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Use of botanicals to suppress the development of maize weevil, Sitophilus zeamais Motsch. (Coleoptera: Curculionidae) in stored sorghum grains

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Abstract: *Laboratory experiments were conducted in order to investigate the potentiality of botanicals from Euphorbia balsamifera Aiton, Lawsonia inermis L., Mitracarpus hirtus and Senna obtusifolia in suppressing the development of Sitophilus zeamais Motsch. in stored sorghum grains. Twenty sorghum grains were randomly taken from each container with varying concentrations of 2.5, 5.0 and 10.0 x 10^4 ppm of leaf powders and methanolic, ethanolic and aqueous extracts of each of the botanicals separately 14 days after introducing the weevils. The grain samples were soaked in warm water and then immersed in acid fuchsin. The stained grains were rinsed with water, air-dried and viewed under Photo micrographic microscope. Percentage oviposition deterrence (POD), inhibition rate (IR) in adult emergence and developmental periods of S. zeamais were determined. Highest (94.68 ± 2.68%) POD was recorded in 10.0 x 10^4 of ethanolic extracts of E. balsamifera, while the least (56.25 ± 2.44%) was in 2.5 x 10^4 of S. obtusifolia powders. All the botanicals in the form of powders and extracts resulted in complete inhibition in adult emergence of S. zeamais except aqueous extracts where the IR ranged between 89.41 ± 0.42 and 96.77± 0.30%. No developmental periods were recorded in treatments of powders, methanolic and ethanolic extracts due to non-emergence of F_1 progenies. However, the developmental period in aqueous extracts ranged from 50.25 ± 0.25 to 54.00 ± 0.41. The test botanicals have demonstrated their ability of suppressing S. zeamais development in stored sorghum and could be utilized to protect sorghum grains during storage.*

***Keywords*:** *Botanicals, Developmental periods, Adult emergence, Oviposition deterrence, Sitophilus zeamais*

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I. Introduction

Sorghum is the primary food crop in virtually all parts of northern Nigeria [1]. Boiled sorghum is one of the simplest traditional food preparations of the grain. The whole grain may be ground into flour which is then used in various traditional dishes [2].The food situation has remained unsecured in sub-Saharan Africa, where more than 50% of the populations earn their livelihood from agriculture, leading to high levels of cyclic famine and poverty [3]. The major cause of food insecurity is grain loss during storage caused mainly by insect pests and S. zeamais is one of the most destructive insect pests on sorghum grain.S. zeamais has been reported as a primary pest that attacks whole grains with moisture content of 10.5% and above [4]. Grains with less than 10% moisture are not attacked by S. zeamais [5]. The developmental and feeding activities of the weevils often lead to severe powdering and tainting of the grain with their excrements [6]. The infested grains are also rendered susceptible to cracking and mould infection as a result of respiration of the weevils that heats the grain and drives water vapour to other areas where it condenses to wet the grain thereby reducing their market value [7. 8]. It was explained that an attacked grain losses agronomic, nutritional and economic value, since it could not be sold or sown [9]. S. zeamais has been identified as a serious pest causing a greater weight loss of maize which could probably be explained by feeding behavior and type of mouthparts of the insect [10].Eggs of S. zeamais are laid throughout most of the adult life, with up to 150 eggs laid per female. The eggs are laid individually in small cavities chewed into cereal grains by the female and then seals the cavity with a waxy secretion (egg plug), which effectively protects the eggs [11]. The larva is white, grub-like and aphodous, which begins to feed inside the grain, excavating a tunnel as it develops [12]. Pupation occurs within the kernel, and under optimal conditions of 27 to 31^{o}C and 40 to 75% R.H., the maize weevil's life cycle takes 5 to 8 weeks to complete [13, 14]. While [15] recorded the mean developmental period of S. zeamais ranging between 33 and 35 days at the mean temperature of 26 ± 2^{o}C, [7] recorded the total developmental period of S. zeamais as 39

days at 28°C. The optimum temperature for development ranges from 26°C to 30°C [5]. The total developmental period of S. zeamais was also reported to have ranged from 35 days under optimum conditions to over 110 days in unfavourable conditions [12].In order to understand proper way for management of S. zeamais in stored grains, researchers worked on the use of botanicals to suppress the development of the weevils. Some of the tested botanicals were oviposition deterrents, some inhibited adult emergence and some delayed the developmental periods of the insects. Application of Citrullus vulgaris Schrad at 3.0 g/ 50 g maize grains was reported to have reduced the number of eggs laid by S. zeamais from 25.5 to 1.25 and concluded that botanical powders could be used to deter egg-laying by female S. zeamais [16]. Oviposition deterrence of was tested on C. maculatus by [17] and reported that leaf powder of L. inermis deterred 54.26% egg deposition on cowpea seeds. The number of eggs laid by S. zeamais reduced from 36.25 ± 2.27 to 8.00 ± 0.91 in aqueous stem bark extracts of Alstonia boonei De Wild applied at 0.4 ml / 20 g maize grains was reported by [18].Little is known about the ability of E. balsamifera, L. inermis, M. hirtus and S. obtusifolia in inhibiting adult emergence of S. zeamais in sorghum grains. However, the suppressing activity in adult emergence of L. inermis was recorded against C. maculatus with inhibition rate of 45.76% when applied at 5% concentration [19]. Inhibition rate in adult emergence of S. zeamais in stored maize treated with botanical powders of Zingiber officinale, Olax subscorpiodea and Aframomum melegueta ranged from 28.76 ± 0.33 to 94.13 ± 1.06% [20]. Similarly, [16] recorded only 0.50 adults of S. zeamais in maize grains treated with cotyledon powder of C. vulgaris at the rate of 3.0 g / 50 g, while there were 29.50 in the control, at 21 days after treatment.Several investigations on botanical control of S. zeamais did not address their influence in the developmental periodof S. zeamais [18, 20, 21, 22, 23, 24].Although a lot of plant species have been tested as stored grain protectants against S. zeamais, there is scanty information about the utilization of E. balsamifera, L. inermis, M. hirtus and S. obtusifolia to suppress insect pests' development in stored sorghum and other cereals. This study was therefore aimed at investigating effects of the botanicals in suppressing the development of S. zeamais in order to reduce its infestation to stored sorghum.

II. Materials And Methods

2.1 Mass rearing of S. zeamais:

Fifty pairs of S. zeamais were introduced into each of rearing bottles containing 250 g of disinfested sorghum grains which served as parent stock. The bottles were covered with muslin cloth and secured with rubber bands [25]. The bottles were then kept an incubator for oviposition at 30 ± 2°C and 70 ± 5% R.H. for 14 days, after which the parents were removed. The bottles were maintained in the incubator under the same condition for emergence of new adult weevils which were used bioassay.

2.2 Preparation of the botanicals:

Fresh leaves of E. balsamifera, L. inermis, M. hirtus and S. obtusifolia were collected from an uncultivated area around Umaru Musa Yar'adua University, Katsina (UMYUK), Nigeria. The leaves were rinsed with distilled water and shade-dried at room temperature for 14 days. The dried leaves were ground into powder using a laboratory blender and sieved into fine powder.One hundred gram of each of the plant powders was dissolved in 400 ml of methanol, ethanol and distilled water, separately, in conical flasks. Mouth of the flasks 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. The filtrate was separately concentrated by evaporating excess solvents using rotary evaporator with rotary speed of 3 to 6 rpm for 8 hours. The resulting extracts were air-dried to remove traces of the solvent and stored in refrigerator at 4°C [26].

