Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(1): 1280-1287

Received: 26-11-2017
Accepted: 27-12-2017

Mohammed Suleiman
a) Department of Zoology and Wildlife Conservation, University of Dar es Salaam, Tanzania
b) Department of Biology, Umaru Musa Yar'adua University, Katsina, Nigeria

Costancia P Rugumamu
Department of Crop Sciences and Beekeeping Technology, University of Dar es Salaam, Tanzania

Nasiru D Ibrahim
Department of Crop Science, Usmanu Danfodiyo University, Sokoto, Nigeria

Correspondence
Mohammed Suleiman
a) Department of Zoology and Wildlife Conservation, University of Dar es Salaam, Tanzania
b) Department of Biology, Umaru Musa Yar'adua University, Katsina, Nigeria

Insecticidal toxicity of some botanicals against *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) in stored sorghum grains in Nigeria

Mohammed Suleiman, Costancia P Rugumamu and Nasiru D Ibrahim

Abstract
Toxicity of leaf powders and extracts of *Euphorbia balsamifera*, *Lawsonia inermis*, *Mitracarpus hirtus* and *Senna obtusifolia* against *Sitophilus zeamais* was evaluated. The study was conducted in Postgraduate laboratory of the Department of Biology, Umaru Musa Yar'adua University, Katsina (Nigeria). Five pairs of 7 day old *S. zeamais* were released in 20 g of disinfested sorghum variety, Farar Kaura (FK) treated with powders, methanolic, ethanolic and aqueous extracts of the botanicals in plastic bottles, separately, at different concentrations of 2.5, 5.0 and 10.0 x 10^4 ppm. Botanical powders caused 67.50 ± 2.50 to 100.00 ± 0.00% adult morality of *S. zeamais* within 12 days after treatment (DAT). Both methanolic and ethanolic extracts applied at the three concentrations led to total adult mortality within 5 DAT. The highest (75.00 ± 2.89%) mortality recorded in aqueous extracts treatments was at 10.0 x 10^4 ppm of *E. balsamifera*, while the least (30.00 ± 4.08%) was in 2.5 x 10^4 ppm of *S. obtusifolia* within 28 DAT. *E. balsamifera* was the most effective botanical with its LC_{50} values ranging from 0.049 ± 0.739 to 1.410 ± 0.874 x 10^4 ppm. The botanicals were found to be highly effective in killing adult *S. zeamais* and therefore could be utilized to reduce the weevils' infestations in stored sorghum. However, further investigations on their toxicity on mammals and other insect pests are hereby recommended.

Keywords: Botanicals, LC_{50}, LD_{50}, mortality, *Sitophilus zeamais*, sorghum grains, toxicity

1. Introduction
The main stay of Nigerian economy is agriculture, which involves subsistence farmers scattered over a wide expense of land area [1]. The major cereals in Nigeria include rice, maize, sorghum, wheat, and millet, with sorghum accounting for 50% of the total cereal production and occupying about 45% of the total land area devoted to cereal production in Nigeria [2]. Sorghum belongs to the grass family Gramineae and one of the most important cereal crops grown in the tropics and sub-tropics of the world [3]. It is the second cereal crop and the fifth among all crops in terms of production in Africa, and in Nigerian sorghum production represented 25% of the total cereal production of the year 2012 [4]. The crop has the ability to withstand harsh conditions such as drought and water logging, and is used for food, animal feed, fodder and bio-ethanol [3].

In Nigeria where many farmers are rural dwellers and illiterate, government intervention in crop protection is low and insect infestations have been a major threat to food production [5]. Post-harvest insect pests attacking stored sorghum are the major biotic constraints that cause considerable economic losses in the storage sector [3, 6]. The cosmopolitan *S. zeamais* is one of the most destructive field-to-store pests and was reported to have caused 53.30 to 65.50% grain damage of stored sorghum [7, 8]. Further, grain damage of 27.88% was reported in maize infested by *S. zeamais* [6].

Synthetic insecticides have been commonly used for controlling pests in stored products. This has resulted in problems such as pest resurgence and increase in costs of application, arising from the development of resistance to insecticides [9]. The hazardous nature of chemical insecticides necessitated a search for alternative, eco-friendly methods of controlling insect pests of storage such as the use of botanicals [10, 11, 12].

Some researchers reported insecticidal effects of different plant materials against *S. zeamais* in stored grains and recorded high mortality of the weevils [5, 6, 7, 13, 14]. Medicinal plants such as *O. subscorpioidea*, *A. melegueta* and *Z. officinale* caused adult mortality of *S. zeamais* ranging

from 18.35 to 88.35% after 72 hours of exposure [5]. Toxicity effects of seed powder of *A. indica* against *S. zeamais* were studied and 23.00 to 28.67% adult mortality was recorded after 45 days of treatment [15]. It is advanced that *A. auriculiformis* and *A. goddsefiana* powders were found to show insecticidal toxicity against *S. oryzae* where they caused adult mortality ranging from 20.00 to 100.00% [16].

There is inadequate literature on the use of powder and/or extracts of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* in the control of *S. zeamais* on sorghum and/or any cereal during storage [17-19]. However, leaf powder of *L. inermis* was reported to have resulted in 100% mortality of *T. granarium* in stored wheat at 1, 2, 4 and 6% w/w after 14 days of post treatment period [17]. Application of *L. inermis* powders at 2% concentration on stored wheat was found to have resulted in 77.40% adult mortality of *R. dominica* [18]. Similarly, leaf powders of *L. inermis* applied at 2.5 g/ 20 g cowpea seeds were reported to have resulted in 81.14% adult mortality of *C. maculatus* after 120 hours of post treatment [19].

This study was therefore, aimed at investigating the toxicity of leaf powders and extracts of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* against adult *S. zeamais* on sorghum grains.

2. Materials and Methods

2.1 Rearing of *S. zeamais* for the experiments

Fifty pairs of *S. zeamais* were obtained from infested grain stores at Katsina Central Market, Nigeria, and then introduced into six rearing bottles containing 250 g of the disinfested sorghum grains of a local variety called Farar Kaura (FK), serving as a parent stock. The bottles were covered with pieces of muslin cloth and kept in an incubator (Model: NYC-40) for oviposition at 30 ± 2^{0}C and 70 ± 5% R.H. for 14 days, after which the parents were removed [20]. The rearing bottles were maintained in the incubator under the same condition for adult emergence. Emerging weevils were sieved daily, placed in another set of labeled bottles containing sorghum grains and kept in the incubator. When the emerged progeny reached 7 days old, they were sieved and used for the experiments.

