Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(4): 1320-1325

Received: 10-05-2019
Accepted: 12-06-2019

Danjumma BJ
Waziri Umaru Federal Polytechnic Department of Science Laboratory Technology Birnin Kebbi, Nigeria

Majeed Q
Usmanu Danfodiyo University Sokoto, Department of Biological Science Sokoto, Nigeria

Ibrahim ND
Usmanu Danfodiyo University Sokoto, Department of Biological Science Sokoto, Nigeria

Correspondence
Danjumma BJ
Waziri Umaru Federal Polytechnic Department of Science Laboratory Technology Birnin Kebbi, Nigeria

Organoleptic properties of maize treated with the botanicals

Danjumma BJ, Majeed Q and Ibrahim ND

Abstract

This present study investigated the efficacy of *Acacia. Nilotica, Balanite. Aegyptiaca,* and *Citrus aurantifolia,* ground leaf powders as grain protectants against *Sitophilus zeamais* in stored maize, in Usmanu danfodiyo university sokoto, Nigeria. Effect of leaf powders were evaluated on percent weight loss of grain, percent germination, insect infestation, grain colour and odour over 180 days (≈six months) duration. Leaf powders (2, 4 and 6 g/kg), synthetic pesticide (Actellic, pirimiphos methyl (0.5 g/kg)) and anuntreated control were used as treatments. All plant powders significantly minimized grain damage and infestation 96 days post treatment (≈three months) and had no effect on percent germination of maize grains when compared to controls. Grain colour and odour were not affected by plant powders after six months of storage. All plant significantly reduce grain damage and insect infestation with no adverse effects on seed germination, colour and odour hence can be used as sustainable alternatives to synthetic insecticides in maize storage especially by small holder farmers.

Keywords: *S. Zeamais, A. nilotica, B. aegyptiaca, C. aurantifolia,* maize and organoleptic

1. Introduction

1.1 Back Ground to the Study

Maize, *Zea mays* L., belongs to the family Gramineae. Is the most important cereal crops used for its nutritional and functional properties in the world [1]. Maize is a widely adapted crop, capable of growing during the appropriate season in almost every part of the world where farming is done [2]. Corn products are rapidly replacing petroleum products in many industrial applications. Polylactide (PLA), a biodegradable polymer made from corn is being used successfully in the manufacture of a wide variety of everyday items such as clothing, packaging, carpeting, and recreational equipment and food utensils of renewable resource [2].

Despite its numerous uses, it suffers destruction by pests during storage. Maize weevil, larger and lesser grain borers are the most destructive pests of stored maize worldwide [2]. They are all primary pests of whole grains, in which immature stages develop [4]. Infested grains are hollowed out and perforated, thereby allowing entry of secondary pests which accentuate damage [4]. Maize weevil (*Sitophilus zeamais* Motschulsky) measures 3.5-4mm in length. It is reddish- brown to black in colour. The ideal temperature for it to lay eggs was 25^0C -28^0C, the total developmental period was 39 days [5]. Depending on the temperature and relative humidity (rh) of the environment, the whole development cycle takes 4-16 weeks, the number of the eggs laid, the viability of these eggs and time taken for adult to emerge may all vary in samples of different maize varieties [6, 7] estimated that out of a total annual harvest of 250,000,000.00 tons of maize in Ghana, about 20% was lost to *S. zeamais*, in some cases even total losses were recorded.

Female weevil, through three generations of weevils per year has the biotic potential to produce 1.5 million offsprings that will consume 1.5 million kernels of rice [8]. Stated that damage to maize grain is actually done to endosperm, and major economic loss caused by these weevils is not always the actual material they consume, but also the amount of contamination from their excreta, thereby making they unfit for human consumption.

[9, 10] estimated that in sub-Saharan region of Africa the loss of food grain during storage at farm or village level amounted to 25 – 40% of the harvested crop. It is also observed that in Nigeria up to 28% losses were recorded in stored maize in cribs due to insect damage [10]. Various materials and methods are currently being tested for the control of *Sitophilus* spp. These include: use of resistant variety, physical, chemical and botanical control. This research therefore, reported on the use of plant extract for their toxicidal efficacy against *S. zeamais* and their effect on the organoleptic properties of treated maize.