2.3 Determination of number of eggs deposition by S. zeamais:

Four replicates of 2.5, 5.0 and 10.0 x 10^4 ppm of each leaf powder of E. balsamifera, L. inermis, M. hirtus and S. obtusifolia along with 0.056 x 10^4 ppm of permethrin powder were admixed separately with 20 g of disinfested sorghum grains in 250 ml plastic bottles. The control contained grains only without any powder [27]. Five pairs of 1-7 day old adult weevils were introduced into each of the bottles, covered with muslin cloth, tied with rubber bands and placed in an incubator at 30 ± 2°C and 70 ± 5% R.H. Similar set-ups were made for methanolic, ethanolic and aqueous extracts of the botanicals where 2 ml of each of the extracts at 2.5, 5.0 and 10.0 x 10^4 ppm was added to the grains separately. Those grains mixed with methanol, ethanol and distilled water only served as controls. Twenty sorghum grains were randomly taken from each container 14 days after introducing the weevils. The grain samples were soaked in warm water for 2 minutes and immersed in acid fuchsin for another 2 minutes. The stained grains were rinsed with water and air-dried. They were then viewed under photo-micrographic microscope. Presence of cherry red egg plugs indicated the presence of eggs. The plugs were counted and recorded.

The percentage of oviposition deterrence (POD) was calculated by the following formula [28]:

$$POD = \frac{E_C - E_t}{E_C} \times 100$$

Where:
POD = Percentage of oviposition deterrence;
E_c = Number of eggs laid in control grain; and
E_t = Number of eggs laid in treated grain.

2.4 Adult emergence of S. zeamais:

The set-ups for oviposition test were maintained in the incubator undisturbed until emergence of F_1 progenies. Grains were inspected daily and the emerging progenies from each bottle were removed, counted and recorded. Observation continued for 49 days after which it was stopped in order to avoid overlapping of generations. Inhibition rate (IR) in adult emergence was calculated using the methods of [29] as shown hereunder:

$$IR = \frac{C_n - T_n}{C_n} \times 100$$

Where:
IR = Inhibition rate in adult emergence;
C_n = Number of insects that emerged in the control; and
T_n = Number of insects that emerged in the treated grains.

2.5 Determination of developmental periods of S. zeamais:

The developmental periods of the weevils were then estimated as median time (days) from the middle of the oviposition period to the emergence of 50% of the offspring in all the treated and untreated sorghum grains [30].

2.6 Statistical analysis:

Graph Pad Prism (version 7.03) was used to analyze all data obtained from this study. Analysis of variance (ANOVA) was employed to test if POD, IR (%) in adult emergence and developmental periods of S. zeamais were significantly different among the botanical treatments at the three concentrations of 2.5, 5.0 and 10.0 x 10^4 ppm. Significantly different means were separated using Bonferroni's multiple comparisons test. All analyses were carried out at $p < 0.05$.

III. Results

3.1 Oviposition deterrence of botanicals against S. zeamais in stored sorghum:

3.1.1 Oviposition deterrence of botanical powders against S. zeamais:

Application of botanical powders of E. balsamifera, L. inermis, M. hirtus and S. obtusifolia at 2.5, 5.0 and 10.0 x 10^4 ppm has caused variations in the number of egg plugs made by S. zeamais in sorghum grains after 14 days of introduction (Table 1). Grains treated with 2.5 x 10^4 ppm of E. balsamifera had 5.50 ± 0.65 mean number of egg plugs with percentage oviposition deterrence (POD) of 78.64 ± 2.51%. The mean number of egg plugs and POD recorded in grains treated with 5.0 x 10^4 ppm of the botanical powder were 4.00 ± 0.41 and 84.47 ± 1.59, respectively. At 10.0 x 10^4 ppm of E. balsamifera leaf powder, there were 3.00 ± 0.41egg plugs and 88.25 ± 1.58 as POD.The number of egg plugs and POD recorded in grains treated with L. inermis at 2.5 0 x 10^4 ppm were 7.75 ± 0.63 and 69.90 ± 2.44%, respectively. This was followed by 6.00 ± 0.41 and 76.70 ± 1.58% at 5.0 x 10^4 ppm and 4.25 ± 0.25 egg plugs with 83.50 ± 0.97 POD at 10.0 x 10^4 ppm.The highest number of egg plugs in grains treated with M. hirtus was 9.50 ± 0.65 in 2.5 x 10^4 ppm and the least was 7.00 ± 0.41 in 10.0 x 10^4 ppm. Consequently, the highest POD was in 10.0 x 10^4 ppm and the least was in grains treated with 2.5 x 10^4 ppm of the botanical powder.

Grains treated with S. obtusifolia contained varying number of egg plugs made by the weevil. At 2.5 x 10^4 ppm of the botanical, the number of egg plugs was 10.75 ± 0.63 with POD of 56.25 ± 2.44. Increase in concentration of the powder to 5.0 x 10^4 ppm reduced the number of egg plugs and increased POD to 9.00 ± 0.41 and 65.05 ± 1.58, respectively. At 10.0 x 10^4 ppm, the recorded egg plugs were 7.75 ± 0.48 and the POD was 69.91 ± 1.86. The mean number of egg plugs made by S. zeamais in grains treated with permethrin at 0.056 x 10^4 ppm was 0.25 ± 0.25 and the POD was 99.03 ± 0.97. There were 25.75 ± 0.85 egg plugs within 14 days after induction of the weevils with no POD in the untreated grains.Two-way ANOVA showed that there was significant difference between treatments in number of egg plugs made by S. zeamais, $F(5, 15) = 388.40$, $p < 0.0001$. Also, the number of egg plugs was highly significant, $F(2, 6) = 56.15$, $p = 0.0001$, among varying concentrations of the botanical powders.

Bonferroni's multiple comparisons test showed that the numbers of egg plugs among the three concentrations of each botanical were different. Also the number of egg plugs in grains treated with 2.5 x 10^4 ppm of E. balsamifera and L. inermis were the same and fewer than those in M. hirtus and S. obtusifolia. Also POD among the botanical powders was highly significantly different, $F(5, 15) = 929.40$, $p < 0.0001$. POD of permethrin was different from those of the botanical powders (Table 1).