2.2 Preparation of the botanicals for the study

Fresh leaves of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* were collected from uncultivated lands around Umaru Musa Yar'adua University, Katsina (UMYUK) in Nigeria. These were rinsed with distilled water to remove any dust and unwanted particles. Later they were shade-dried at room temperature for 14 days. The dried leaves were ground into powder using a laboratory blender (Model 8010ES) and sieved using a laboratory sieve with a mesh aperture size of 80 µ. The powders of each botanical were separately kept in black polythene bags at room temperature [21].

One hundred gram of each of the plant powders was dissolved in 400 ml of methanol, ethanol and distilled water, separately, in conical flasks in which the mouths were properly corked and kept in the laboratory at room temperature for 48 hours. The extract was separated using muslin cloth and filtered with Whatman No.1 filter papers using vacuum pump (Dymax 14) [22]. The filtrate was concentrated by evaporating excess solvents using rotary evaporator at a speed of 3 to 6 rpm for 8 hours. When the contents were about to completely evaporate, the aliquot was poured into evaporating dishes and placed in water bath to evaporate the remaining excess solvents. The resulting extracts were air-dried to remove traces of the solvent and stored in refrigerator at 4^{0}C [23] prior to use.

2.3 Assessment of adult mortality in botanical powders

In order to assess the number of dead weevils from the powder treatments, 4 replicates of 2.5 (2.5% w/w), 5.0 (5.0% w/w) and 10.0 x 10^4 ppm (10.0% w/w) of each leaf powder of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia*, and 0.056 x 10^4 ppm (0.056% w/w) of permethrin powder were admixed separately with 20 g of disinfested FK in 250 ml plastic bottles. The concentrations of the botanicals and permethrin powder were chosen based on recommendations by some researchers [24, 25]. The control contained only sorghum grains without any powder [26]. Five pairs of 7 day old adult weevils obtained in the rearing phase were introduced to each of the bottles, which was covered with muslin cloth, tied with rubber bands and placed in the incubator at 30 ± 2 ^{0}C and 70 ± 5% R.H. Dead weevils were recognized when they could not respond to probe with a sharp object. Data obtained from mortality of the adult *S. zeamais* were organized, analyzed and presented as mortalities within 4, 6, 8, 10 and 12 DAT. All treatments were arranged in a completely randomized design (CRD).

2.4 Assessment of adult mortality in botanical extracts

Adult mortality was assessed in leaf extracts treatments by adding 2 ml of methanolic, ethanolic and aqueous leaf extracts of the above plants diluted at different concentrations (2.5, 5.0 and 10.0 x 10^4 ppm) to 20 g of FK and mixed thoroughly in plastic bottles (250 ml). Two ml of methanol, ethanol and distilled water were used as controls of their respective treatments separately and air-dried [27].

For treatments with methanolic and ethanolic extracts, data were recorded, organized and analyzed within five days (when total mortality was obtained in all the treatments). Weevils in untreated containers were allowed to remain in the grains until they reached 14 days for oviposition before they were removed. In aqueous extract treatments, adult mortality was observed up to 28 days, after which all remaining live weevils were removed, leaving the grains only.

Adult mortality in both powdered and extracts treatments was assessed as:

$$\% \text{ Mortality} = \left(\frac{\text{Number of Dead Weevils}}{\text{Total Number of Weevils}}\right) \text{X } 100$$

2.5 Statistical analysis

Data generated from adult mortality tests were subjected to analysis of variance at 5% level of significance. Significantly different means were separated by the Bonferroni's multiple comparisons test using Graph Pad Prism version 7.03. Regression analysis was employed to calculate the LD_{50} of the powders and LC_{50} of the extracts using probit analysis at $p<0.05$.

3. Results

3.1 Adult mortality of *S. zeamais* in sorghum grains treated with botanical powders

Adult mortality of *S. zeamais* caused by *E. balsamifera* 2.5 x 10^4 ppm were 10.00 ± 0.00, 12.50 ± 2.50, 70.00 ± 5.77 and 100.00 ± 0.00% within 4, 6, 8 and 10 DAT as shown in Table 1.The mortality in grains treated with 5.0 x 10^4 ppm of the botanical ranged from 12.50 ± 2.50 to 100.00 ± 0.00% after 10 days of treatment, while at 10.0 x 10^4 ppm it varied between 20.00 ± 0.00 and 100.00 ± 0.00% within 8 DAT.

No weevils died in grains treated with leaf powder of *L. inermis* at the application rate of 2.5 x 10^4 ppm within 6 DAT. However, the adult mortality was 65.00 ± 2.89 and 100.00 ± 0.00% at 8 and 10 DAT. Both 5.0 and 10.0 x 10^4 ppm of *L.*

inermis caused 100.00 ± 0.00% mortality of the weevil within 10 DAT.

Table 1 shows the effect of *M. hirtus* in causing varying mortalities within 4, 6, 8, 10 and 12 DAT. The adult mortality varied between 2.50 ± 2.50 and 100.00 ± 0.00% when 2.5 x 10^4 ppm of the botanical was applied after 4 to 12 days. There was 7.50 ± 2.50 to 100.00 ± 0.00% mean mortality of *S. zeamais* in grains treated with 5.0 x 10^4 ppm of the botanical within 10 DAT. At 10.0 x 10^4 ppm, the mortalities were 7.50 ± 2.50% at 4 DAT, 37.50 ± 2.50% at 6 DAT, 87.50 ± 4.79% at 8 DAT and 100.00 ± 0.00% at 10 DAT.

The use of *S. obtusifolia* at the same concentrations, 2.5, 5.0 and 10.0 x 10^4 ppm did not cause any adult mortality of *S. zeamais* within 6 DAT, but 12 days after, the resultant mortalities were 67.50 ± 2.50, 85.00 ± 2.89 and 100.00 ± 0.00% at 2.5, 5.0 and 10.0 x 10^4 ppm, respectively (Table 1).

Application of permethrin powder at 0.056 x 10^4 ppm caused total mortality of the weevils within 4 DAT. Up to 12 DAT, no mortality was recorded in the control.

Two-way ANOVA indicated that the difference in adult mortalities of *S. zeamais* among the botanicals at the three concentrations within 12 DAT was not significant ($p > 0.05$).

