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Effects of leaf powder of *Citrus aurantifolia* and *Senna occidentalis* on the development of maize weevil (*Sitophilus zeamais* Motschulsky, Coleoptera Curculionidae)

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Abstract
The present investigation was to study the effects of leaf powders of *Citrus aurantifolia* and *Senna occidentalis* on development of *Sitophilus zeamais* (Motsch) in Entomology laboratory Usmanu Danfodiyo University Sokoto. The mortality of *S. zeamais* in maize treated with *Citrus aurantifolia* were observed to be high, actellic dust (0.5g/100g) and were significantly ($P<0.05$) higher from the untreated (control). Effects of plant powder on the emergence of adult *S. zeamais* was significantly ($p<0.05$) higher. The highest emergence (25.07±0.67) was observed from the grains treated with 2.0g of *Senna occidentalis* and least (4.00±0.58) was 6.0g of *Citrus aurantifolia.* This result indicated that the *Citrus aurantifolia and Senna occidentalis* can be use in protecting the maize from maize weevil infestation during storage.

Keywords: Maize grain, *Sitophilus zeamais, Citrus aurantifolia, Senna occidentalis* and actallic dust

1. Introduction
Maize weevil, *Sitophilus zeamais* Motschulsky (Curculionidae: Coleoptera) measures 3.5-4mm in length [1]. It is reddish-brown to black in colour. The adult weevil has a characteristic rostrum and antennae that is elbowed and clubbed, a head with a definite beek, which is elongated and curved. Its body elytra and legs are very hard, forming a solid well-armored exterior [2].

Zea Mays L. is an annual monocotyledonous diploid (2n=20) a member of the family Poaceae Maydeae tribe of which eight different generations have been recognized by taxonomists [2]. Maize has been of great importance in providing food for human, feed for livestock and raw materials for some agro-based industries [1]. Despite the numerous uses of this important crop, it suffers destruction by pest during storage. Maize weevil, larger grain borer and lesser grain borer are the most destructive pests of stored maize worldwide [1].

In Africa alone, post-harvest grain losses account for $4.0 Billion. This loss grain production could meet the minimum annual requirement of 48 million people [3]. The quantity of dry maize cobs lost annually in Nigeria was 165,836 metric tons correspond to a value of N7.29billion (i.e. N44,000 per metric tons) [4].

The challenge that is currently confronting Nigerian agriculture is low productivity because of insect losses and damage [5]. To reduce the extent of losses of stored maize, cause by insects in general and *S. zeamais* in particular, several methods ranging from traditional, biological, genetic, physical and chemical methods have been devised [5]. Unfortunately, these methods have some shortcoming albeit their efficacy. Physical methods are often too expensive as they require sophisticated technology. However, the extensive use of chemical in the control of weevil is associated with many challenges directly or indirectly [5].

The use of plant materials such as leaves, bark, stems and roots of *Azadirachta indica, Lantana camara, lecus metinicensus*; Lemon grass, and *Nicotiana tabacum* leaves, in storing crop products by local farmers in Nigeria, is an old age practice [5]. The toxicidal effect of some of these plant materials against Maize and Cowpea weevil have been studied [6-8].

However, specific controls against *S. zeamais* using these plant materials have not been tried in the area. Locally available plant materials that are known to be easily degradable were chosen for this work.

Based on indigenous information, two of the locally available plants viz; *Citrus aurantifolia* and *Senna occidentalis* were selected for the study.

1.2 Aim and Objectives

The aim of this present work was to assess the toxicity of leaves *Citrus aurantifolia* and *Senna occidentalis* in the control of maize weevil and also to see to their effects on the viability of the grain.

2. Materials and Methods

The planned experiments were carried out in the Entomology Laboratory, Department of Biological Sciences, Usmanu Danfodiyo University Sokoto, from February to November under the Laboratory conditions. The monthly average temperature and relative humidity varies from 20^0C- 45^0C and 55% -70% [9].

2.1 Collection and Preparation of Maize Grains

The local maize used in the experiments was purchased from Ministry of Agriculture in Binin Kebbi, Kebbi State, Nigeria. Uninfested seeds were separated from infested ones. The uninfested maize was fumigated using one tablet of Aluminium phosphide (phostoxin) wrapped in a paper, in an air tight black polythene bag for 96 hours (4days) to kill any prior infestation by the weevils and later aired for two days to allow dissipation of fumigant effect.