3.1.2 Oviposition deterrence of methanolic botanical extracts against S. zeamais:

The numbers of egg plugs of S. zeamais in grains treated with methanolic leaf extract of E. balsamifera, L. inermis, M. hirtus and S. obtusifolia at the concentrations of 2.5, 5.0 and 10.0 x 10^4 ppm after 14 days of treatment are contained in Table 2. The number of egg plugs in grains treated with E. balsamifera at 2.5 x 10^4 ppm was 4.25 ± 1.89 with POD as 81.94 ± 4.04. Grains with 5.0 x 10^4 ppm of the botanical had 3.25 ± 0.96 egg plugs and 86.17 ± 2.04 POD, but at 10.0 x 10^4 ppm the number of egg plugs and POD were 1.25 ± 1.26 and 94.68 ± 2.68.In grains treated with L. inermis, the mean numbers of egg plugs made by the weevils were 5.75 ± 2.50, 6.50 ± 1.73 and 7.50 ± 1.29 at 2.5, 5.0 and 10.0 x 10^4 ppm and the POD of the botanical were recorded as 68.09 ± 2.75, 72.34 ± 3.69 and 75.53 ± 5.32.The number of egg plugs made by S. zeamais in grains mixed with M. hirtus was 8.25 ± 3.59 at 2.5 x 10^4 ppm, 4.75 ± 3.59 at 5.0 x 10^4 ppm and 4.25 ± 2.22 at 10.0 x 10^4 ppm. POD of the botanical extract was highest (81.91 ± 4.72) in 10.0 x 10^4 ppm and the lowest (64.89 ± 7.65) was recorded in 2.5 x 10^4 ppm treatments.The highest number of egg plugs of S. zeamais was 9.75 ± 0.96 in 2.5 x 10^4 ppm of S. obtusifolia, while he least (4.75 ± 0.50) was observed in 10.0 x 10^4 ppm. The POD of the botanical ranged from 58.51 ± 2.04 at 2.5 x 10^4 ppm to 79.79 ± 1.07 at 10.0 x 10^4 ppm. The untreated grains had 23.50 ± 1.92 egg plugs without any POD.There was highly significant difference, $F(4, 12) = 104.60$, $p < 0.0001$ in number of egg plugs in grains treated with methanolic extracts of the botanicals applied at the 2.5, 5.0 and 10.0 x 10^4 ppm.Bonferroni's multiple comparisons indicated that the numbers of egg plugs in grains treated with 2.5 x 10^4 ppm of L. inermis, M. hirtus and S. obtusifolia were the same and higher than those from E. balsamifera at the same concentration. At 5.0 x 10^4 ppm, mean numbers of egg plugs in E. balsamifera and M. hirtus were the same and lower than those of L. inermis and S. obtusifolia at the same concentration. Furthermore, the multiple comparisons test showed that the mean number of egg plugs at 10.0 x 10^4 ppm of the methanolic extracts of E. balsamifera was lower than the rest. This also shows that the mean POD of E. balsamifera at 10.0 x 10^4 ppm was higher than those from L. inermis, M. hirtus and S. obtusifolia at all the concentrations of 2.5, 5.0 and 10.0 x 10^4 ppm (Table 2).Two-way ANOVA showed that the difference in POD among the methanolic extracts of the botanicals was highly significant, $F(4, 12) = 197.70$, $p < 0.0001$. Similarly, a significant difference, $F(2, 6) = 13.51$, $p = 0.0060$, in POD exist among the varying concentrations, 2.5, 5.0 and 10.0 x 10^4 ppm of the methanolic extracts applied.

3.1.3 Oviposition deterrence of ethanolic botanical extracts against S. zeamais:

Table 3 shows that the number of egg plugs in grains treated with ethanolic extracts of E. balsamifera, L. inermis, M. hirtus and S. obtusifolia followed similar pattern to that of botanical powders and methanolic extracts. The number of egg plugs in grains treated with ethanolic extracts of E. balsamifera at 2.5 x 10^4 ppm was 3.75 ± 0.48 with POD of 84.85 ± 1.93. Grains treated with 5.0 x 10^4 ppm of the botanical had 2.00 ± 0.41egg plugs and POD of 91.92 ± 1.65 and at 10.0 x 10^4 ppm the number of egg plugs and POD were 1.50 ± 0.29 and 93.94 ± 1.17.In grains treated with L. inermis, the mean numbers of egg plugs made by the weevils were 5.25 ± 0.48, 3.50 ± 0.29 and 2.75 ± 0.25 at 2.5, 5.0 and 10.0 x 10^4 ppm, respectively, while the corresponding POD of the botanical were recorded as 78.79 ± 1.93, 85.86 ± 1.17 and 88.89 ± 1.01.The number of egg plugs by S. zeamais in ethanolic extracts treatments of M. hirtus was 6.75 ± 0.48 at 2.5 x 10^4 ppm, 5.75 ± 0.48 at 5.0 x 10^4 ppm and 4.75 ± 0.48 at 10.0 x 10^4 ppm (Table 3). The POD of the botanical extract was highest (80.81 ± 1.93) in 10.0 x 10^4 ppm and the least (72.78 ± 2.07) was recorded in 2.5 x 10^4 ppm treatments. The highest number of egg plugs of S. zeamais in grains treated with ethanolic extracts of S. obtusifolia was 10.00 ± 0.41 at 2.5 x 10^4 ppm, while he least (5.25 ± 0.48) was in 10.0 x 10^4 ppm. POD of the botanical varied between 59.60 ± 1.65 and 78.79 ± 1.93. The mean number of egg plugs in the untreated grains was 24.75 ± 0.85 and the POD was recorded as zero.Two-way ANOVA showed that the difference in mean numbers of egg plugs in sorghum grains treated with different ethanolic botanical extracts at the concentrations of 2.5, 5.0 and 10.0 x 10^4 ppm was highly significant, $F(4, 12) = 421.90$, $p < 0.0001$.Bonferroni's multiple comparisons test indicated that the mean number of egg plugs in grains treated with 2.5 x 10^4 ppm of E. balsamifera was lower than those from the other botanicals at the same concentration, the numbers of egg plugs in grains treated with M. hirtus and S. obtusifolia at 5.0 x 10^4 ppm were statistically the same and higher than those from E. balsamifera and L. inermis at the same concentration. Additionally, the mean numbers of egg plugs in grains treated with 10.0 x 10^4 ppm of E. balsamifera and L. inermis were the same and lower than those of M. hirtus and S. obtusifolia. Untreated grains had higher number of egg plugs than the treated ones (Table 3).There was highly significant difference in

POD, F (4, 12) = 2575.00, $p < 0.0001$, among the ethanolic leaf extracts of all the botanicals. The multiple comparisons test revealed similar trend to that of the number of egg plugs.