1.2 Justification of the Study
The toxicidal effects of some of these plant materials e.g *Nicotiana. tabacum* and *Tagetes minuta,* against maize and cowpea weevil have been studied in Nigeria by many researchers such as, [11, 12]. However, only few have investigated the effect of these, often strong smelling botanical plants on treated grains in the study area. The choice of these plants was based on the indigenous knowledge along with previous studies. It is hoped that the findings obtained from the study will substantially help in the selection of plant material that have less effect on organoleptic properperites of grain.

1.3 Aim and Objectives
The aim of this work is to assess the effect of organoleptic properties of treated maize.
1. To determine the toxicidal efficacy of five selected leaf powders against maize weevil.
2. Resultant effect on organoleptic properties of maize treated with the botanicals.

2. Materials and Methods
The experiments were carried out in the Entomology Laboratory, Department of Biological Sciences, Usmanu Danfodiyo University Sokoto, Nigeria, from February 2014 to November 2016 under the Laboratory conditions. The monthly average temperature and relative humidity varies from 20^0C- 45^0C and 55% -70% [13].

2.1 Collection and Preparation of Maize Grains
Untreated maize grain was sourced from Ministry of Agriculture in Binin Kebbi, Nigeria. In the laboratory, grain was sieved to remove fluffy material and other foreign matter [12]. The uninfested maize was treated with 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. They were later aired for two days to allow dissipation of fumigant effect [14]. Moisture content, the percent of broken and seed viability were assessed before commencement of experiments.

2.2 Collection and Identification of Leaf Materials Used for Testing Toxicity
The following plants were selected based on some indigenous knowledge about their toxicity and their toxic roles as described [15, 12] in the control of weevil. *Acacia nilotica, Balanites aegyptiaca* L. (Del) and *Citrus aurantifolia* were obtained from Biological Garden of the Usmanu Danfodiyo University Sokoto, The plants were identified and authenticated in the Department of Biological Sciences, of the University, Sokoto the assistance of herbarium curators and a vourcher specimen (*A. nilotica*, UDUH/ ANS/0195; *B. aegyptiaca*, UDUH/ANS/0189; *C. aurantifolia*, UDUH/ANS/0216; were prepared and deposited in the herbarium for posterity. All the collected plant materials were shade dried for ten days. The dried materials were ground separately into coarse powder that was sieved into fine powder using 0.08mm mesh size. Five hundred gram (500g) of the powder of each plant was obtained and kept in separate polyethylene bags in the laboratory for use. Actellic dust 2% (Pirimiphos methyl), used for weevil control was purchased from the Market (selected as check/ standard).

2.3 Insect Culture
Maize grains infested with maize weevil were purchased from Birnin Kebbi Central Market, to obtain adult *Sitophilus zeamais,* five hundred unsexed adult S. zeamais were reared under ambient laboratory conditions in one- liter glass jars containing 500g of uninfested maize grains. The top of each glass jar was covered with a cloth and fastened tightly with rubber bands. Insect were allowed to oviposit for 10 days after which all adults were removed through sieving [12]. Seaved grain was placed in clean jores and left for a period of 28-35 days during which emergence of adult was assessed by sieving the grain. Adult that emerged on the same day were considered of the same age. New generations were sustained by the replacement of devoured grain with fresh and uninfested grain. Experiments were conducted using the first generation of insects reared.

Table 1: Plant Species used in Testing Toxicidal Efficacy

	Botanical Name	Common Name	Local name	Family	Part used
1	*Acacia nilotica* L.	Arabian wattle	Bagaruwa	Leguminoseae	Leaves
2	*Balanites aegyptiaca* L. (Del)	Desert date	Aduwa	Zygophyllaceae	Leaves
3	*Citrus aurantifolia* (Christm. & Panzer) Swinge	Lime orange	Lemuntsami	Rutaceae	Leaves
6	Pirimiphos methyl	Actellic dust 2%			

2.4 Toxicidal Efficacy of Selected Plant Material
To study the toxicidal efficacy of varying doses of leaf powders of selected plants against maize weevil, five (5) sterilized plastic containers were obtained and to each 100g of sterilized maize was added. In the first three, the grains were dusted with 2.0gm of each of the three powders separately, while the 4th container was treated with Actellic dust 0.50g (Standard dose) and the 5th 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 five (5) containers. All containers were kept in the laboratory under ambient condition for seven days. Observations were made daily to record mortality among adults. Similar experiments were conducted using the increased amount to 4gm and 6gm/100g of seed and similar observations were made [12, 14, 16]. All experiments were replicated three times.