2.2. Collection, Identification of Plants Test Materials

The Leaves of *Citrus aurantifolia* and *Senna occidentalis* were selected based on some indigenous information regarding their toxicity and their toxic roles as described (10) and [11] in the control of weevil.

2.2.1 Sample collection

C. aurantifolia (Leaves) were obtained from Biological Garden of the Usman Danfodio University Sokoto, while *S. occidentalis* was obtained from their natural habitat in Fadama area from Dundaye Kware local Government Sokoto.

2.2.2 Identification of sample

The plants identification was confirmed at the Herbarium of the Department of Biological Sciences Usmanu Danfodiyo Sokoto, by comparing them with the voucher specimen present there with the assistance of herbarium Curators.

2.2.3 Preparation of sample

C. aurantifolia and *S. occidentalis* collected were shade dried for ten days at room temperature. The dried material was ground separately into coarse powder using mortal and pestle and then sieved into fine powder using 0.08mm size mesh. Five hundred gram (500g) powder of each *C. aurantifolia* and *S. occidentalis* obtained were kept in separate polyethylene bags in the laboratory for use. Actellic dust 2% (Pirimiphos methyl) used for weevils control purchased from the Sokoto Central Market.

2.3. Insect Culture

Maize grain infested with maize weevil was purchased from Birnin Kebbi Central Market, to obtain adult *Sitophilus zeamais.* The samples were taken to the Entomology Laboratory in the Department of Biological Sciences, Faculty of Science, Usmanu Danfodiyo Sokoto. The identification of the weevil was confirmed following the identification key by [12]. The adults were then reared separately on maize to maintain a mother stock which is used to obtain newly emerged adults of S. *zeamais* for experimental purposes.

The Jar was covered with a muslin cloth tied with a rubber band and kept under ambient conditions for two weeks. After which both the dead and surviving weevils were removed from each jar, leaving only the grains. New generation of the weevil started emerging after 5 –6 weeks. The newly emerged adults F_1 generation were used for the experimental purpose. The stock was maintained to obtain experimental insects [13].

2.3.1 Toxicidal efficacy of selected plant materials

To study the toxicidal efficacy of varying doses of leaf powders of selected plants against maize weevil, Seven [7] sterilized plastic containers were obtained. Each was added one hundred grams of sterilized maize. In first five containers, the grain was dusted with 2.0gm of each of the five powders separately. While the maize grain in the 6^{th} container was treated with Actellic dust 0.50g (Standard dose). The grain in the 7^{th} container was left untreated and used as control. Twenty pairs (20pairs) of newly emerged adults of *S. zeamais* of both sexes were collected from the mother stock and inoculated into each of the seven [7] containers. All containers were kept in the laboratory under ambient condition. Observations were made daily to record mortality among adults and emergence of new generation was observed after five weeks. Similar experiments were conducted using the increased amount of plant powders to 4gm and 6gm/100g of seed and similar observations were made. All experiments were replicated thrice.

2.3.2 Quantitative loss (Loss in weight and grain damage) to maize

The percentage seeds damage was calculated according to [14], at the end of the twelve weeks of the experiment. One hundred (100) grain picking at random and sorting them into holed (damaged) and whole (undamaged) and the following formula was used to calculate the percentage damage.

$$(\%)\ \text{Seed damage} = \frac{\text{Number of damaged seeds}}{\text{Total number of seeds}} \text{ X } 100$$

Percentage seed weight loss was calculated according to [15]

Percentage seed weight loss = W_O - $W_{1=}W_{2\,/}$ W_O X 100

Where, W_O is the initial weight of maize,

W_1 is the final weight of maize at the end of the experiment period andW_2 is the different in weight loss.

% weight loss = $\frac{W_2 x100}{W_O}$ [15]

2.3.4 Effects of Leaf powder on Viability of treated grain

The maize seeds treated with varying amount of different *C. aurantifolia* and *S. occidentalis* were tested for viability. The viability was tested by randomly selecting ten seeds from each treated group of seeds which were soaked in water for 3 hours, and planted in the moist soil. Each set up was replicated three times, following [16]

2.4 Statistical Analysis

The data obtained from the experiment were subjected to analysis of variance using Statistical analysis system (SAS). Treatment means that are found significantly different were separated using Duncan's New Multiple Range Test (DNMRT) at 5% level of significance.