3.1.4 Oviposition deterrence of aqueous botanical extracts against S. zeamais:

The numbers of egg plugs on grains treated with E. balsamifera were 6.75 ± 0.48, 5.75 ± 0.48 and 4.75 ± 0.48 at the three concentrations of 2.5, 5.0 and 10.0 x 10^4 ppm, respectively, as presented in Table 4. The corresponding PODs were 73.53 ± 1.88, 77.45 ± 1.88 and 81.70 ± 1.88.The number of egg plugs and POD in grains treated with L. inermis was 8.25 ± 0.48 and 67.65 ± 1.88 at 2.5 x 10^4 ppm. At 5.0 x 10^4 ppm, there were 6.25 ± 0.48 egg plugs and the corresponding POD was 75.49 ± 1.88. The highest concentration of 10.0 x 10^4 ppm reduced the number of egg plugs to 5.50 ± 0.29 with the corresponding POD 76.47 ± 2.77.The mean numbers of egg plugs in grains treated with M. hirtus 2.5, 5.0 and 10.0 x 10^4 ppm were 6.50 ± 0.65, 5.50 ± 0.29 and 5.00 ± 0.41, respectively and equivalent PODs were 74.56 ± 2.49, 78.43 ± 1.13 and 80.39 ± 1.60. There were 8.25 ± 0.48, 7.50 ± 0.65 and 5.50 ± 0.65 egg plugs in grains treated with 2.5, 5.0 and 10.0 x 10^4 ppm of S. obtusifolia. The POD was 67.65 ± 1.88 at 2.5 x 10^4 ppm, 70.59 ± 2.53 at 5.0 x 10^4 ppm and 78.43 ± 2.53 at 10.0 x 10^4 ppm.The number of egg plugs in aqueous extracts and differed significantly, F (4, 12) = 886.80, $p < 0.0001$, among the treatments. Similarly, the difference in PODs among the botanicals was highly significant, F (4, 12) = 263.20, $p < 0.0001$.Bonferroni's multiple comparisons test indicated that, the mean numbers of egg plugs in grains treated with 2.5, 5.0 and 10.0 x 10^4 ppm of aqueous extracts were higher than those in the untreated grains. PODs of E. balsamifera and M. hirtus at 2.5 x 10^4 ppm were the same and higher than those of L. inermis and S. obtusifolia at the same concentration. All the botanicals at 10.0 x 10^4 ppm were the same but lower than that of 2.5 x 10^4 ppm.

3.2 Emergence of Adult S. zeamais in stored sorghum grains treated with the botanicals:

There was no emergence of adult S. zeamais in sorghum grains treated with the botanical powders and methanolic and ethanolic extracts of E. balsamifera, L. inermis, M. hirtus and S. obtusifolia within 12 weeks after they were introduced. However, the numbers of emerged weevils in respective untreated grains were 162.50 ± 1.85, 165.80 ± 4.13 and 156.80 ± 5.41, respectively. However, botanical powders, methanolic and ethanolic extracts of all the botanicals at the three concentrations of 2.5, 5.0 and 10.0 x 10^4 ppm and permethrin at 0.056 x 10^4 ppm resulted in total (100%) inhibition rate in adult emergence of S. zeamais in sorghum grains (Tables 1, 2 and 3).There were varying numbers of emerged weevils in grains treated with aqueous extracts of the test botanicals at different concentrations. The number of F_1 progeny in grains treated with aqueous leaf extract of E. balsamifera at 2.5 x 10^4 ppm was 8.50 ± 0.50 and at 5.0 and 10.0 x 10^4 ppm 5.50 ± 0.50 with corresponding Inhibition rate (IR) as 95.00 ± 0.29 and 96.77 ± 0.30% (Table 4). The numbers of adults that emerged from grains treated L. inermis were 10.00 ± 1.47, 6.50 ± 0.65 and 5.50 ± 0.87 at 2.5, 5.0 and 10.0 x 10^4 ppm, respectively. The IR in adult emergence in grains treated with L. inermis ranged from 94.12 ± 0.87 to 96.77 ± 0.51%.Sorghum grains treated with M. hirtus recorded 16.00 ± 1.47, 11.75 ± 0.25 and 7.25 ± 0.75 individuals at 2.5, 5.0 and 10.0 x 10^4 ppm with related IR of 90.59 ± 0.87, 93.09 ± 0.15 and 95.74 ± 0.44%. The numbers of weevils emerging from treatments made with S. obtusifolia were 18.00 ± 0.71 at 2.5 x 10^4 ppm, 11.75 ± 0.25 at 5.0 x 10^4 ppm and 9.25 ± 0.85 at 10.0 x 10^4 ppm and the IR of 89.41 ± 0.42 to 94.56 ± 0.50%. The untreated grains had 170.00 ± 4.60 F_1 without any IR. This was observed to be in the order E. balsamifera < L. inermis < M. hirtus < S. obtusifolia.Two-way ANOVA showed that there was a highly significant difference in the numbers of emerged adults of S. zeamais among grains treated with aqueous extracts of the botanicals at 2.5, 5.0 and 10.0 x 10^4 ppm, F (4, 12) = 1182.00, $p < 0.0001$. The Bonferroni's multiple comparisons test indicated that the mean numbers of adults that emerged in E. balsamifera and L. inermis at all concentrations were the same and lower than those in M. hirtus and S. obtusifolia at 2.5 and 5.0 x 10^4 ppm. The test also indicated that adult emergence in the control was different from all the botanicals at all the concentrations.The difference in IR in adult emergence of S. zeamais among the grains treated with aqueous botanical extracts was highly significant, F (4, 12) = 22619.00, $p < 0.0001$.

3.3 Developmental periods of S. zeamais in stored sorghum grains treated with various botanicals:

No developmental period of S. zeamais was observed in grains treated with powders, methanolic and ethanolic extracts of the test plants and permethrin powder due to non- emergence of adults in the treatments presented above. However, the developmental periods in their respective controls were 40.25 ± 0.63, 41.00 ± 0.71 and 39.00 ± 0.41 days (Tables 1, 2 and 3).Table 4 shows longer developmental periods of S. zeamais in grains treated with aqueous extracts of E. balsamifera at 2.5, 5.0 and 10.0 x 10^4 ppm than in the other botanicals and varied from 50.25 ± 0.25 to 54.00 ± 0.41 days. This was followed by L. inermis at 2.5, 5.0 and 10.0 x 10^4 ppm where 51.00 ± 0.41, 51.75 ± 0.25 and 52.25 ± 0.48 days were recorded, respectively. Application of M. hirtus delayed this to 51.00 ± 0.00 at 2.5 x 10^4 ppm, 51.75 ± 0.25 at 5.0 x 10^4 ppm and 52.25 ± 0.48 days at 10.0 x 10^4 ppm. Similarly in S. obtusifolia where 50.25 ± 0.25, 51.75 ± 0.25 and 52.00 ± 0.41 days were recorded at

2.5, 5.0 and 10.0 x 10^4 ppm.In the untreated grains, the developmental period of the weevils was 37.50 ± 0.29 days.Developmental periods of S. zeamais was highly significantly different, F (4, 12) = 819.00, p < 0.0001, among sorghum grains treated with aqueous extracts of the botanicals at varying concentrations. Bonferroni's test indicated that the mean development period in grains treated with E. balsamifera at highest concentration was longer than in other botanicals at all concentrations. That of untreated grains was shorter than those in the botanical treatments.