2.5 Quantitative loss (Loss in weight and grain damage) to maize
In order to evaluate the quantitative loss caused to maize by *S. zeamais* infestation 100g used in each treatment was reweighed at the end of the 12 weeks of experiment to observe the loss in weight. The percentage seeds damage was calculated according to [17], also one hundred (100) grains were picked at random and sorting them into holed (damaged) and whole (undamaged) and the following formula was used to calculate the percentage damage.

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

Percentage seed weight loss was calculated according to [17]
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 difference in weight loss.

$$\% \text{ weight loss} = \frac{W_2 x100}{W_O}$$

2.6 Organoleptic Test of Treated Maize Grain

Sensory evaluation of maize treated with different plant powders through hedonic evaluation at 95% Confidence level was carried out by testing the treated seed for taste, odour and appearance, 120 days post treatment. Twenty gram (20gm) of each treated and control maize was measured and rinsed with clean water before cooking. Each sample was cooked with 200ml of water for 1hr under moderate temperature on an electric cooker. Small amount of cooking salt was added to each sample to add taste. The cooked grain was served warm in labeled disposable container to a team of five (5) panelists. Questionnaires were administered to assess the effect of treatments on the taste, odour and appearance of the treated grains. A 5- point hedonic scale (ranging from poor to excellent) was used for the assessment [11, 18].

2.7 Data Analysis

The data obtained from the experiment were subjected to analysis of variance using startistical package for social science (SPSS), version 20. Treatment means 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*

Mortality of adults

The plant powders tested for their insecticidal efficacy were found to be toxic, causing the mortality among adults of *S. zeamais,* and this was directly proportional to the amount of powder used in each of the treatment. Table 2 shows that most of the powders used caused fifty percent mortality even at low doses. *B. aegyptiaca* was least effective among all the plants resulting in 31.68% adult mortality, while the powder of *A. nilotica* was observed to be most effective causing 59.18% mortality, even when used in low amount (2.0g). The mortality among the adults reared on maize treated with the same amount of *C. aurantifolia* was slightly less (47.57%). The mean mortality recorded among adults reared on untreated but infested maize (control) was 4.18%. The highest mortality rate of (100%) was observed on maize treated with 0.5g Actellic dust (Pirimiphos methyl) within 4.67 days of post infestation.

The increase in concentration of the powders to 4.0g and 6.0g resulted in an increase in the mortality within 7 days of their introduction. Actellic dust took an average of 4.33 days to cause total mortality, while control had 2.50% mortality. All the plants powders used have significant effects on the mortality of adults. The rate of mortality was also observed to be dose dependent. However, highly significant ($p<0.05$) differences were observed between all the test leaf powders and control.

Table 2: Mortality among adults of *S. zeamais* reared on local variety of maize treated with powders of selected plants leaves (Within 7 days of post infestation) (Each observation is based on three replicates)

Powders used as 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
A. nilotica	23.67^{b}± 0.33(59.18)	34.00^{b}±0.58 (85.00)	40.00^{a}± 0.00 (100)
B. aegyptiaca	20.33^{cd}±0.33 (50.83)	32.33^{c}±0.67 (80.83)	39.00^{ab}± 0.33(98.33)
C. aurantifolia	19.00^{d}± 0.58(47.57)	30.67^{d}±0.33 (76.68)	39.33^{ab}±0.33 (98.33)
Pirimiphos methyl (0.5g)	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 of significance using Duncan's New Multiple Range Test (DNMRT)

3.2 Quantitative loss in weight to maize grains

The quantitative losses, of weight and grain damages caused to maize by *S. zeamais* are presented in Table 3. All the maize grains treated with different amount of plant powders showed varying significant quantitative losses.

It is observed in Table 3 that grains treated with Actellic dust had least losses and damage (0.15%) while untreated grains have the highest loss (16.10%). The grains treated with plant powders have varying degree of losses which were less than the untreated (control) but slightly higher than Actellic dust. Maize treated with 2.0g of *A. nilotica* had small weight loss (3.93%), followed *C. aurantifolia* (6.17%), and *B. aegyptiaca* (11.03%). There was a decrease in quantitative losses caused to maize treated with an increased amount of 4.0g and 6.0g of various plant powders (Table 3). The higher the amount the lower the weight loss. Actellic dust, which had a fixed concentration, had almost the same amount of loss (0.17%) while untreated Control had maximum 16.03%.