3.2 Adult mortality of *S. zeamais* in sorghum grains treated with methanolic leaf extracts

Table 2 shows that application of *E. balsamifera* at 2.5, 5.0 and 10.0 x 10^4 ppm to the sorghum grains resulted in adult mortality of *S. zeamais* which varied between 50.00 ± 4.08 and 100.00 ± 0.00% at 2.5 x 10^4 ppm within 1, 2, 3 and 4 DAT. Treatments with 5.0 x 10^4 ppm of the botanical caused 70.00 ± 4.08, 90.00 ± 5.77 and 100.00 ± 0.00% adult mortality after 1, 2 and 3 days, respectively. Application of 10 x 10^4 ppm of the powder resulted in 80.00 ± 4.08, 97.50 ± 2.50 and 100.00 ± 0.00% of the weevils died within the same periods.

When the grains were treated with *L. inermis* at 2.5 x 10^4 ppm, the percent adult mortalities of the weevils were 45.00 ± 2.89, 67.50 ± 4.79, 82.50 ± 2.50 and 100.00 ± 0.00% within 1, 2, 3 and 4 DAT. The mortalities recorded at 5.0 x 10^4 ppm of the botanical ranged from 60.00 ± 4.08 to 100.00 ± 0.00% after 4 days. Increase in concentration to 10.0 x 10^4 ppm resulted in 70.00 ± 4.08 to 100.00 ± 0.00% mortality.

The use of *M. hirtus* led to substantial killing of adult *S. zeamais* within 5 DAT. The adult mortality varied between 22.50 ± 4.79 and 100.00 ± 0.00% in grains treated with 2.5 x 10^4 ppm of the botanical within 5 DAT (Table 2). Adult mortalities recorded at 5.0 x 10^4 ppm were 37.50 ± 4.79, 60.00 ± 4.08, 80.00 ± 4.08 and 100.00 ± 0.00% within 1, 2, 3 and 4 DAT. When the concentration was raised to 10.0 x 10^4 ppm, the mortalities were 50.00 ± 4.08, 70.00 ± 2.89 and 100.00 ± 0.00% within 1, 2 and 3 DAT.

The highest mortality of the weevils in *S. obtusifolia* treatments at the application rate of 2.5 x 10^4 ppm was 100.00 ± 0.00% and the least was 25.00 ± 2.89% within 5 DAT. At 5.0 x 10^4 ppm, the botanical resulted in mortality which ranged from 27.50 ± 2.50% to 100.00 ± 0.00% after 5 days. The mortalities were recorded as 32.50 ± 2.50, 50.00 ± 4.08, 67.50 ± 2.50, 90.00 ± 5.77 and 100.00 ± 0.00% at 10.0 x 10^4 ppm within 1, 2, 3, 4 and 5 DAT (Table 2).

No adult mortality was observed in untreated grains for 5 days after introduction.

Analysis of variance showed that the adult mortalities of *S. zeamais* were not significantly different ($p > 0.05$) among the botanical treatments at the concentrations, 2.5, 5.0 and 10.0 x 10^4 ppm application concentrations within 5 DAT.

3.3 Adult mortality of *S. zeamais* in sorghum grains treated with ethanolic leaf extracts

Table 3 shows that the adult mortality of the weevils in grains treated with *E. balsamifera* resulted in adult mortality ranging from 65.00 ± 2.89 to 100.00 ± 0.00% at 2.5 x 10^4 ppm within 3 DAT. The mortality in 5.0 10^4 ppm of the botanical was 75.00 ± 2.89, 95.00 ± 2.89 and 100.00 ± 0.00% after 1, 2 and 3 days, respectively. At 10.0 x 10^4 ppm, the mortality ranged from 85.00 ± 2.89 to 100.00 ± 0.00% at the end of 3 days of treatment.

L. inermis at 2.5 x 10^4 ppm resulted in adult mortality which varied between 55.00 ± 2.89 and 100.00 ± 0.00% at 1 to 5 DAT (Table 3). Application rate of 5.0 x 10^4 ppm of the botanical caused 72.50 ± 2.50, 92.50 ± 2.50 and 100.00 ± 0.00% at 1, 2 and 3 DAT. The mortalities recorded in 10.0 x 10^4 ppm concentration, within 1, 2 and 3 DAT were 77.50 ± 2.50, 95.00 ± 2.89 and 100.00 ± 0.00%, respectively.

The adult mortality of *S. zeamais* in grains treated with *M. hirtus* varied. The least mortality caused by the botanical treatments was 67.50 ± 4.89% within one day at 2.5 x 10^4 ppm, which increased to total mortality within 4 DAT (Table 3). The botanical led to the death of 70.00 ± 4.08% of the weevils in grains with 5.0 x 10^4 ppm treatments after one day which increased to 92.50 ± 4.89 and 100.00 ± 0.00% within 2 and 3 DAT. The mortality ranged from 75.00 ± 2.89 to 100.00 ± 0.00% at 10.0 x 10^4 ppm within 3 DAT.

Adult mortality of *S. zeamais* in grains treated with 2.5 x 10^4 ppm of *S. obtusifolia* was 55.00 ± 2.89, 72.50 ± 2.50, 82.50 ± 2.50, 92.50 ± 2.50 and 100.00 ± 0.00% within 1, 2, 3, 4 and 5 DAT, respectively. At 5.0 x 10^4 ppm, the percent mortality ranged from 67.50 ± 4.79 to 100.00 ± 0.00% within 4 DAT. The highest (100.00 ± 0.00%) mortality was recorded within 3 DAT when 10.0 x 10^4 ppm of the botanical was applied, and the least (70.00 ± 4.08%) was obtained after one day of treatment.

No weevil was recorded dead in the control within the same period.

Analysis of variance indicated that the adult mortalities of *S. zeamais* in sorghum grains treated with ethanolic extracts at 2.5, 5.0 and 10.0 x 10^4 ppm were not significantly different, $p > 0.05$, among the treatments within 5 DAT.

3.4 Adult mortality of *S. zeamais* in sorghum grains treated with aqueous leaf extracts

E. balsamifera at the concentration of 2.5 x 10^4 ppm resulted in adult mortalities as 10.00 ± 4.08, 32.50 ± 2.50, 40.00 ± 4.08 and 45.00 ± 2.89% within 7, 14, 21 and 28 DAT (Table 4). Treatments with 5.0 x 10^4 ppm of the botanical caused 20.00 ± 4.08, 42.50 ± 4.79, 50.00 ± 2.89 and 62.50 ± 2.50% within 7, 14, 21 and 28 DAT, respectively. Similar trend was recorded in grains treated with 10.0 x 10^4 ppm where the mortality ranged from 30.00 ± 0.00 to 75.00 ± 2.89%.