Table 1: Number of egg plugs, POD, number of emerged adults, IR and developmental periods of S. zeamais in stored sorghum grains treated with botanical powders

Treatments	Conc. (x 10^4 ppm)	Number of Egg Plugs (Mean ± S.E.)	POD (Mean ± S.E.)	Number of Emerged Adults (Mean ± S.E.)	IR (%) (Mean ± S.E.)	Developmental Periods (Days ± S.E.)
E. balsamifera	2.5	5.50 ± 0.65^{c}	78.64 ± 2.51^{c}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	5.0	4.00 ± 0.41^{bc}	84.47 ± 1.59^{bc}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	10.0	3.00 ± 0.41^{d}	88.25 ± 1.58^{b}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
L. inermis	2.5	7.75 ± 0.63^{c}	69.90 ± 2.44^{c}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	5.0	6.00 ± 0.41^{cd}	76.70 ± 1.58^{bc}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	10.0	4.25 ± 0.25^{d}	83.50 ± 0.97^{b}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
M. hirtus	2.5	9.50 ± 0.65^{b}	63.11 ± 2.51^{d}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	5.0	8.25 ± 0.48^{bc}	67.96 ± 1.86^{cd}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	10.0	7.00 ± 0.41^{c}	72.82 ± 1.59^{c}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
S. obtusifolia	2.5	10.75 ± 0.63^{b}	56.25 ± 2.44^{d}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	5.0	9.00 ± 0.41^{bc}	65.05 ± 1.58^{cd}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	10.0	7.75 ± 0.48^{c}	69.91 ± 1.86^{c}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
Permethrin	0.056	0.25 ± 0.25^{e}	99.03 ± 0.97^{a}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
Control	0.0	25.75 ± 0.85^{a}	0.00 ± 0.00^{e}	162.50 ± 1.85^{a}	0.00 ± 0.00^{b}	40.25 ± 0.63

Conc. = Concentration; POD = Percentage oviposition deterrence; IR = Inhibition rate; --- = No emergence was observedMeans in the same column followed by a different letter superscript are significantly different at p < 0.05 by the Bonferroni's Multiple Comparisons Test.

Table 2: Number of egg plugs, POD, number of emerged adults, IR and developmental periods of S. zeamais in stored sorghum grains treated with botanical powders

Treatments	Conc. (x 10^4 ppm)	Number of Egg Plugs (Mean ± S.E.)	POD (Mean ± S.E.)	Number of Emerged Adults (Mean ± S.E.)	IR (%) (Mean ± S.E.)	Developmental Periods (Days ± S.E.)
E. balsamifera	2.5	4.25 ± 1.89^{bc}	81.94 ± 4.04^{ab}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	5.0	3.25 ± 0.96^{bc}	86.17 ± 2.04^{ab}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	10.0	1.25 ± 1.26^{c}	94.68 ± 2.68^{a}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
L. inermis	2.5	7.50 ± 1.29^{b}	68.09 ± 2.75^{b}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	5.0	6.50 ± 1.73^{b}	72.34 ± 3.69^{b}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	10.0	5.75 ± 2.50^{bc}	75.53 ± 5.32^{ab}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
M. hirtus	2.5	8.25 ± 3.59^{b}	64.89 ± 7.65^{b}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	5.0	4.75 ± 3.59^{bc}	79.79 ± 7.65^{ab}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	10.0	4.25 ± 2.22^{bc}	81.91 ± 4.72^{ab}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
S. obtusifolia	2.5	9.75 ± 0.96^{b}	58.51 ± 2.04^{b}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	5.0	6.50 ± 1.29^{b}	72.34 ± 2.75^{b}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	10.0	4.75 ± 0.50^{ab}	79.79 ± 1.07^{ab}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
Control	0.0	23.50 ± 1.92^{a}	0.00 ± 0.00^{c}	165.80 ± 4.13^{a}	0.00 ± 0.00^{b}	41.00 ± 0.71

Conc. = Concentration; POD = Percentage oviposition deterrence; IR = Inhibition rate; --- = No emergence was observed

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

Table 3: Number of egg plugs, POD, number of emerged adults, IR and developmental periods of S. zeamais in stored sorghum grains treated with ethanolic botanical extracts:

Treatments	Conc. (x 10^4 ppm)	Number of Egg Plugs (Mean ± S.E.)	POD (Mean ± S.E.)	Number of Emerged Adults (Mean ± S.E.)	IR (%) (Mean ± S.E.)	Developmental Periods (Days ± S.E.)
E. balsamifera	2.5	3.75 ± 0.48^{cd}	84.85 ± 1.93^{ab}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	5.0	2.00 ± 0.41^{d}	91.92 ± 1.65^{a}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	10.0	1.50 ± 0.29^{d}	93.94 ± 1.17^{a}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
L. inermis	2.5	5.25 ± 0.48^{c}	78.79 ± 1.93^{b}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	5.0	3.50 ± 0.29^{cd}	85.86 ± 1.17^{ab}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	10.0	2.75 ± 0.25^{d}	88.89 ± 1.01^{a}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
M. hirtus	2.5	6.75 ± 0.48^{c}	72.78 ± 2.07^{b}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---

	5.0	5.75 ± 0.48^{c}	76.77 ± 1.93^{b}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	10.0	4.75 ± 0.48^{c}	80.81 ± 1.93^{b}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
S. obtusifolia	2.5	10.00 ± 0.41^{b}	59.60 ± 1.65^{c}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	5.0	6.00 ± 0.41^{c}	75.76 ± 1.65^{b}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
	10.0	5.25 ± 0.48^{c}	78.79 ± 1.93^{b}	0.00 ± 0.00^{b}	100.00 ± 0.00^{a}	---
Control	0.0	24.75 ± 0.85^{a}	0.00 ± 0.00^{d}	156.80 ± 5.41^{a}	0.00 ± 0.00^{b}	39.00 ± 0.41

Conc. = Concentration; POD = Percentage oviposition deterrence; IR = Inhibition rate; --- = No emergence was observedMeans in the same column followed by a different letter superscript are significantly different at $p < 0.05$ by the Bonferroni's Multiple Comparisons Test.

Table 4: Number of egg plugs, POD, number of emerged adults, IR and developmental periods of S. zeamais in stored sorghum grains treated with aqueous botanical extracts

Treatments	Conc. ($x\ 10^4$ ppm)	Number of Egg Plugs (Mean ± S.E.)	POD (Mean ± S.E.)	Number of Emerged Adults (Mean ± S.E.)	IR (%) (Mean ± S.E.)	Developmental Periods (Days ± S.E.)
E. balsamifera	2.5	6.75 ± 0.48^{bc}	73.53 ± 1.88^{ab}	8.50 ± 0.50^{c}	95.00 ± 0.29^{a}	52.00 ± 0.00^{b}
	5.0	5.75 ± 0.48^{c}	77.45 ± 1.88^{a}	5.50 ± 0.50^{c}	96.77 ± 0.30^{a}	53.75 ± 0.48^{ab}
	10.0	4.75 ± 0.48^{c}	81.70 ± 1.88^{a}	5.50 ± 0.50^{c}	96.77 ± 0.30^{a}	54.00 ± 0.41^{a}
L. inermis	2.5	8.25 ± 0.48^{b}	67.65 ± 1.88^{b}	10.00 ± 1.47^{c}	94.12 ± 0.87^{a}	51.00 ± 0.41^{b}
	5.0	6.25 ± 0.48^{bc}	75.49 ± 1.88^{ab}	6.50 ± 0.65^{c}	96.18 ± 0.38^{a}	51.75 ± 0.25^{b}
	10.0	5.50 ± 0.29^{c}	76.47 ± 2.77^{a}	5.50 ± 0.87^{c}	96.77 ± 0.51^{a}	52.25 ± 0.48^{b}
M. hirtus	2.5	6.50 ± 0.65^{bc}	74.56 ± 2.49^{ab}	16.00 ± 1.47^{b}	90.59 ± 0.87^{b}	51.00 ± 0.00^{b}
	5.0	5.50 ± 0.29^{c}	78.43 ± 1.13^{a}	11.75 ± 0.25^{bc}	93.09 ± 0.15^{ab}	51.75 ± 0.25^{b}
	10.0	5.00 ± 0.41^{c}	80.39 ± 1.60^{a}	7.25 ± 0.75^{c}	95.74 ± 0.44^{a}	52.25 ± 0.48^{b}
S. obtusifolia	2.5	8.25 ± 0.48^{b}	67.65 ± 1.88^{b}	18.00 ± 0.71^{b}	89.41 ± 0.42^{b}	50.25 ± 0.25^{b}
	5.0	7.50 ± 0.65^{bc}	70.59 ± 2.53^{ab}	11.75 ± 0.25^{bc}	92.65 ± 0.74^{ab}	51.75 ± 0.25^{b}
	10.0	5.50 ± 0.65^{c}	78.43 ± 2.53^{a}	9.25 ± 0.85^{c}	94.56 ± 0.50^{a}	52.00 ± 0.41^{b}
Control	0.0	25.50 ± 1.04^{a}	0.00 ± 0.00^{c}	170.00 ± 4.60^{a}	0.00 ± 0.00^{c}	37.50 ± 0.29^{c}

