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Entomocidal Activity of Powders and Extracts of Four Medicinal Plants Against *Sitophilus oryzae* (L), *Oryzaephilus mercator* (Faur) and *Ryzopertha dominica* (Fabr.)

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Abstract

Powders and extracts of *Azadirachta indica, Zanthoxylum zanthoxyloides*, *Anacardium occidentale* and *Moringa oleifera* were assessed in the laboratory at ambient temperature of 28±2^{o}C and relative humidity of 75±5% for their insecticidal activity against *Sitophilus oryzae, Oryzaephilus mercator* and *Ryzopertha dominica* infesting paddy rice. The powders of these plants were tested against these insects at 0.4g, 0.6g, 0.8g and 1g/50g of paddy while the extracts were tested at 2%, 4%, 6% and 8% concentrations. Both the powders and extracts of these botanicals evoked a high mortality effect on the insects. Moreover, both the extracts and powders of *A. indica* and *Z. zanthoxyloides* showed greater insecticidal bustle than the powders and extracts of *A. occidentale* and *M. oleifera* as they both achieved 100% insect mortality within a short period after treatment. The extracts of these plants were also able to prevent the emergence of adult insects. *S. oryzae* and *R. dominica* were more affected with all the powders and extracts of these botanicals than *O. mercator* which was more vulnerable to the extracts and powders of *Z. zanthoxyloides* than other botanicals. Moreover, all the plants used showed a greater insecticidal effect and could be integrated into pest management system.

Keywords: *Azadirachta indica, Zanthoxylum zanthoxyloides, Anacardium occidentale, Moringa oleifera, Sitophilus oryzae, Oryzaephilus mercator, Rhyzopertha dominica*

1. Introduction

Loss of cereal grains via insect infestation during storage is a serious problem, particularly in the developing countries, where damage to stored grains and their products by insects may amount to 5 - 10% in the temperate countries and 20 - 30% in the tropical zones (Dubey *et al*., 2008; Rajashekar and Shivanandappa, 2010; Ileke and Oni, 2011; Akinneye and Ogungbite, 2013). Rice is the seed of the monocot plant *Oryza sativa* (Ashamo and Akinnawonu, 2012). It is the grain with the second highest worldwide production, after maize (FAO, 2010). Rice helped Africa to conquer its famine of 1203 (NRC, 1996; Ashamo and Akinnawonu, 2012). Rice, being one of the staple foods mostly consumed by many parts of the world, has been infested by many important insect pests such as *Sitotroga cerealella, S. oryzae, S. granarius, R. dominica, O.mercator* as well as *Scirpophaga incertulas* and *Scirpophaga innotata* among others (Sarwar, 2012; Ashamo and Akinnawonu, 2012). Therefore, crop protection plays a vital and integral role in modern agricultural production; and the ever-lasting demands on yield as well as intensification of farming practices have increased the problem of pest damage and hence control (Martins *et al.*, 2012).

Infestation control of stored grains insect pests is primarily achieved by the use of synthetic chemical insecticides, such as methyl bromide and phosphine. In several countries, due to environmental concerns and human health hazards, several chemical insecticides have either been banned or restricted (Tapandjou *et al.*, 2002). The adverse effects of the most novel chemical insecticides have led researchers to try to find new avenue of insect control, which has led to the discovery of plant products as an alternative way of controlling insects (Sutherland *et al*., 2002; Zibaee, 2011). Moreover, tropical regions are believed to be endowed with many plant species with insecticidal properties and some of them are with medicinal properties (Ileke and Oni, 2011). Therefore, this research investigates the entomocidal of powders and oil extracts of four medicinal plants against *S. oryzae, R. dominica*, and *O. mercator* which are important insect pests of paddy rice in storage.

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2. Materials and Methods

2.1. Insect Culture

The adults *S. oryzae, R. dominica* and *O. mercator* used were obtained from the existing cultures in the Department of Environmental Biology and Fishery Research Laboratory, Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria. Clean un-infested paddy rice variety FARO-36, collected from the International Institute for Tropical Agriculture, Ibadan, Nigeria, was used to rear the insects inside 2 litres jars covered with muslin cloth. The jars were kept at 28±2e°C and 75±5% relative humidity in insect cages and the culture was maintained by replacing the devoured grains with fresh uninfested one.