3. Results and Discussion

3.1. Toxicidal effects of leaf powders on the development of *S. zeamais*

3.1.1 Mortality among adults

The result in Table 1shows that *C. aurantifolia* and *S. occidentalis* were found to be toxic, causing mortality among adults *S. zeamais*. The mortality was found to be directly proportional to the amount of powder used for treatment of grains. Powder of *S. occidentallis* leaves was least affective among all the powders resulting in 31.68% mortality, while the powder of *C. aurantifolia* was observed to be most effective causing 47.57% mortality, even when used in low amount.

The increase in concentration of the powders to 4.0g resulted in an increase in the mortality within 6-7 days of their introduction. Maize treated with 4.0g of *C. aurantifolia* resulted in 76.68%. The lowest mortality 68.33% was observed from *S. occidentalis*. Higher mortality (99.33%) was observed among adults reared on maize treated with 6.0g of *C. aurantifolia.* The mean mortality recorded among adults reared on untreated but infested maize (control) was 4.18%. Actellic dust (Pirimiphos methyl) took an average of 4.67 days of post infestation to cause cent per cent mortality, while control (untreated) had 2.50% mortality.

Table 2: Mortality among adults *S. zeamais* reared on local variety of maize treated with *C. aurantifolia* and *S. occidentalis* powders (Within 7 days of post infestation)

Treatment	Mean No. of Adults dead ±SE (Mortality in per cent)		
	Amount of powder applied (g)/ 100g of grains		
	2.0	4.0	6.0
C. aurantifolia	19.00^{d}± 0.58(47.57)	30.67^{d}±0.33 (76.68)	39.33^{ab}±0.33 (98.33)
S. occidentallis	12.67^{e}± 0.67(31.68)	27.33^{e}±0.33 (68.33)	38.33^{b}± 0.33(95.83)
Pirimiphos methyl	40.00^{a}±0.00 (100)	40.00^{a} ± 0.00 (100)	40.00^{a}±0.00 (100)
Control (Untreated)	1.67^{f}± 0.33(4.18)	1.00^{f}± 0.58(2.50)	1.00^{c}± 0.58(2.50)

Means that have the same super script within a column are not significantly different at 5% level using Duncan's New Multiple Range Test (DNMRT)

3.3.2 Emergence of adults

Result in Table 2 shows that both powder used in treating the grains affected the emergence of adults. Significant differences were observed in the emergence of adults reared on the treated and untreated grains. *C. aurantifolia* powder was found to be the most effective in affecting the emergence resulting in least emergence 15.33% , while *S. occidentalis* was observed to be the least effective powder causing maximum emergence of 25.67%. The emergence observed from the grains treated with actellic dust and untreated (control) was 0.00 and 57.67 respectively. When the concentration of powders applied to treat same quantity (100g) of maize, was increased to 4.0 g, profound effects were observed. Females reared on maize treated with 4.0g of powders of *C. aurantifolia,* had the lowest rate of emergence of adults averaging 11.33%, while *S. occidentalis* (18.67%). Actellic dust (standard) showed that only 0.67% adults emerged, while the untreated control 59.33 adults emerged.

The Table 2 also showed a significant decrease in the progeny emergence when 6.0g of various plant powders were used for treating 100g maize grains. Similar pattern was observed in *C. aurantifolia* with least emergence of (4.00), and *S. occidentalis* (10.67). From untreated maize (control) highest number of adults (59.00) emerged resulting in highest emergence compared to treated samples.

Table 2: Emergence of adults of *S. zeamais* in F1 progeny from adults reared on maize treated with varying amount of leaf plant powders. (Each observation is based on three replicates)

Treatment	Mean No. of Adults Emerged in first progeny		
	Amount of powder applied (g)/ 100g of grain		
	2.0	4.0	6.0
C. aurantifolia	15.33^{e}±0.88	11.33^{e}±0.67	4.00^{d}±0.58
S. occidentallis	25.67^{c}±0.67	18.67^{c}±0.67	10.67^{c}±1.20
Pirimiphos methyl	0.0^{f}±0.00	0.67^{f}±0.67	0.00^{e}±0.00
Control (Untreated)	57.67a±2.33	59.33^{a}±1.20	59.00^{a}±1.73