Conc. = Concentration; POD = Percentage oviposition deterrence; IR = Inhibition rateMeans in the same column followed by a different letter superscript are significantly different at $p < 0.05$ by the Bonferroni's Multiple Comparisons Test.

IV. Discussion

4.1 Oviposition deterrence of botanicals against S. zeamais:

Findings of this study revealed that all the selected botanicals had effects on egg laying by S. zeamais in stored sorghum. Oviposition by S. zeamais was significantly lower in powders and extracts treated sorghum grains than in untreated sorghum grains. Botanical powders of E. balsamifera, L. inermis, M. hirtus and S. obtusifolia as well as permethrin resulted in significant ($p < 0.05$) reduction in number of egg plugs compared to the control. This is in conformity with [31] who reported a reduction of number of eggs deposited by S. zeamais from 25.75 in controls to 18.50 in C. vulgaris applied at the concentration of 3.0 g / 50 g maize grains after 1 month post treatment. Similarly, [16] reported that application of C. vulgaris at 3.0 g / 50 g maize grains reduced number of eggs laid by S. zeamais (25.5 to 1.25). Oviposition deterrence of leaf powder of L. inermis was tested on C. maculatus by [17] and found that the plant powder deterred 54.26% egg deposition on cowpea seeds.Methanolic, ethanolic and aqueous extracts of the selected botanicals have shown oviposition deterrence against S. zeamais in stored sorghum. This is in line with [18] who reported a reduction in the number of eggs laid by S. zeamais from 36.25 ± 2.27 in the control to 8.00 ± 0.91 in aqueous stem bark extracts of A. boonei applied at 0.4 ml / 20 g maize grains.Effectiveness of E. balsamifera in reducing egg deposition by S. zeamais concurs with [32] who reported ovipositional deterrence of aqueous and ethanolic extracts of Euphorbia hirta against C. maculatus. The present findings are supported by [19] who reported 52.90 POD of aqueous extracts of L. inermis of against C. maculatus.Findings of this study have revealed that the high oviposition deterrence of the test botanicals could be as a result of ovicidal effects of the botanicals as well as total adult mortality of the insect which occurred within a few days after treatment with powders, methanolic and ethanolic extracts. In addition to adult mortality, the mechanical effect of large quantities of powders might have probably interfered with oviposition as suggested by [33]. This could be seen in the present findings where oviposition was lowest at higher concentrations (large quantities) of the leaf powders.The oviposition deterrence of the test powders corroborates the earlier findings that leaf powders of E. balsamifera and L. inermis caused early mortality of C. maculatus thus interfering with their ability to commence a fresh cycle of oviposition [34]. Similar observation on oviposition deterrence of C. vulgaris powder against S. zeamais in maize grains was made [16]. Findings of this study are in accordance with [26] and [31] who concluded that plant powders reduceoviposition of bruchids and weevils, respectively.The effectiveness of methanolic, ethanolic and aqueous extracts of the botanicals in reducing egg laying capacity of S. zeamais might be due to the fact that the botanicals inhibited insect's locomotion, hence, the weevils could not move freely as a result of their repellent activities, thereby affecting mating activities and fecundity. Effects of the extracts of E. balsamifera, L. inermis, M. hirtus and S. obtusifolia

on oviposition of S. zeamais could also be linked with respiratory impairment, which probably affects the process of metabolism and consequently other systems of the weevil's body.

4.2 Effect of botanicals on adult emergence of S. zeamais:

Outcomes of this study have revealed that all the botanicals tested had total inhibition rate in adult emergence of S. zeamais in sorghum grains treated with powders, methanolic and ethanolic extracts as there was no adult emergence recorded. However, aqueous extracts of the botanicals were found to be less effective than the other formulations, even though the IR was very high compared to the control. The use of plant powders in suppressing adult emergence of S. zeamais was previously reported by others [16, 20, 22, 23].Performance of leaf powders of the study botanicals in reducing adult emergence of S. zeamais agrees with the findings of [20] who reported that botanical powders of Z. officinale, O. subscorpiodea and A. melegueta inhibited 28.76 ± 0.33 to 94.13% ± 1.06 adult emergence of S. zeamais in stored maize. Similarly, [16] recorded 0.50 adult emergence of S. zeamais in maize grains treated with cotyledon powder of C. vulgaris at the rate of 3.0 g / 50 g at 21 days after treatment.Complete suppression of adult emergence of S. zeamais by leaf powders, methanolic and ethanolic extracts of the botanicals achieved in this study is in accordance with [22]. They reported that plant powders of root bark of Piptadeniastrum africanum and Aristolochia repens completely suppressed the emergence of S. zeamais 42 days after introducing the weevils in the treated maize grains. Similarly, [23] reported none emergence of adult S. zeamais in maize treated with Peumus boldus foliage powder at 1.0% w/w.The present study has found that E. balsamifera was more effective than the other botanicals, while aqueous extracts of the botanicals recorded more emergence than the other forms, even though its inhibition rate was high too.Total inhibition rate in adult emergence of S. zeamais in sorghum treated with methanolic and ethanolic leaf extracts of E. balsamifera, L. inermis, M. hirtus and S. obtusifolia at varying concentrations was achieved 84 DAT. This outcome is in line with the findings of [18] who recorded complete inhibition of adult emergence of S. zeamais after 30 days of exposure to aqueous extracts of A. boonei applied at 0.4 ml / 20 g maize. Similar result was obtained by [20] that 6, 8 and 10% oil extract of A. melegueta caused 100% inhibition rate in adult emergence of S. zeamais in stored maize 42 days after treatment. The suppression activity in adult emergence of L. inermis was also recorded against C. maculatus where 45.76% inhibition rate was reported when applied at 5% concentration [19].It could be deduced that the complete inhibition in adult emergence of S. zeamais by leaf powders, methanolic and ethanolic extracts of the test botanicals and permethrin might be due to total mortality observed at early days after treatment. This resulted in inability of the insects to mate, which deterred oviposition and hence, inhibited emergence. It is also found that the botanicals might be toxic to the few eggs deposited and as such led to reduced number of emergence in grains treated with aqueous extracts concurring with [19] that toxic substances present in the extracts may enter into the egg through chorion and suppressed further embryonic development.Further, [22] concluded that the non emergence of F_1 generation of S. zeamais treated with some botanical powders could be as a result of high mortality of adult insects, thus disrupting mating and sexual communication as well as deterring females from laying eggs and complete suppression of the developmental stages of insects. According to [18] and [20], reduced adult emergence could be due to high mortality of the insect which might have consequently reduced the rate of mating and oviposition.Results have shown that there was positive correlation between egg deposition and adult emergence. This was clearly observed in untreated grains where significant oviposition and adult emergence were recorded. The outcome is corroborative with what has already been previously reported [18, 20, 22.].