Number of damaged seeds in each treated maize is shown in Table 3. When the maize was treated with 2.0, 4.0 and 6.0g /100g, *B. aegyptiaca* shows highest exit hole (11.67%) followed by *C. auranifolia*. *A. nilotica* treated seeds had 5.67%, the actellic dust did not show any exit hole, and control (untreated) has 15.33% exit hole. When the powder was increased to 4.0g, the number of exit hole decreased. The highest exit hole recorded from the *B. aegyptiaca* (9.33%) and the loweste from *A. nilotica* (3.00%), while the actellic dust 0.67%. untreated but infested had 14.67% damaged seed. When the plant powder was increased to 6g/100g all the grains show few damage seeds, the higher the amount of powder used for treatment, the less is the loss and damage to maize grain.

3.3 Sensory Evaluation of the Treated Maize Grains

Response of panelists on the effects of varying doses of different plant powders, and synthethic pesticide on the color, odour and taste of treated cooked maize seeds after 90 days of storage are contained in Tables 4-6

Table 4 and 5 indicated, the effects observed on colour, odour and taste of cooked maize grains treated with 2g and 4g of various powder. The application of varying doses of different plant powders and insecticides used in the control of maize weevil did not cause any significant change on the maize. Significantly higher values (4.56-4.78) were recorded on grains treated with varying doses of *A. nilotica*, *C.aurantifolia* and Actellic dust. *B. aegyptiaca* caused slight change at varying doses 3.89-3.90. Control/ untreated grain recorded the lowest values (2.78-3.00).

Table 3: Effect of various doses of different plant powders on the weight and damage caused maize due to infestation by *S. zeamais*

Powders used As treatment	Amount Applied (g/100g)	No of adult inoculated	Mean Weight loss ±SE/% weight loss		MeanDamage ±SE/ % Damage	
			MWL	%WL	MDG	%DG
A. nilotica	2	20	3.53^{f}±0.07	3.93	5.67^{e}±0.67	5.67
	4	20	2.00^{f}±0.07	2.13	3.00^{e}±0.02	3.00
	6	20	0.73^{f}±0.07	0.73	1.33^{ed}±0.33	1.33
B. aegyptiaca	2	20	9.10^{b}±0.10	11.03	11.67^{b}±0.67	11.67
	4	20	7.07^{b}±0.70	9.13	9.33^{b}±0.33	9.33
	6	20	5.80^{b}±0.07	6.13	6.00^{b}±0.58	6.00
C. aurantifolia	2	20	5.50^{e}±0.12	6.17	7.33^{d}±0.33	7.33
	4	20	3.13^{e}±0.12	3.57	4.33^{d}±0.33	4.33
	6	20	1.30^{e}±0.15	1.30	1.67^{d}±0.33	1.67
Actellic dust 2%	0.5	20	0.15^{g}±0.03	0.15	0.67^{f}±0.33	0.01
	0.5	20	0.17^{g}±0.33	0.17	0.67^{f}±0.33	0.67
	0.5	20	0.17^{g}±0.33	0.13	0.33^{e}±0.33	0.33
Control	0.0	20	13.35^{a}±0.08	16.10	14.33^{a}±0.67	15.33
	0.0	20	13.13^{a}±0.13	15.97	14.67^{a}±0.33	14.67
	0.0	20	13.20^{a}±0.15	16.03	13.33^{a}±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)

Response from the panelists shows that all the plant materials did not cause any significant change in grains color, odour and taste almost remain unchanged (the grains is still attractive).