Means that have the same super script within a column are not significantly different at 5% level using Duncan's New Multiple Range Test (DNMRT)

3.3.3 Quantitative loss in weight to maize grains

It is observed from Table 4 that grains treated with Actellic dust had least losses and damage (0.15 per cent) while untreated grains were found to have highest loss (16.10%). The grains treated with *C. aurantifolia* and *S. occidentalis* were having varying degree of losses which were less than the untreated (control) grains but a little bit higher than Actellic dust. Maize treated with 2.0g of *C. aurantifolia* had small weight loss (6.17%) while *S. occidentalis* (10.0%).

Table 4 also shows a decrease in quantitative losses caused to maize treated with an increased amount of 4.0g of various plant powders. The observations indicated that the higher the amount, the lower the weight loss. Actellic dust, which had a fixed concentration at each trial, had almost the same amount of loss (0.17%) while untreated Control had 15.97%.

Table 4: Show the effect of various doses of different plant powders on the weight and damage caused maize due to infestation by *S. zeamais* (Each observation is based on three replicates)

Treatment	Amount Applied (g/100g)	No of adult inoculated	Mean Weight loss ±SE / % weight loss		Mean Damage ±SE / % Damage	
			MWL	WL%	MDG	DG%
C. aurantifolia	2	20	5.50c±0.12	6.17	7.33c±0.33	7.33
	4	20	3.13c±0.12	3.57	4.33c±0.33	4.33
	6	20	1.30c±0.15	1.30	1.67c±0.33	1.67
S. occidentalis	2	20	8.67b±0.2	10.01	10.67b±0.33	10.67
	4	20	6.13b±0.15	7.90	7.33b±0.33	7.33
	6	20	4.60b±0.18	4.67	4.00b±0.02	4.00
Actellic dust 2%	0.5	20	0.15d±0.03	0.15	0.67d±0.33	0.01
	0.5	20	0.17d±0.33	0.17	0.67d±0.33	0.67
	0.5	20	0.17d±0.33	0.13	0.33d±0.33	0.33
Control	0.0	20	13.35a±0.08	16.10	14.33a±0.67	15.33
	0.0	20	13.13a±0.13	15.97	14.67a±0.33	14.67
	0.0	20	13.20a±0.15	16.03	13.33a±0.33	15.33

MWL- (Mean weight loss) %WL- (Percentage weight loss). MDG- (Mean damage grain) %DG-Percentage damage grain Means that have the same super script within a column are not significantly different at 5% level using Duncan's New Multiple Range Test (DNMRT)

Table 4 further showed the number of damaged seed from each treated maize grain. When the maize was treated with 2g /100g *S. occidentalis* shows highest exit hole (10.67) *C. auranifolia* with lowest number of exit hole 7.33, the actellic dust did not show any exit hole. And control (untreated) has 15.33% exit hole. When the plant powder where increased to 6g/100g all the grains shows small number of damage seed, actellic dust (0.33) followed *C. auranifolia* and *S. occidentalis,* (1.67, and 4.00).

3.3.4 Viability of treated grains

Result in Table 5 revealed that the application of varying doses of different *C. aurantifolia* and *S. occidentalis* powders and insecticides used in the control of maize weevil have no effect on the viability of grains. Almost all (80-90%) grain treated with plant material geminated except the grain treated with *L. mertinicensis* which has 70- 80% germination. It can be deduces that all the plant used for control of *S. zeamais* in this experiment does not have any negative effect on the germination of the grains.

Table 5: Germination of maize grain treated with varying amount of selected plant powders (Each observation is based on three replicate)

Powders used	Amount applied	No of grains tested (Sown)	Mean no of grain germinated	Germination of grain (Percent)
C. aurantifolia	2g	10	9.00ab ±0.33	90.00
	6g	10	9.00ab ±0.33	90.00
S. occidentalis	2g	10	9.33ab ±0.33	93.30
	6g	10	9.00ab ±0.33	90.00
Actellic dust	0.5g	10	9.33ab ±0.33	93.30
	0.5g	10	9.67a ±0.33	96.70
Control	0.0	10	5.67c ±0.33	60.00
	0.0	10	5.33d ±0.33	56.70