The adult mortalities of *S. zeamais* grains treated with 2.5 x 10^4 ppm of *L. inermis* were 5.00 ± 2.89, 20.00 ± 4.08, 37.50 ± 2.50 and 42.50 ± 2.50% within 7, 14, 21 and 28 DAT. The mortality in treatments with 5.0 x 10^4 ppm varied between 17.50 ± 2.50 and 60.00 ± 4.08% within 28 DAT. Using 10.0 x 10^4 ppm of *L. inermis* resulted in 25.00 ± 2.89, 42.50 ± 2.50, 55.00 ± 2.89 and 70.00 ± 4.08% mortalities within 7, 14, 21 and 28 DAT.

Application of *M. hirtus* at 2.5 x 10^4 ppm resulted in 5.00 ± 2.89 to 32.50 ± 2.50% mortality of the weevil at the end of 28 days of exposure. At of 5.0 and 10.0 x 10^4 ppm, the adult mortality ranged from 22.50 ± 2.50 to 65.00 ± 2.89% within 28 DAT (Table 4).

Application of *S. obtusifolia* at similar concentrations to the above caused 7.50 ± 2.50, 15.00 ± 5.00, 22.50 ± 2.50 and 30.00 ± 4.08% when 2.5 x 10^4 ppm of the botanical was applied within 7, 14, 21 and 28 DAT. When the concentration was raised to 5.0 x 10^4 ppm, the mortality varied between 20.00 ± 5.77% after 7 days of treatment and 45.00 ± 2.89% within 28 DAT. This pattern was maintained at 10.0 x 10^4 ppm where the recorded mortality varied between 22.50 ± 4.79% and 55.00 ± 2.89%.

Table 4 shows that there was 5.00 ± 2.89% only of adult mortality of *S. zeamais* in untreated grains within 28 DAT.

The adult mortality of *S. zeamais* caused by the botanicals at the different concentrations within 28 DAT increased in the following order: *S. obtusifolia* < *M. hirtus* < *L. inermis* < *E. balsamifera*.

There was a high significant difference, F (4, 12) = 160.80, p < 0.0001, in adult mortality of *S. zeamais* among the treatments at 28 DAT.

Bonferroni's multiple comparisons test showed that the percentage mean mortality of 10.0 x 10^4 ppm of *E. balsamifera* was higher than those in grains treated with *L. inermis*, *M. hirtus* and *S. obtusifolia* at the same concentration within 28 DAT. Those of 5.0 x 10^4 ppm in *E. balsamifera*, *inermis* and *M. hirtus* were the same but greater than *S. obtusifolia*. Also, adult mortalities caused by 2.5 x 10^4 ppm were lower than 5.0 and 10.0 x 10^4 ppm and statistically the same among themselves within 28 DAT (Table 4).

3.5 LD_{50} and LC_{50} of the botanicals against *S. zeamais*

Lethal dose (LD_{50}) of the botanical powders of against *S. zeamais* after 7 days of treatment is presented in Table 5. The LD_{50} values differed between treatments which are 0.674 ± 0.248, 0.818 ± 0.245, 1.145 ± 0.235 and 1.293 ± 0.250 x 10^4 ppm for *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia*, respectively. The LD_{50} of the botanical powders was in the order of increasing toxicity level as follows: *S. obtusifolia* < *M. hirtus* < *L. inermis* < *E. balsamifera*.

The highest LC_{50} value of methanolic extracts against *S. zeamais* at 1 DAT was in *S. obtusifolia* as 2.261 ± 0.743 followed by *M. hirtus* with 0.985 ± 0.743, *L. inermis* with 0.498 ± 0.700 and *E. balsamifera* had the least, 0.376 ± 0.714 x 10^4 ppm.

For ethanolic extracts, *L. inermis* had the highest LC_{50} value as 0.236 ± 0.712 x 10^4 ppm, while *E. balsamifera* had the least, 0.049 ± 0.739 x 10^4 ppm within 1 DAT. *M. hirtus* and *S. obtusifolia* had their LC_{50} values as 0.154 ± 0.723 and 0.150 ± 0.701 x 10^4 ppm, respectively.

Among the aqueous leaf extracts, *S. obtusifolia* had the highest LC_{50} value as 1.651 ± 0.912 x 10^4 ppm and *E. balsamifera* had the least as 1.410 ± 0.874 x 10^4 ppm within 7 DAT. *L. inermis* and *M. hirtus* had 1.414 ± 0.989 and 1.512 ± 1.036 x 10^4 ppm, respectively.

The LD_{50}/LC_{50} values of various botanical formulations were in the order of decreasing toxicity: ethanolic extracts > methanolic extracts > powders > aqueous extracts, while for the botanical type, the order was *E. balsamifera* > *L. inermis* > *M. hirtus* > *S. obtusifolia* in all formulations except in ethanolic extracts where the trend was *E. balsamifera* > *S. obtusifolia* > *M. hirtus* > *L. inermis*.

Table 1: Percent Mortality of adult *S. zeamais* exposed to 2.5, 5.0 and 10.0 x 10^4 ppm of botanical powders within 12 days after treatment

Treatments	Conc. (x 10^4 ppm)	Mean Adult Mortality (% ± S. E.)				
		Days after Treatment (DAT)				
		4	6	8	10	12
E. balsamifera	2.5	10.00 ± 0.00^{c}	12.50 ± 2.50^{fg}	70.00 ± 5.77^{b}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	5.0	12.50 ± 2.50^{c}	17.50 ± 2.50^{f}	97.50 ± 2.50^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	10.0	20.00 ± 0.00^{b}	52.50 ± 2.50^{b}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
L. inermis	2.5	0.00 ± 0.00^{d}	0.00 ± 0.00^{h}	65.00 ± 2.89^{b}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	5.0	0.00 ± 0.00^{d}	15.00 ± 2.89^{f}	92.50 ± 4.79^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	10.0	10.00 ± 0.00^{c}	45.00 ± 2.89^{c}	97.50 ± 2.50^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
M. hirtus	2.5	2.50 ± 2.50^{d}	7.50 ± 2.50^{g}	52.50 ± 4.79^{bc}	92.50 ± 4.79^{ab}	100.00 ± 0.00^{a}
	5.0	7.50 ± 2.50^{c}	26.00 ± 2.89^{e}	70.00 ± 5.77^{b}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	10.0	7.50 ± 2.50^{c}	37.50 ± 2.50^{d}	87.50 ± 4.79^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
S. obtusifolia	2.5	0.00 ± 0.00^{d}	0.00 ± 0.00^{h}	42.50 ± 2.50^{c}	67.50 ± 2.50^{c}	100.00 ± 0.00^{a}
	5.0	0.00 ± 0.00^{d}	0.00 ± 0.00^{h}	52.50 ± 4.79^{bc}	85.00 ± 2.89^{b}	100.00 ± 0.00^{a}
	10.0	0.00 ± 0.00^{d}	0.00 ± 0.00^{h}	60.00 ± 4.08^{b}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
Permethrin	0.056	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
Control	0.0	0.00 ± 0.00^{d}	0.00 ± 0.00^{h}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{b}

Conc. = Concentration.