Table 4: Organoleptic Qualities of cooked maize grains treated with 2g of Different plant powders

Organoleptic Quality					
Powders used	**Amount used**	**Colour**	**0dour**	**Taste**	**Acceptance**
A. nilotica	2.0	5.00^{a}±0.00	4.67^{a}±0.33	4.67^{a}±0.33	4.78^{a}
B. aegyptiaca	2.0	3.67^{b}±0.33	4.00^{b}±0.02	4.00^{b}±0.00	3.90b
C. aurantifolia	2.0	4.67^{a}±0.33	4.67^{a}±0.33	4.33^{b}±0.33	4.56^{a}
Control	0.0	3.00^{c}±0.0	3.00^{c}±0.01	3.00^{c}±0.01	3.00^{c}

Hedonic Scale: 5- Excellent. 4- V Good. 3- Good. 2- Fair. 1- Bad. 0 - Poor. Means that have the same super script within a column are not significantly different at 5% level of significance of significance using Duncan's New Multiple Range Test (DNMRT)

Table 5: Organoleptic Qualities of cooked maize grains treated with 4g of Different plant powders

Organoleptic Quality					
Powders used	**Amount used**	**Colour**	**0dour**	**Taste**	**Acceptance**
A. nilotica	2.0	4.67^{ab}±0.33	4.67^{a}±0.33	4.67^{a}±0.33	4.67
B. aegyptiaca	2.0	4.00^{bc}±0.0	4.00^{b}±0.01	3.67^{b}±0.33	3.9^{c}
C. aurantifolia	2.0	5.00^{a}±0.0	4.33^{a}±0.33	4.33^{b}±0.33	4.55^{a}
Actellic dust	0.5	4.67^{ab}±0.33	4.67^{a}±0.33	4.67^{a}±0.33	4.67^{a}
Control	0.0	2.67^{d}±0.33	3.00^{c}±0.01	2.67^{c}±0.33	2.78^{d}

Hedonic Scale: 5- Excellent. 4- V Good. 3- Good. 2- Fair. 1- Bad. 0- Poor. Means that have the same super script within a column are not significantly different at 5% level of significance of significance using Duncan's New Multiple Range Test (DNMRT)

Table 6 revedal that the application of 6g of different plant powders and insecticide used in the control of maize weevil have no effect on the Colour, odour and taste of cooked grains. Significantly higher values were obtained from of *A. nilotica, C. aurantifolia* and Actellic dust showing higher acceptance (4.22-4.33). Grain treated with varying doses of *B. aegyptiaca* recorded moderate values, without any significance difference. The lowest scores were recorded on control/untreated. The overall assessment showed almost all the treatment displayed moderate level of acceptance.

Table 6: Organoleptic Qualities of cooked maize grains treated with Different plant powders

		Organoleptic Quality			
Powders used		**Colour**	**0dour**	**Taste**	**Acceptance**
A. nilotica	6.0	4.33^{ab}±0.33	4.33^{b}±0.33	4.33^{b}±0.33	4.33^{a}
B. aegyptiaca	2.0	4.00^{ab}±0.0	3.67^{b}±0.33	3.33^{bc}±0.33	3.67^{b}
C. aurantifolia	2.0	4.33^{ab}±0.33	4.33^{a}±0.01	4.00^{b}±0.33	4.22^{a}
Actellic dust	0.5	4.67^{ab}±0.33	4.33^{a}±0.33	4.33^{ab}±0.33	4.44^{a}
Control	0.0	2.67^{c}±0.33	3.00^{c}±0.01	3.00^{c}±0.02	2.89^{c}

Hedonic Scale: 5- Excellent. 4- V Good. 3- Good. 2- Fair. 1- Bad. 0- Poor. Means that have the same super script within a column are not significantly different at 5% level of significance of significance using Duncan's New Multiple Range Test (DNMRT)

4. Discussion

Local variety of maize treated with various leafs powders, indicatedthe potentials of these products as protectants against maize weevil. Admixture of maize with *A. nilotica* seems to be most effective in killing the adult weevil especially at higher doses, followed by *B. aegyptiaca* Treament with *C. aurantifolia*. Produce moderate results compared with *A. nilotica B. aegyptiaca* and Actellic dust treated samples showed higher mortality, this is similar to [19] who reported the effectiveness of *Eucalyptus grandis* and *Tagetes minute l*eaf powder as post-harvest grain protectants against *S. zeamais*. Significant differences were observed between treatments and the controls.