Means that have the same super script within a column are not significantly different at 5% level using Duncan's New Multiple Range Test (DNMRT)

4 Discussion

Observations made on the mortality of adult weevils on the local maize variety treated with *C. aurantifolia* and *S. occidentalis* powders, confirmed the potentials of these products as protectants against maize weevil. A mixture of maize with *C. aurantifolia* seems to be most effective in reducing the adult weevil especially at higher doses, and *S. occidentalis* produce moderate results compared with Actellic dust treated samples of grain showed higher mortality. Significant differences were observed between treatments and the controls. The application of higher dose of 6g/100 of the powder resulted in higher and quick mortality but the differences among them were not significant. *S. occidentalis* showed comparatively least effect on the mortality even at the higher dose.

The differences in mortality exhibited by the different powders could be attributed to the presence of different bioactive components present in different quantity in *C. aurantifolia* and *S. occidentalis*. This result is in line with that of [17] who reported a similar finding that mortality rate among weevils is associated with lethal doses of the treatment resulting in stomach poisoning and consequently leading to insect mortality [18, 19] also reported pesticidal activity of plants products including Neem, phyrethrum and Tephrosia against insects in storage [18, 19] further reported similar effect on *A. nilotica, B. aegyptiaca* and *L. martinicensis* on *S. zeamais*

C. aurantifolia leave powder observed to be more promising in killing the insect (45%), even at small doses (2.0g). Accelerating effect on mortality was observed with an increased amount of the powder applied. Highest mortality (100%) was observed at higher dose (6.0g) of *C. aurantifolia* only after 168h of infestation. This result is in line with that of [20] who reported that the powder of *C. patens* is highly toxic to *S. zeamais* within 96hrs post treatment. [21] also recorded significant reduction in the number of live maize weevil, *S. zaemais* when treated with leaf powder of *E. macrorhyncha* F. *Azadirachta indica* A juss and *Lantana camara* L.

Result of this work also agree with that of [22] who observed that the extract of *S. occidentalis*. effectively reduced *S. oryzea, S. zeamais* and *C. maculatus* infestation providing effective means of control against such pests [23]. Stated that maize treated with 10ml/kg of different plant oil induced

100% mortality within 24hours. It can be deduced that both plants powders used during the research work have a significant effect on the mortality of adult weevils. The rate of mortality was also observed to be dose dependent. However, highly significant (p<0.05) differences were observed between the *C. aurantifolia* and *S. occidentalis* powders and control.

Result shows that different *C. aurantifolia* and *S. occidentalis* powder used have significant (p<0.05) effects on emergence of adults. The marked differences in adult emergence between treated and untreated maize indicate that the *C. aurantifolia* and *S. occidentalis* of different plants had marked effects on developmental stages which in turn affected emergence. The emergence of adults was found to be indirectly proportional to the doses of plant powder. *C. aurantifolia* resulted in least emergence while *S. occidentalis* have moderate adult emergence. The chemical compound containing the bioactive component might be the reason affecting the development or improper placement of eggs and may also be the reason for low emergence.

Similar, significant effects on emergence was observed, [24] observed that sun dried orange peel was also effective in reducing F1 adult emergence of *Z. subfasciatus* from 31.66% to 17.66%when 5g and 10g/250g were applied respectively after 45days application. It was also observed that treatment of the maize variety with the various powders significantly reduced loss of weight in all the samples treated. A significant difference was observed between treated and untreated (control) in which the percentage weight loss was higher with more than 25% of the total weight loss.

Observation also have showed that viability of all treated grains was not significantly affected, as the treated grains even after three (3) month of infestation could germinate varying from 73.30- 96.70%. This is similar with Obengofori [25] who reported that oils and crude powder of several plant species have no adverse effects on the germination of maize, sorghum, and pigeon pea. [26] also reported that treatment of maize weevil with *Lantana camara* have no adverse effect on seed germination.

5. Conclusion and Recommendation

From the results obtained it can be concluded that the *C. aurantifolia* and *S. occidentalis* powders used were effective in minimizing adult progeny of weevil and also in reducing the grain damage caused by the weevils. There is need to develop effective formulation for the plant based botanicals, which can be commercialize for insect control and also Government should encourage them to use these botanicals control methods for greater safety of consumption

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