Means in the same column followed by different letter superscript are significantly different at p<0.05 by the Bonferroni's Multiple Comparisons Test.

Table 2: Percent Mortality of adult *S. zeamais* exposed to 2.5, 5.0 and 10.0 x 10^4 ppm of methanolic botanical extracts within five days after treatment

Treatments	Conc. (x 10^4 ppm)	Mean Adult Mortality (% ± S. E.)				
		Days After Treatment (DAT)				
		1	2	3	4	5
E. balsamifera	2.5	50.00 ± 4.08^{b}	72.50 ± 2.50^{b}	87.50 ± 4.79^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	5.0	70.00 ± 4.08^{a}	90.00 ± 5.77^{ab}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	10.0	80.00 ± 4.08^{a}	97.50 ± 2.50^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
L. inermis	2.5	45.00 ± 2.89^{b}	67.50 ± 4.79^{b}	82.50 ± 2.50^{b}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	5.0	60.00 ± 4.08^{ab}	80.00 ± 5.77^{b}	97.50 ± 2.50^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	10.0	70.00 ± 4.08^{a}	92.50 ± 2.50^{ab}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
M. hirtus	2.5	22.50 ± 4.79^{c}	42.50 ± 2.50^{c}	62.50 ± 4.79^{cd}	80.00 ± 4.08^{b}	100.00 ± 0.00^{a}
	5.0	37.50 ± 4.79^{bc}	60.00 ± 4.08^{bc}	80.00 ± 4.08^{b}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	10.0	50.00 ± 4.08^{b}	70.00 ± 2.89^{b}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
S. obtusifolia	2.5	25.00 ± 2.89^{c}	37.50 ± 4.79^{c}	50.00 ± 4.08^{d}	60.00 ± 5.77^{c}	100.00 ± 0.00^{a}
	5.0	27.50 ± 2.50^{c}	45.50 ± 2.89^{c}	60.00 ± 4.08^{cd}	77.50 ± 2.50^{b}	100.00 ± 0.00^{a}
	10.0	32.50 ± 2.50^{bc}	50.00 ± 4.08^{c}	67.50 ± 2.50^{c}	90.00 ± 5.77^{ab}	100.00 ± 0.00^{a}
Control	0.0	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{d}	0.00 ± 0.00^{b}

Conc. = Concentration.

Means in the same column followed by different letter superscript are significantly different at $p<0.05$ by the Bonferroni's Multiple Comparisons Test.

Table 3: Mortality of adult *S. zeamais* exposed to 2.5, 5.0 and 10.0 x 10^4 ppm of ethanolic botanical extracts within five days after treatment

Treatments	Conc. (x 10^4 ppm)	Mean Adult Mortality (% ± S. E.)				
		Days After Treatment (DAT)				
		1	2	3	4	5
E. balsamifera	2.5	65.00 ± 2.89^{bc}	90.00 ± 4.08^{ab}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	5.0	75.00 ± 2.89^{ab}	95.00 ± 2.89^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	10.0	85.00 ± 2.89^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
L. inermis	2.5	55.00 ± 2.89^{c}	77.50 ± 4.79^{b}	97.50 ± 2.50^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	5.0	72.50 ± 2.50^{b}	92.50 ± 2.50^{ab}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	10.0	77.50 ± 2.50^{ab}	95.00 ± 2.89^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
M. hirtus	2.5	67.50 ± 4.89^{bc}	80.00 ± 4.08^{ab}	95.00 ± 2.89^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	5.0	70.00 ± 4.08^{bc}	92.50 ± 4.89^{ab}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	10.0	75.00 ± 2.89^{ab}	95.00 ± 2.89^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
S. obtusifolia	2.5	55.00 ± 2.89^{c}	72.50 ± 2.50^{b}	82.50 ± 2.50^{b}	92.50 ± 2.50^{b}	100.00 ± 0.00^{a}
	5.0	67.50 ± 4.79^{bc}	85.00 ± 2.89^{ab}	95.00 ± 2.89^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
	10.0	70.00 ± 4.08^{bc}	90.00 ± 4.08^{ab}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
Control	0.0	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}

Conc. = Concentration

Means in the same column followed by different letter superscript are significantly different at $p<0.05$ by the Bonferroni's Multiple Comparisons Test.

Table 4: Mortality of adult *S. zeamais* exposed to 2.5, 5.0 and 10.0 x 10^4 ppm of aqueous botanical extracts within 28 days after treatment

Treatments	Conc. (x 10^4 ppm)	Mean Adult Mortality (% ± S. E.)			
		Days After Treatment (DAT)			
		7	14	21	28
E. balsamifera	2.5	10.00 ± 4.08^{b}	32.50 ± 2.50^{bc}	40.00 ± 4.08^{b}	45.00 ± 2.89^{b}
	5.0	20.00 ± 4.08^{b}	42.50 ± 4.79^{ab}	50.00 ± 2.89^{ab}	62.50 ± 2.50^{ab}
	10.0	30.00 ± 0.00^{a}	52.50 ± 4.79^{a}	65.00 ± 2.89^{a}	75.00 ± 2.89^{a}
L. inermis	2.5	5.00 ± 2.89^{b}	20.00 ± 4.08^{b}	37.50 ± 2.50^{b}	42.50 ± 2.50^{b}
	5.0	17.50 ± 2.50^{ab}	35.00 ± 2.89^{b}	45.00 ± 2.89^{b}	60.00 ± 4.08^{ab}
	10.0	25.00 ± 2.89^{ab}	42.50 ± 2.50^{ab}	55.00 ± 2.89^{ab}	70.00 ± 4.08^{ab}
M. hirtus	2.5	5.00 ± 2.89^{b}	15.00 ± 2.89^{c}	27.50 ± 2.50^{bc}	32.50 ± 2.50^{b}
	5.0	12.50 ± 4.79^{ab}	30.00 ± 4.08^{bc}	40.00 ± 0.00^{b}	50.00 ± 4.08^{ab}
	10.0	22.50 ± 2.50^{ab}	42.50 ± 4.79^{ab}	52.50 ± 2.50^{ab}	65.00 ± 2.89^{ab}
S. obtusifolia	2.5	7.50 ± 2.50^{b}	15.00 ± 5.00^{c}	22.50 ± 2.50^{c}	30.00 ± 4.08^{b}
	5.0	20.00 ± 5.77^{ab}	27.50 ± 2.50^{c}	37.50 ± 2.50^{b}	45.00 ± 2.89^{b}
	10.0	22.50 ± 4.79^{ab}	35.00 ± 2.89^{ab}	45.00 ± 2.89^{b}	55.00 ± 2.89^{ab}
Control	0.0	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	5.00 ± 2.89^{c}

Conc. = Concentration

Means in the same column followed by different letter superscript are significantly different at $p<0.05$ by the Bonferroni's Multiple Comparisons Test.