The possible reason could be that the active components of all plants might have affected the physiology of the beetles. ***A.*** *nilotica* leaf powder observed to be more promising in killing the insect (50%), even at small doses (2.0g). Highest mortality (100%) was observed at higher dose (4.0g) of *A. nilotica* only after 168 hr of infestation. This is in conformity with [20] who found that the extract of *A. nilotica* have strong antifeedent activity and act as contact poison against variety of insect pests. Efficacy of *A. nilotica* bark and root powder on the mortality of *S. zeamais* was assessed by [16] who recorded 100% mortality among 10 pair of *S. zeamais* within144h of treatment with 1.5g/20g dose of powders.

Accelerating effect on mortality was observed with an increased amount of the powder. [21] Recorded a high repellency effect of *B. aegyptiaca* extractva gainst *S. zeamais*. Response based on 5-point hedonic scale pertaining to the effect of the plant and synthetic powders on the organoleptic property of the cooked treated maize grains after six months period of storage confirmed that the grains treated with both the plant powders and synthetic insecticide could be accepted by general public for consumption. The highest acceptance for consumption was with *A. nilotica*, and *C. aurantifolia* and actellic dust (Pirimiphus methyl), while *B. aegyptiaca* have moderately affected the odour of the grains, but still generously acceptable. [11] Reported that crude powder of several plant species have no effect on organoleptic properties of stored grain. [19] Stated that *Eucalyptus grandis* and *Tagetes minuta* leaf powders effectively protect stored maize against *S. zeamais* without affecting grains organoleptic properties. Present observations are contrary to the findings of [22] who reported that plant products and insect infestation adversely affect the taste, aroma, and overall acceptability of chapattis from the treated maize rendering the grains unsuitable for human consumption. Okunola *et al*. (2007) also evaluated the effect of essential seed oil applied on the cowpea and maize grains after storage for six (6), where panelist's assessment showed that the qualities of the seeds treated with lower doses (5ml/kg) of *Piper guineense, Eugenia aromatic* and *Monodoura myristica* seed oil were are significantly less affected by the oil treatments. Similarly [23] also reported that the use of crude powder of 17 botanical plant species on sorghum had no effect on seed germination.

5. Conclusion

One of the major concerns regarding use of insecticidal plants to control grain storage pests is the perceived fear that these products can adversely affect the taste, aroma and overall acceptability of treated grain. This study evaluated both the insecticidal and organoleptic properties of ground powders of *A. nilotica B. aegyptiaca*, and *C. aurantifolia,* find out that theare still acceptable to the palanist

6. Reference

1. IITA. (2006). Maize overview. In: Research to Nourish Africa. Www, iitaresearch.org. Retrieved Oct, 2013.
2. Akande SR, Lamidi GO. Performance of quality protein maize varieties and disease reaction in the derived savannah agro-ecology of South West Nigeria. Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria. 2006; 1-4.
3. Efidi TT, Nwani CD, Udoh S. Efficacy of some plant species for the control of cowpea weevil (*Callosobruchus maculantus*) and maize weevil (*Sitophilus zeamais*) International Journal of Agriculture and Biology. 2009; 10(5):588-590.
4. Nwaubani SI, Fasoranti JO. Efficacy of cow bone charcoal dust in the management of maize weevil, *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae), and lesser grain borer, *Rhyzopertha dominica* Fab. (Coleoptera: Bostrichidae), infesting stored maize (*Zea mays* L.) grains. Nigeria Journal of Entomology. 2008; 25:15-25.
5. Parugrug ML, Roxas AC. Insecticidal action of five plants against Maize weevil, *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae). Journal of Science and Technology. 2008; 8(1):24-38.
6. Makate N. Susceptibility of different maize varieties to post-harvest infestation by *Sitophilus zeamais* (Coleoptera: Curculionidae). Scientific Research and Essay. 2010; 5(1):030-034.
7. Obeng-ofori D, Amiteye S. Efficancy of mixing vegetable oils with Pirimiphos-methyl against the maize weevil, *Sitophilus zeamais* Motschulsky in stored maize. Journal of Stored Products Research. 2005; 41:57-66.
8. Kossou DK, Bosque-Perez NA. Insect Pests of maize in Storage, Biology and Control. IITA Research Guide 32, Training program, International Institute of Tropical Agriculture (IITA), Second edition Ibadan, Nigeria, 1995, 28.
9. FAO. Global food losses and food waste extent causes

and prevention FAO: Rome, Italy Retrieved July 2012, 2011.

