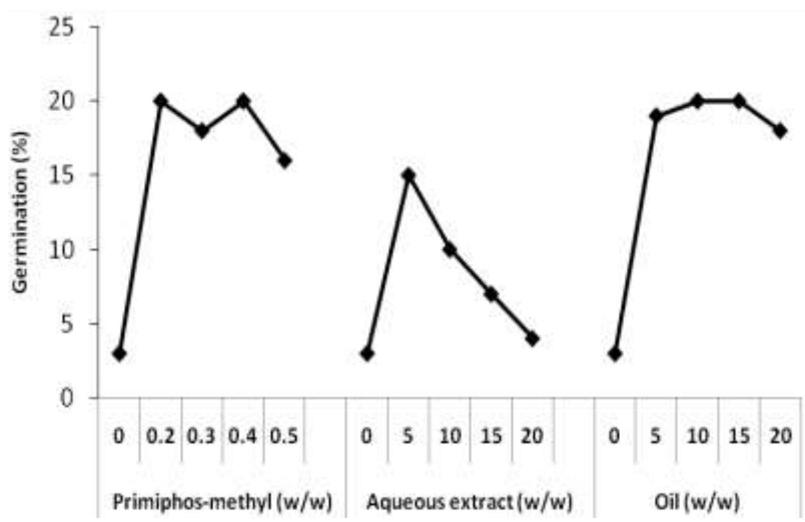

Figure 4. Percentage of germination.

Number of holes

The number of holes on maize seeds was significantly different between treatment levels ($F_{11, 24}$= 631.1, p<0.0001). Number of seeds with holes were significantly different between treated and untreated maize grains (p<0.0001) (Figure 3).

Percent grain weight loss

Grain weight loss significantly varied between treatment levels after two months and a half ($F_{11, 24}$= 1499.2, p<0.0001). After two and half months, percent weight loss of untreated seeds was about 35%. Treated ones did not lose weight (Figure 3).

Percent germination of seeds

Similarly, rate of seed germination significantly varied between treated and untreated seeds ($F_{11, 24}$= 93.53, p<0.0001). Germination rates did not vary significantly between doses of the *P. santalionis* oil and *P. santalionis* aqueous *leaf* extracts (Figure 4).

DISCUSSION

The results of this study justified the role of *P.s antalinoides* aqueous leaf extract and *P. santalinoides* oil extract in the storage of maize grain against degradation by storage insects. The treatments have been observed to significantly reduce the ability of maize weevils to lay eggs on the protected seeds and thus led to a reduction in the level of damage.

Weevils did not reproduce on treated maize seeds because they did not find these seeds suitable for reproduction to takes place. From the result, it could be concluded that treatments controlled maize weevil reproduction almost 100% for two months and a half. The mechanism of action may be their antifeedant or repellent nature. Antifeedants, or feeding deterrents are chemicals that inhibit feeding or those that disrupt insect feeding by rendering the treated materials unattractive or unpalatable (Saxena et al., 1998). Therefore, according to the result of the analysis of variance, damage, that is, grain weight loss and number of holes of both extracts were significantly reduced or completely prevented by using these botanical products.

Oils are used in insect control because they are relatively efficacious against virtually all life stages of insects (Adedire, 2003; Rajashekar et al., 2014). Topical application caused high mortality to *S. zeamais* suggesting that oils have contact toxicity on the insects. *P. methyl* was very effective in controlling adult *S. zeamais* which agreed with Asawalam and Emosairue (2006) who reported 100% mortality to *S. zeamais* when treated with *P. methyl* in stored maize.

P. santalinoides aqueous and *P. santalinoides* oil extracts may have been potent because of the strong odours emitted thereby disrupting normal respiratory activities of the weevils; resulting in asphyxiation and subsequent death (Adedire and Ajayi, 1996). However, their effectiveness was dependent on dosages and exposure period. Highly significant difference on the emergence of adults *S. zeamais* reared on treated and untreated maize indicated that insecticidal materials tested had significant effects on the developmental stages which in turn affected emergence.

Arannilewa et al. (2003) reported that the oil extract on application covered the outer layer (testa) of the seeds serving as food poison to the adult insects; while some of them penetrated the endosperm and germ layer thereby suppressing oviposition and larval development. Significantly lower number of emerged F_1 progeny relative to control suggests the presence of some active principles in the plants that had contact toxicity and fumigants action on the weevils (Adedire, 2003).

Tahir et al. (2015) did repellency work using four indigenous plant extracts and found that M. longifolia was the most effective repellent while C. longa was least effective repellent against R. dominica. Significant difference in repellency was observed with increasing exposure time and dose rate. The repellency action is contributed to the presence of active metabolites in extract. These metabolites are composed of essential oils which are responsible for the repellent action (Gunarathna and Karunaratne, 2009; Saljoqi et al., 2006; Al-Jabr et al., 2001; Geetha and Roy, 2014) also reported the same trend.

Application of *P. santalinoides* aqueous and *P. santalinoides* oil extracts with pirimiphos – methyl to grains resulted in significant reduction of percentage weight loss. After two and half months, about 70% of untreated maize grains had holes and treated ones did not have holes. Grain weight declined with increasing number of holes and, therefore, weight loss and number of holes were directly related (Pearson’s correlation coefficient r=0.99, P<0.0001, N=36). Infested maize seeds exhibit holes through which the adults emerge (Sahaf et al., 2008). Many indigenous plants, in powder form, effectively control cowpea seed beetles (Ofuya, 2003). Similar results have been reported earlier. For example, weight loss of wheat was prevented by applying the powder of *A. indica* and *A. boone* (Ileke and Oni, 2011). When maize weevils perforate maize grains, the weight of the grains declines.