4.3 Effect of botanicals on developmental periods of S. zeamais:

No developmental period of S. zeamais was recorded in sorghum treated with leaf powders, methanolic and ethanolic extracts of E. balsamifera, L. inermis, M. hirtus and S. obtusifolia. This might be due to the absence of adult emergence in the treatments which could be connected to mortality and anti-oviposition effects of the botanicals (as discussed earlier). This outcome concurs with [35] who recorded no developmental period of S. zeamais in sorghum treated with J. curcas at the dose of 2.0 g / 20 g and permethrin powder, while it was delayed to 44.25 ± 0.38 and 42.00 ± 0.00 days in E. balsamifera and L. inermis powders treatments, respectively, compared to 37.50 ± 0.50 days in the control.The developmental periods of S. zeamais in sorghum grains treated with aqueous extracts varied slightly according to botanical type and concentration, though not significantly different ($p > 0.05$). In all cases, the developmental periods were delayed and longer than in the control. However, the developmental periods of S. zeamais in the respective controls ranged within the reported weevil's life cycle of 5 to 8 weeks at 30 ± 2^0C and 70 ± 5% R.H. [12, 13, 14]. Findings of this research agree with [36] who reported 34.1 days as mean developmental period of S. zeamais in sorghum grains.It could be noticed that the leaf powders, methanolic and ethanolic extracts of the selected botanicals completely inhibited development of S. zeamais in stored sorghum, while in aqueous extracts (within which a brief emergence occurred) it was delayed to longer periods than the control. Although there are recent research findings on the control of S. zeamais using plant materials [37, 38, 39, 40, 41], little is known on their effects on the insect's

developmental period.The delay or absence of developmental periods of S. zeamais in stored sorghum treated with E. balsamifera, L. inermis, M. hirtus and S. obtusifolia might be due to total adult mortality of the insect, anti-oviposition activities of the botanicals and their high inhibition rate in adult emergence. The selected plant materials were effective in disrupting the development of S. zeamais and therefore could probably be utilized to protect sorghum grains from the insect's infestation during storage.

V. Conclusion

Findings of this study have shown that leaf powders and organic extracts of E. balsamifera, L. inermis, M. hirtus and S. obtusifolia were highly effective as anti-oviposition, adult emergence inhibition and developmental periods delay agents against S. zeamais. E. balsamifera was found to be the most effective botanical, even though all the plant materials gave similar yield to permethrin powder except aqueous extracts where a comparatively less efficacy was observed. These botanicals could be used as alternatives to chemical insecticides in interfering with reproductive activities of the maize weevils attacking stored sorghum. In order to evaluate more bioactivities of the botanicals, further research is recommended on other insects of stored sorghum.

References

[1] USDA (2010). Grain and feed annual. Grain Report Number: NI10007. United States Department of Agriculture. 11pp.

[2] Leder, I. (2004). Sorghum and millets In: Fuleky G (Ed.) Cultivated plants primarily as food sources. Encyclopedia of Life Support Systems (EOLSS), developed under auspices of the UNESCO, Eolss publishers, Oxford, UK (http://www.eolss.net), 18pp.

[3] Othira, J.O., Onek, L.A., Deng, L.A. and Omolo, E.O. (2009). Insecticidal potency of Hyptis spicigera preparations against Sitophilus zeamais (Motsch.) and Tribolium castaneum (Herbst) on stored maize grains. Afr. J. Agric. Res., 4(3): 187-192.

[4] Miekle, W.G., Holst, N., Scholz, D. and Markham, R.H. (1998). Simulation model of Prostephanus truncatus (Coleoptera: Bostrichidae) in rural maize stores in the Republic of Benin. Environmental Entomology, 279(1): 59-68.

[5] Sharma, H.C., Ashok, S.A., Ravinder, R.C., Jayaraj, K., Varaprasad, V.J., Varaprasad, R.K.M., Belum, V.S.R. and Rai, K.N. (2007). Management of Sorghum and Pearl Millet Pests in Bulk Storage. Global Theme on crop improvement. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India. 20pp.

[6] Adedire, C.O. (2001). Biology, ecology and control of insect pests of stored cereal grains. In: Ofuya TI and Lale NES (eds.). Pests of Stored Cereals and Pulses in Nigeria. 59-94pp. Dave Collins Publications, Akure, Nigeria.

[7] Parugrug, A.M. and Roxas, C. (2008). Insecticidal action of five plants against maize weevil, Sitophilus zeamais Motsch. (Coleoptera: Curculionidae). KMITL Sci. Technol. J. 8(1): 24-38.

[8] van Emden, H.F. (2013). Handbook of Agricultural Entomology. John Wiley & Sons, Ltd. West Sussex, UK. 321pp.

[9] Ngamo, T.S.L., Ngassoum, M.B., Mapongmestsem, P.M., Noudjou, W.F., Malaisse, F., Haubruge, E., Lognay, G., Kouninki, H. and Hance, T. (2007). Use of essential oils of aromatic plants as protectants of grains during storage. Agric. J., 2(2): 204-209.

[10] Rugumamu, C.P. (2009). Influence of simultaneous infestations of Protephanus truncatus and Sitophilus zeamais on the reproductive performance and maize damage. Tanzania J. Sci., 31(1): 65-72.

[11] Mutambuki, K. and Harberd, A.J. (2004). Reference manual on the major insect pests of stored cereal and pulse grains in Somalia and their control. Integrated Pest Management Project in Somalia, Nairobi. 135pp.

[12] Anankware, P.J., Fatunbi, A.O., Afreh-Nuamah, K., Obeng-Ofori, D. and Ansah, A.F. (2012). Efficacy of the multiple-layer hermetic storage bag for bio rational management of primary beetle pests of stored maize. Acad. J. Entomol,. 5(1): 47-53.

[13] Srinivasan, R., Uthamasamy, S., Mohan, S. and Rani, B.U. (2003). The effect of three plant products on Sitophilus oryzae (L.) in maize. Plant Protec. Bullet. 55(1+2): 23-26.

[14] Murdolelono, B. and Hosang, E. (2009). Effect of storage techniques on quality of maize seeds of Lamuru and Local varieties in East Nusa Tenggara. Indonesian J. Agric., 2(2): 93-102.