Table 5: LD_{50} and LC_{50} (x 10^4 ppm) of some botanical powders and extracts against adult *S. zeamais* in sorghum

Botanicals	Powders	Methanolic Extracts	Ethanolic Extracts	Aqueous Extracts
	LD_{50} ± S.E.	LC_{50} ± S.E.	LC_{50} ± S.E.	LC_{50} ± S.E.
	DAT			
	7	1	1	7
E. balsamifera	0.674 ± 0.248	0.376 ± 0.714	0.049 ± 0.739	1.410 ± 0.874
L. inermis	0.818 ± 0.245	0.498 ± 0.700	0.236 ± 0.712	1.414 ± 0.989
M. hirtus	1.145 ± 0.235	0.985 ± 0.743	0.154 ± 0.723	1.512 ± 1.036
S. obtusifolia	1.293 ± 0.250	2.261 ± 0.743	0.150 ± 0.701	1.651 ± 0.912

DAT = Days after treatment

4. Discussion

4.1 Mortality effects of the botanicals against adult *S. zeamais*

Findings of this study have revealed that leaves of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* were significantly toxic against adult *S. zeamais*. The plant species resulted in total adult mortality of *S. zeamais* within 12 days after treatment even at lower concentration. This is supported by a report that a high (90.00%) adult mortality of *C. maculatus* was recorded in cowpea seeds treated with leaf powder of *E. balsamifera* at 1.0/ 20 g (w/w) within 96 hours of exposure [28]. The total mortality of *S. zeamais* caused by *L. inermis* leaf powder confirms the previous report that 100% mortality of *T. granarium* exposed to 1, 2, 4 and 6% of the leaf powder was achieved at 14 DAT [17]. Similarly, 77.40% mortality of adult *S. oryzae* was observed after 180 days of treatments with *L. inermis* at 2% concentration in stored wheat [29]. Leaf powder of *L. inermis* was also reported to have caused 33.33% adult mortality of *T. castaneum* in stored groundnuts when applied at 20/ 250 g (w/w) at 14 DAT [30].

Although total mortality was obtained, increase in concentration of powders increased the rate of mortality within the exposure periods. High mortalities of insects exposed to plant powders have the tendency by blocking spiracles of the insect's body, thus impairing respiration leading to the death [31]. Similarly, it was stated that the mortality effects of powders of *O. subscorpioidea*, *A. melegueta* and *Z. officinale* against *S. zeamais* increased with increase in concentration [5]. The mode of action of botanicals is partially attributed to interference in normal respiration that results in suffocation [32]. Other botanical powders such as *A. melegueta*, *M. fragrans*, *P. guineense* and *P. nitida*, resulted in total mortality of *S. zeamais* in maize grains [13, 32]. However, botanical powders from some plant species such as *A. indica*, *D. regia*, *P. glandulosus* and *Z. officinale* caused adult mortalities of *S. zeamais* ranging from less than 10.0 to 88.00% at different concentration [5, 7, 15].

Powders of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* used at the concentrations, 2.5, 5.0 and 10^4 ppm, showed similar toxicity to permethrin powder against adult *S. zeamais*, even though the weevils responded faster in permethrin than the botanical powders. Permethrin has been described as a synthetic pyrethroid that acts by interfering with the electrical signal passing down the axon of insect's nerve cells leading to loss of coordination and ultimate death [33].

The small particle size of leaf powders of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* might have contributed to their efficacy against *S. zeamais* as they could be well coated to the grain surface leading to desiccation, agreeing with a previous report that smaller particle size of *P. glandulosus* could be effective against the weevils through parchedness [34]. Better efficacy of smaller particles of *P. guineense* powder against *S. zeamais* compared to the larger particles was reported elsewhere [35].

In addition to the particle size, shade drying of the botanicals could also have an impact on their mortality effects against the weevils. This was possible because the botanicals might contain all the active ingredients as there might not be photo- and thermo-degradation due to exposure to sunlight [36].

Application of methanolic and ethanolic leaf extracts of all the treatments offered a highly significant effect on adult mortality of *S. zeamais* in stored sorghum by causing total mortality of the weevils within 5 DAT. Total mortality of adult *S. zeamais* in 20 g maize grains treated with 2.0% methanolic extracts of *M. fragrans* and *A. melegueta* at 96 hours after treatment [32].

Ethanolic extracts of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* were found to be highly effective by resulting in total mortality of adults of *S. zeamais* in sorghum grains at all concentrations. The efficacy of the test botanicals is in line with earlier findings that ethanolic extracts of some plant species caused adult mortality of the weevils. Ethanolic extract of *D. regia* seeds applied at 2.0 mg/g maize grains was reported to result in 12.50% adult mortality of *S. zeamais* after five days of exposure [7]. Similarly, application of ethanolic leaf extract of *C. odorata* at 10 ml/50g maize was found to cause 14.00% adult mortality of *S. zeamais* at 7 DAT [37]. The observed increase in mortality of *S. zeamais* caused by ethanolic extracts with increase in post-treatment period in this study agrees with previous findings [7, 37].

Aqueous leaf extracts of the test botanicals exhibited considerable mortality effects against *S. zeamais* with *E. balsamifera* showing the highest upshot. Findings of this work have confirmed the earlier results that aqueous extracts of some plant species resulted in the death of adult *S. zeamais* [38]. The mortality effects of aqueous leaf extracts of *M. azedarach*, *P. dodecandra*, *X. strumarium*, *S. molle*, and *M. piperita* against *S. zeamais* increased with increase in concentration as well as extension of exposure period from 24 to 72 hrs [38]. Aqueous leaf extracts of all the tested plants were less effective than the powders and the other two extracts. This could be due to the fact that some of the bioactive compounds were not soluble in water and therefore remained in the residue, thus reducing effectiveness of the extract.