In the present experiment, the *P. santalinoides* aqueous leaf and *P. santalinoides* oil extracts have prevented the formation of holes on seeds. This result is also supported by other researches on cowpea bruchids (Swella and Mushobozv, 2007) and common beans (Busungu and Mushobozv, 1991). Malathion treated common beans did not lose weight whereas the untreated ones did. Beans which were treated by Actellic super dust (as in the present study) and coconut oil to prevent *Z. subfasciatus* had the lowest number of holed seeds and the highest weight of seeds as compared to the untreated ones (Busungu and Mushobozv, 1991).

Increase in percent damaged bean seeds and weight loss is because of increasing bruchid number and the degradation of oils with time (Swella and Mushobozv, 2007). Just 2% turmeric powder provided good protection to rice or wheat and reduced grain weight loss (Saxena et al., 1998). Botanical insecticides such as pyrethrum, derris, nicotine, oil of citronella, and other plant extracts have been used for centuries (Singh and Upadhyay, 1993). In the plant powder, 99.1% mortality was recorded in *V. nugundo*, 94% in *N. speciosum*, and 96% in *A. officinuarium.* Adult emergence was registered in *A. indica* and A. *officinarum (*both 18%) followed by *G. superpa* (20%). The lowest grain weight loss was reported in *A. indica* (18.55%) and *A. officinarum* (18.56%) (Akinnusi, 1986).

The result of an earlier study by Okonkwo and Okoye (1996) showed that percentage weight loss was related to the population of adult *S. zeamais.* Seed viability pre-treated with the extracts showed that the treatments did not negatively affect seed germination. When maize weevils perforate maize grains, seed germination rate declines. Insect pests inflict their damage on stored products mainly by direct feeding (Malek and Parveen, 1989).

Some species feed on the endosperm causing loss of weight and quality, while other species feed on the germ, resulting in poor seed germination and low viability. *P. santalinoides* aqueous and oil extracts prevented the formation of holes on seeds due to their insecticidal properties. In this study, the germination rate of untreated maize grain by *P. santalinoides* aqueous leaf and oil extracts is lower than that of the treated one almost by 80%.

Presence of S*. zeamais* in maize grains led to a reduction in germination with increasing developmental stage of the insects, from 13% at the egg stage to 93% at the adult stage (Santos et al., 1990). This result is also supported by other researches on cowpea bruchids (Swella and Mushobozv, 2007) and on common beans (Busungu and Mushobozv, 1991). This agrees with the report of Adedire et al., (2011) which gave no significant differences in viability of seeds pre-treated with 0.5 and 2.0% of four plant extract concentrations and the control. Results obtained from this study demonstrates active potentials of this plant products as plant-derived insecticides against maize weevil and provide a scientific rationale for the use of these botanicals as alternative to synthetic insecticides in post harvest protection.

The problems posed by broad spectrum synthetic pesticides have led to the need for effective biodegradable pesticides with greater selectivity (Dayan et al., 2009). The efficacy of the products tested in the present study indicates their potential for replacing synthetic pesticides.

The two plant extracts regardless of dose prevented reproduction. That was a great leap forward. Synthetic insecticides not only do they pollute the environment but they also speed up weevil resistance to synthetic pesticides (Ileleji et al., 2007). On the other hand, pest insects have little chance of developing resistance to botanical products.

Botanical products are receiving more and more attention for pest control. What is needed is refining those using conventional scientific procedures. They have been with grain producers and traders for centuries. For example, Egyptian and Indian farmers used ash and leaves and seeds of neem for the control of stored grain pests (Varma and Dubey, 1999; Ahmed and Koppel, 1985). In eastern Africa, leaves of the wild shrub *O. suave* and the cloves of *Eugenia aromatic* are traditionally used as stored grain protectants (Powell, 1989). In Rwanda, farmers store edible beans in a traditional closed structure and whole leaves of *O. canum* are usually added to the stored foodstuff to prevent insect damage within these structures.

Essential oil constituents such as thymol, citronellal and α- terpineol are effective as feeding deterrents against tobacco cutworm, *Spodoptera litura* (Hummel and Isman, 2001). Synergism or additive effects of a combination of monoterpenoids from essential oils have been good against *S. litura* larvae. The *H. spicigera* essential oils showed fumigant toxicity against *S. zeamais*. The mortality rate of *S. zeamais* increased with the concentration and duration of exposure to the essential oils (Wekesa et al., 2011).

Conclusions

So, protecting our food from storage insects is a priority to ensure food security. The treatments decreased weevil reproduction; grain weight loss and grain damage (holes on grains) and increased mortality. No loss of weight and perforation of holes were observed on treated maize grains. However, untreated grains sustained huge weight loss, the greatest number of offspring and holes. As the amount of *P. santalinoides* oil applied increased, the rate of germination was affected unlike that of *P. santalinoides* aqueous extracts, which does not have a negative impact on the rate of germination of maize grains. Generally, *P. santalinoides* extracts treatments were found to be effective against the attack of *S. zeamais.* This provides good arguments for carrying out this study on natural pesticides. Thus, the tested products could serve as potential tools for the management of storage insect pests. Future efforts should focus on product optimization, packaging and marketing.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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