10. Lipinski B, Hanson C, Lomaw J, Kitinoja L, Waite R, Searchinger T. Reducing food loss and waste. Working Paper Installment 2 of Creating a Sustainable Food Future. Washington, DC World Resources Institute. 2013; 2-16.
11. Ojanuga AG. Agroecological zones of Nigeria Manual, National Special programme for food security FAO. Abuja, Nigeria, 2006, 124.
12. Golob P, Webley DJ. The use of plants and minerals as traditional protectants of stored products. Tropical Research Institute. 1980; 138:1-32.
13. Danjumma BJ, Ibrahim ND, Majeed Q, Yahaya MA, Bandiya HM, Yahaya MM. Toxicidal efficacy of *Azadirachta indica* (A. Juss) Kernel and *Ocimum basilicum* (Linn.) leaves against maize grain weevil, *Sitophilus zeamais* (Motsch.) infesting *Zea mays* (Linn.). Journal of Agriculture and Environment. 2009; 5 (2)**:**85-90.
14. Danjumma BJ, Yusuf M, Nege P, Majeed Q. Effects of powder of *Citrus aurantifolia* and *Senna occidentalis* on the development of maize weevils, (*Sitophilus zeamais* Motschulsky, Coleoptera: Curculionidae). Journal of Entomology and Zoology studies. 2018; 6(2):2216-2221.
15. Abdullahi N, Umar I, Tukur Z, Babura SR. Comparative efficacy of the bark and root powders of *Acacia nilotica* against maize weevil *Sitophilus zeamais* (Motsculsky) (Coleoptera: Curculionidae) in Kano state of Nigeria. African Journal of Agricultural Research. 2014; 9(6):588-592.
16. Tefera TM, Muga S, Ikhayo P, Tende R. Effects of insect population density and storage time on grain damage and weight loss in maize due to the maize weevil *Sitophilus zeamais* and larger grain borer *Prostephanus truncatus*, African Journal of Agricultural research. 2011; 6:2249-2254.
17. Enobakhare DA, Law-Ogbomo KE. Reduction of postharvest loss caused by *Sitophilus zeamais* (motsch) in three varieties of maize treated with plant Products. Postharvest Science. 2002; 1:1-6.
18. Ogendo JO, Deng AL, Belmain SR, Walker DJ, Musandu AAO. Effect of insecticidal plant materials, *Lantana camara L.* and *Tephrosia vogelli* Hook, on the quality parameters of stored maize grain. African Journal of Food Technology. 2004; 9:29-36.
19. Okunola CO, Okunola AA, Abulude FO, Ogunkoya MO. Organoleptic qualities of maize and cowpea stored with same essential oils. African Crop Science Conference Proceedings. 2007; 8:2113-2116.
20. Singh RN, Saratchandra B. The development of Botanical products with special reference to seriecosystem. Casian Journal of environmental Science. 2005; 3(1):1-8
21. Lekhu G, Singh PM. Repellent powder of some plant extract against *Calosobruchus maculatus F. infesting* Beans seeds (*Vigna unguiculata*). Advances in Plant Science. 2004; **7**(2):457-459.
22. Sule H, Ahmed BI. Effect of plant product, application rates and grain type on the control of red flour Beetle *Tribolium casteneum* Herbst (Coleoptera: Tenebrionidae) on stored millet (*Pennisetum glaucum*). Academic Journal of Entomology. 2009; 2(1):22-30.
23. Musundire R, Mazodze F, Machela L, Ngadze RT, Mubaiwa J, Manditsera F. *Eucalyptus grandis and Tagetes Minuta* leaf powders effectively protect stored maize against *Sitohphilus zeamais* without affecting grain organoleptic properties. African Journal of Agriulture Research. 2014; 10(2):49-57.
24. Jood S, Kapoor AC. Protein and Uric acid Contents of Cereal Grains as Affected by Insect Infestation. Food Chemistry. 1993; 46:143-146.
25. Kasa A, Tadese A. Evaluation of some botanicals against the maize weevil, *Sitophilus Zemais* Motsch., on stored sorghum at Bako. In: Bekele,E, Abdullahi, A., and Yemane, A.,(eds.). Proc. 3rd Annual Conference of the Crop Protection Society of Ethopia. May 18-19. 1995 Addis Abeba Ethopia. CPSE. 1996, 120-126.