All the selected botanicals in different formulations were effective against the weevil even at lower concentration. This was possible because plants contain secondary metabolites which are vast repository of compounds such as the steroids, phenolic compounds and tannins with wide range of biological activity which were reported to have great impact on insecticidal activities [39]. Other bioactive compounds such as terpenoids, flavonoids, alkaloids, saponins and glycosides were found in the leaf extracts of *E. balsamifera*, *L. inermis*, and *S. obtusifolia* and are believed to be pesticidal in nature [40-42]. Presence of alkaloids, flavonoids, saponins and tannins, in the powders and methanolic extracts of *M. fragrans* and *A. melegueta* was concluded to be of insecticidal effects against *S. zeamais* [32]. The characteristic smell of *E. balsamifera*, *L.*

inermis, *M. hirtus* and *S. obtusifolia* might have contributed greatly in their insecticidal activity by repelling the insect away from the grains [32].

4.2 LD_{50} and LC_{50} of the test botanicals against *S. zeamais*

The LD_{50} and LC_{50} of the plants showed that leaf powders, methanolic and aqueous extracts of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* had great efficacy by causing 50% adult mortality of *S. zeamais* in stored sorghum even at concentration below the lowest amount used. Findings of this study have shown that *E. balsamifera* was more effective than the other botanicals followed by *L. inermis*. The effectiveness of the selected botanicals in killing adult weevils at lower concentration within short period of time is in conformity with a previous finding that *L. inermis* was highly effective against *T. castaneum* [39]. Good toxicity of methanolic extracts of the botanicals concurs with a report that among methanolic extracts of some plants tested, *Momordica charantia* L. was the most effective with LC_{50} of 2.82 mg/20 g maize grains [43]. It was found that the concentration of ethanolic extracts of *E. balsamifera* needed to kill 50% *S. zeamais* was lower than that of permethrin powder. This means that the methanolic extracts of the botanicals are at par to permethrin.

5. Conclusion

Leaf powders and extracts of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* are toxic against adult *S. zeamais*. All the botanical powders applied at varying concentrations of 2.5, 5.0 and 10.0 x 10^4 ppm were as effective as permethrin powder when the exposure period was prolonged to 12 days. It was also found that methanolic and ethanolic extracts resulted in total mortality after five days of treatment. The aqueous extracts caused a relatively lower mortality than powders and methanolic extracts, though a promising result was obtained when the exposure period was extended to 28 DAT.

The lethal dose (LD_{50}) and lethal concentration (LC_{50}) of the botanicals were found to be either lower than or within the range of recommended dose/concentration (1-5%) of botanical powers in stored commodity. It is established that application of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* at the lowest concentration of 2.5 x 10^4 ppm could cause the death of 50% *S. zeamais* within one to seven days. This study has also found that *E. balsamifera* was the most effective botanical, while *S. obtusifolia* was the least. Further research on the toxicity of the botanicals against other insect pests and mammals is recommended. Studies on isolation and identification of active ingredients of the botanicals should also be carried out.

6. Acknowledgement

The authors are grateful to the Head, Department of Biology, Umaru Musa Yar'adua University, Katsina, for providing laboratory facilities.

7. References

1. Ismaila U, Gana AS, Tswanya NM, Dogara D. Cereals production in Nigeria: Problems, constraints and opportunities for betterment. African Journal of Agricultural Research. 2010; 5(12):1341-1350.
2. NAERLS. Prospects and problems of the 1996 cropping season. A Report of a Study Conducted by the National Agricultural Extension Research and Liaison Service (NAERLS) and Agricultural Planning Monitoring and Evaluation Unit (APMEU). Ahmadu Bello University, Zaria. 1996, 62.
3. Mofokeng MA. Control strategies and breeding efforts in sorghum for resistance to storage weevils. African Journal of Agricultural Research. 2016; 11(33):3065-3073.
4. FAO. Food and agricultural commodities production. FAOSTAT. Food and Agriculture Organization of the United Nations, 2013. http://faostat.fao.org/site/339/default.aspx.
5. Oni MO, Ogungbite OC. Entomotoxicant potential of powders and oil extracts of three medicinal plants in the control of *Sitophilus zeamais* infesting stored maize. Journal of Plant and Pest Science. 2015; 2(1):8-17.
6. Wini GJ, Nukenine EC, Ndjonka D, Suh C, Cornel A. Efficacy of diatomaceous earth and wood ash for the control of *Sitophilus zeamais* in stored maize. Journal of Entomology and Zoology Studies. 2015; 3(5):390-397.
7. Ajayi OE. Insecticidal activity of powder and extracts of *Delonix regia* seed against maize weevil, *Sitophilus zeamais* (Coleoptera: Curculionidae). FUTA Journal of Research in Sciences. 2013; 1:54-62.
8. Suleiman M. Efficacy of some spices as sorghum grain protectants against *Sitophilus zeamais* Motschulsky [Coleoptera: Curculionidae]. African Journal of Agricultural Research. 2014; 9(9):841-845.
9. Zhi LL, Na NZ, Chun ML, Ligang Z, Shu SD. Identification of insecticidal constituents of the essential oil of *Curcuma wenyujin* rhizomes active against *Liposcelis bostrychophila* Badonnel. Molecules. 2012; 17:12049-12060.
10. Ogendo JO, Deng AL, Belmain SR, Walker DJ, Musandu AAO. Effects of insecticidal plant materials, *Lantana camara* L. and *Tephrosia vogelii* Hook, on the quality parameters of stored maize grains. The Journal of Food Technology in Africa. 2004; 9(1):29-35.
11. Rotimi J, Evboumwan CO. Deterrent effects of citrus peel oils on oviposition and adult emergence of cowpea weevil, *Callosobruchus maculatus* (F) (Coleoptera: Bruhidae). Advances in Applied Science Research. 2012; 3(6):3545-3550.
12. Midega CAO, Murage AW, Pittchar JO and Khan ZR. Managing storage pests of maize: Farmers' knowledge, perception and practices in western Kenya. Crop Protection. 2016; 90:142-149. http://dx.doi.org/10.1016/j.cropro.2016.08.033.
13. Ojo DO, Ogunleye RF. Comparative effectiveness of the powders of some underutilized botanicals for the control of *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae). International Journal of Pure and Applied Sciences and Technology. 2013; 16(2):55-62.
14. Rugumamu CP. Insecticidal activity of botanical pesticides on *Callosobruchus chinensis* (L.) (Coleoptera: Bruchidae) in stored green gram, *Vigna radiate* (L). International Journal of Agricultural Research. 2015; 4(1):013-020.
15. Tilahun FE, Daniel DH. Effect of neem leaf and seed powders against adult maize weevil (*Sitophilus zeamais* Motschulsky) mortality. International Journal of Agricultural Research. 2016; 11:90-94.
16. Oni MO, Ogungbite OC, Bello FO. Biotoxic efficacy of two horticultural plants against infestation of *Sitophilus oryzae* on stored maize. Leonardo Journal of Sciences. 2016; 28:109-122.
17. Al-Moajel NH. Testing some various botanical powders