[15] Makate, N. (2010). The susceptibility of different maize varieties to post- harvest infestation by Sitophilus zeamais (Motsch.) (Coleoptera: Curculionidae). Sci. Res. Ess., 5(1): 030-034.

[16] Edelduok, E.G., Apkabio, E.E., Eyo, J.E. and Ekpe, E.N. (2015). Evaluation of the insecticidal activities of cotyledon powder of melon, Citrullus vulgaris Schrad against the maize weevil, Sitophilus zeamais Motschulsky. J. Biopest. Env. 1: 50-57.

[17] Jose, A.R. and Adesina, J.M. (2014). Oviposition, infestation deterrent and phytochemical screening of Heliotrpium indicum and Lawsonia inermis against Callosobruchus maculatus Fabricius (Coleoptera: Chrysomelidae) on cowpea seeds. Int. J. Mol. Zool., 4(1): 1-8.

[18] Ileke, K.D. (2014). Cheese wood, Astonia boonei De Wild a botanical entomocides for the management of maize weevil, Sitophiluszeamais Motschulsky (Coleoptera: Curculionidae). Octa J. Biosci. 2(2): 64-68.

[19] Chudasama, J.A., Sagarka, N.B. and Sharma, S. (2015). Deterrent effect of plant extracts against Callosobruchus maculatus on stored cowpea in Saurashtra (Guarat, India). J. App. Nat. Sci., 7(1): 187-191.

[20] Oni, M.O.and Ogungbite, O.C. (2015). Entomotoxicant potential of powders and oil extracts of three medicinal plants in the control of Sitophilus zeamais infesting stored maize. J. Plant and Pest Sci. 2(1): 8-17.

[21] Iloba, B.N. and Ekrakene, T. (2006). Comparative assessment of insecticidal effects of Azadirachta indica, Hyptis suaveolens andOcimum gratissimum on Sitophilus zeamais and Callosobruchus maculatus. J. Bio. Sci. 6(3): 626-630.

[22] Ojo, D.O. and Ogunleye, R.F. (2013). Comparative effectiveness of the powders of some underutilized botanicals for the control of Sitophilus zeamais (Motschulsky) (Coleoptera: Curculionidae). Int. J. Pure App. Sci. Technol., 16(2): 55-62.

[23] Rivera, P., Silva, G., Figueroa, I., Tapia, M. and Rodriguez, J.C. (2014). Effect of vacuum storage on shelf life of a grain protector based on Peumus boldus Molina foliage powder and lime against Sitophilus zeamais Motschulsky. Chilean J. Agric. Res., 74(1): 49-54.

[24] Olotuah, O.F. (2015). Effect of age of Eugenia aromatic powder on the control of Callosobruchus maculatus and Sitophilus zeamais. Int. J. Plant and Soil Sci., 5(4): 227-233.

[25] Goftishu, M. and Belete, K. (2014). Susceptibility of sorghum varieties to the maize weevil Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae) Afri. J. Agric. Res., 9(31): 2419-2426. DOI: http://dx.doi.org/10.5897/AJAR2014.8634.

[26] Khaliq, A., Nawas, A., Ahmad, N.H. and Sagheer, M. (2014). Assessment of insecticidal potential of medicinal plant extracts for control of maize weevil, Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae). Basic Res. J. Agric. Sci. Rev., 3(11): 100-104.
[27] Muzemu, S., Chitamba, J. and Mutetwa, B. (2013). Evaluation of Eucalyptus tereticornis, Tagetes minuta and Carica papaya as stored maize grain protectants against Sitophilus zeamais (Motsch.) (Coleoptera: Curculionidae). Agric. For. Fisheries, 2(5): 196-201.
[28] Vanmathi, J.S., Padmalatha, C., Singh, A.J.A.R. and Chairman, K. (2012). Effect of chosen botanicals on the oviposition deterrence and adult emergence of Callosobruchus maculatus (F.) (Coleoptera: Bruchidae). Elixir Bio. Technol., 51A: 11120-11123.
[29] Tapondju, I.A., Alder, A., Fontem, H. and Fontem, D.A. (2002). Efficacy of powder and essential oil from Chenopodium ambrosioides leaves as postharvest grain protectants against six stored products beetles. J. Stored Prod. Res., 38: 395-402.
[30] Dobie, P. (1977). The contribution of the tropical stored products centre to the study of insect resistance in stored maize. Trop. Stored Prod. Infor., 34: 7-22.
[31] Edeldouk, E., Akpabio, E., Eyo, J. and Ekpe, E. (2012). Bio-insecticidal potentials of testa powder of melon, Citrullus vulgaris Schrad for reducing infestation of maize grains by the maize weevil, Sitophilus zeamais Motsch. J. Biol., Agric.Healthcare. 2(8): 13-17.
[32] Kosar, H. and Srivastava, M. (2016). Euphorbiaceae plant extracts as ovipositional deterrent against Callosobruchus chinensis Linn (Coleoptera: Bruchidae). J. Biopest., 9(1): 80-90.
[33] Rajapakse, R.H.S. (2006). The potential of plants and plant products in stored insect pest management. Thai J. Agric. Sci., 2(1): 11-21.
[34] Suleiman M. and Suleiman, H.Y. (2014). Control of Callosobruchus maculatus (F.) [Coleoptera: Bruchidae] using leaf powders of Euphorbia balsamifera L. and Lawsonia inermis L. Int. J. Sci. Env. and Technol., 3(1): 100-109.
[35] Suleiman, M. (2012). Use of Plant Powders as Protectants of Sorghum Grains against Sitophilus zeamais Motsch. (Coleoptera: Curculionidae) During Storage. Unpublished M.Sc. Dissertation, Usmanu Danfodiyo University, Sokoto, Nigeria. 88pp.
[36] Ojo, J.A. and Omoloye, A.A. (2016). Development and life history of Sitophilus zeamais (Coleoptera: Curculionidae) on cereal crops. Advan. Agric., 2016: 1-8.
[37] Yeshaneh, G.T. (2015). Evaluating grain protectant efficacy of some botanicals against maize weevil, Sitophilus zeamais Motsch. World J. Agric. Res., 3(2): 66-69.
[38] Ibrahim, Y.J., Abugri, A.D. and Afun, J.V.K. (2016). Efficacy of ethanolic leaf extract of Chromolaena odurata in controlling Sitophilus zeamais in stored maize. J. Exp. Agric. Int., 14(5): 1-10.
[39] Longe, O.O. (2016). Insecticidal action of some plant powders on maize weevil, [Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae)] affecting stored maize grains (Zea mays). Int. J. Agric. Innov. Res., 4(4): 784-788.
[40] Ouko R..O., Koech, S.C., Arika, W.M., Njagi, S.M., Oduor, R.O. and Ngugi, M.P. (2017). Bioefficacy of organic extracts of Ocimum basilicum against Sitophilus zeamais. Entomol. Ornithol. Herpetol., 6(1): 1-7.
[41] Shiberu, T. and Negeri, M. (2017). Determination of the appropriate doses of promising botanical powders against maize weevil,Sitophilus zeamais Motsch (Coleoptera: Curculionidae) on maize grain. J. Stored Prod. and Postharvest Res., 8(4): 49-53.

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