for protection of wheat grain against *Trogoderma granarium* Everts. Journal of Biological Sciences. 2004; 4(5):592-597.
18. Arya M, Tiwari R. Efficacy of plant animal origin bioproducts against lesser grain borer, *Rhyzopertha dominica* (Fab.) in stored wheat. International Journal of Recent Scientific Research. 2013a; 4**(**5):649-653.
19. Jose AR, Adesina JM. Oviposition, infestation deterrent and phytochemical screening of *Heliotrpium indicum* and *Lawsonia inermis* against *Callosobruchus maculatus* Fabricius (Coleoptera: Chrysomelidae) on cowpea seeds. International Journal of Molecular Zoology. 2014; 4(1):1-8.
20. Goftishu M, Belete K. Susceptibility of sorghum varieties to the maize weevil *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). African Journal of Agricultural Research. 2014; 9(31):2419-2426. DOI: 10.5897/AJAR2014.8634.
21. Parugrug AM, Roxas C. Insecticidal action of five plants against maize weevil, *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae). KMITL Science and Technology Journal. 2008; 8(1):24-38.
22. Khaliq A, Nawas A, Ahmad NH, Sagheer M. Assessment of insecticidal potential of medicinal plant extracts for control of maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). Basic Research Journal of Agricultural Science and Review. 2014; 3(11):100-104.
23. Abou-Elnaga ZS. Efficacy of extracts of some Egyptian plants against economically important stored grains pest *Sitophilus oryzea* L. Journal of Entomology and Zoology Studies. 2015; 3(1):87-91.
24. Dales MJ. A review of plant materials used for controlling insect pests of stored products [Working Paper]. NRI Bulletin. 1996, 91.
25. Mutambuki M, Ngatia CM. Assessment of grain damage and weight loss on farm stored maize in highlands areas of Bungoma District, Kenya. Journal Agricultural Science and Technology. 2012; B(2):349-361.
26. Muzemu S, Chitamba J, Mutetwa B. 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):196-201.
27. de Oliveira TA, Ronche-Teles B, da Fonseca CRV, da Silva SLR, Santos PA, Nunez CV. Insecticidal activity of *Vitex cymosa* (Lamiaceae) and *Eschweilera pedicellata* (Lecythidaceae) extracts against *Sitophilus zeamais* adults (Coleoptera: Curculionidae). Emirates Journal of Food and Agriculture. 2012; 24(1):49-56.
28. Suleiman M, Suleiman HY. Control of *Callosobruchus maculatus* (F.) [Coleoptera: Bruchidae] using leaf powders of *Euphorbia balsamifera* L. and *Lawsonia inermis* L. International Journal of Science, Environment and Technology. 2014; 3(1):100-109.
29. Arya M, Tiwari R. Efficacy of some indigenous bioproducts against rice weevil, *Sitophilus oryzae* (Linn.) on wheat. Indian Journal of Applied Research. 2013b; 3(6):13-15.
30. Joel OO. Efficacy of plant extracts against *Tribolium castaneum* Herbst in stored groundnut (*Arachis hypogaea* L.). African Journal of Plant Science. 2015; 9(2):90-96.
31. Mulungu LS, Lupenza G, Reuben SOWM, Misangu RN. Evaluation of botanical products as stored grain protectant against maize weevil, *Sitophilus zeamais* on maize. Journal of Entomology. 2007; 4(3):258-262.
32. Ileke KD, Adesina JM, Obajulaye EO. Synergic effects of two botanical entomocides as pest- protectants in maize grains. Journal of Biological Research. 2016; 89:34-39.
33. Golob P, Birkinshow LA, Starthers TE, Meyer AN, Belmain SR, Farrell G, Hodges RJ. Pest Management. In: Golob P, Farrell G, Orchard JE (eds.) Crop Post-Harvest: Science and Technology, Volume 1. Blackwell Science Ltd. 2002, 566.
34. Nukenine EN, Chouka FP, Vabi MB, Reichmuth C, Adler C. Comparative toxicity of four local botanical powders to *Sitophilus zeamais* and influence of drying regime and particle size on insecticidal efficacy. International Journal of Biological and Chemical Sciences. 2013; 7(3):1313-1325.
35. Asawalam EF, Emosairue SO. Comparative efficacy of *Piper guineense* (Schum and Thonn) and pirimiphos methyl as poison against *Sitophilus zeamais* (Motsch.). Electronic Journal of Environmental, Agricultural and Food Chemistry. 2006; 5(5):1536-1545.
36. Ilboudo Z, Dabire LCB, Nebie RCH, Dicko IO, Dugravot S, Cortesero AM, Sanon IO. Biological activity and persistence of four essential oils towards the main pest of stored cowpeas, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). Journal of Stored Products Research. 2010; 46:124-128.
37. Ibrahim YJ, Abugri AD, Afun JVK. Efficacy of ethanolic leaf extract of *Chromolaena odurata* in controlling *Sitophilus zeamais* in stored maize. Journal of Experimental Agriculture International. 2016; 14(5):1-10.
38. Yohannes A, Asayew G, Melaku G, Derbew M, Kedir S, Raja N. Evaluation of certain plant leaf powders and aqueous extracts against maize weevil, *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae). Asian Journal of Agricultural Sciences. 2014; 6(3):83-88.
39. Biswas KK, Sharmin N, Rabbi MA. Evaluation of the insecticidal activity of *Lawsonia inermis* Linn. Against the red flour beetle, *Tribolium castaneum* (Herbst). Natural Products. 2016; 12(1):8-11.
40. Doughary JH, El-Mahmood AM, Tyoyina I. Antimicrobial activity of leaf extracts of *Senna obtusifolia* (L.). African Journal of Pharmacy and Pharmacology. 2008; 2(1):007-013.
41. Kamba AS, Hassan LG. Phytochemical screening and antimicrobial activities of *Euphorbia balsamifera* leaves, stems and root against some pathogenic microorganisms. African Journal of Pharmacy and Pharmacology. 2010; 4(9):645-652.
42. Wagini NH, Soliman AS, Abbas MS, Hanafy YA, Badawy EM. Phytochemical analysis of Nigerian and Egyptian henna (*Lawsonia inermis* L.) leaves using TLC, FTIR and GCMS. Plant. 2014; 2(3):27-32.
43. Rani PU, Devanand P. Efficiency of different plant foliar extracts on grain protection and seed germination in maize. Research Journal of Seed Science. 2011; 4(1):1-14.