2.2. Preparation of Plant Materials

The used plant materials, *A. indica* seeds, *Z. zanthoxyloides* roots, *A. occidentale* nuts and *M. oleifera* seeds were sourced fresh from a farm at Ipinsa, Akure, Ondo State, Nigeria. The plants were sun dried, separately milled into fine powders, sieved to pass through 1mm^2 mesh and kept inside different plastic containers with tight lids at 4°C in a refrigerator at prior to use.

2.3. Preparation of the Extracts

Methanolic extracts of *A. indica, Z. zanthoxyloides, A. occidentale* and *M. oleifera* were carried out using cold extraction method. About 150g of the powders were soaked separately in an extraction bottle containing 450ml of absolute methanol. The mixture was stirred occasionally with a glass rod and extraction was terminated after 72 h. The resulting mixture was filtered using a double layer of Whatman No. 1 filter paper and the solvent was evaporated using a rotary evaporator at 30 to 40°C with rotary speed of 3 to 6 rpm for 8 h (Udo, 2011). The resulting materials were air dried in order to remove traces of solvents. From this stock solution, different concentrations of 2%, 4%, 6% and 8% were prepared (Ashamo and Akinnawonu, 2012; Ileke and Bulus, 2012; Ileke *et al*., 2013).

2.4. Toxicity of Plant Powders to Adult Insects

Fifty grams of paddy rice (FARO-36) was weighed into 250ml plastic containers and the plants powders weighing 0.4g, 0.6g, 0.8g and 1.0g were added to each weigh. The powders and the paddy were thoroughly mixed together to ensure uniform spread of the powders. Untreated paddy rice was set as control. Ten pairs of adult insects were introduced into each container.

Four replicates of each treatments and untreated controls were laid out in Complete Randomized Design. Adult mortality was counted and recorded after 48 and 72 hours of application. Both dead and alive insects were removed away on the fourth day and experiments were left for 35days to allow for emergence of F1 generation and the number of adults emerged was counted. Inhibition rate (%IR) in adult emergence was calculated using the method described by Tapandjuo *et al.* (2002).

$$\%IR = \frac{C_n - T_n}{C_n} x \frac{100}{1}$$

where Cn is the number of emerged insects in the control and Tn is the number of emerged insects in the treated container.

2.5. Effect of Oil Extracts on Mortality of Adult Insects

Fifty grams of paddy rice (FARO-36) were weighed into 250ml plastic containers and 1ml of plant extracts concentrations of 2, 4, 6 and 8% were separately mixed with the paddy and were left for 1hr to ensure the evaporation of the volatile solvent. Two control treatments were set up, one with solvent alone and one without solvent or extract (untreated control). Ten pairs of adult insects were introduced into each container. Four replicates of the treatments and untreated controls were laid out in Complete Randomized Design. Adult mortality was observed after 48 and 72hours of application. Both dead and alive insects were removed on the fourth day and experiments were left for 35days to allow for adult emergence of F1 generation and the number of emerged adults were counted. Inhibition rate (%IR) in adult emergence was calculated as described above.

2.6. Analysis of Data

All the data obtained were subjected to one-way analysis of variance at 5% significance level and means were separated using New Duncan's Multiple Range Tests.

3. Results

3.1. Effect of Plant Powders on Mortality of S. oryzae, O. mercator and R. dominica

Table 1 presents the effect of plant powders on mortality of *S. oryzae*, *O. mercator* and *R. dominica*. All the plant powders had a significantly high mortality effect on the three tested stored product insects at (p<0.05). Within 48h of application, only the powder of *A. indica* at 1.0g concentration achieved 100% mortality of *S. oryzae* and was significantly different from other powders. Also, the powder of *Z. zanthoxyloides* at 1g affected significantly with 100% mortality of *O. mercator* within 48h of exposure at (p<0.05). However, none of the tested powders was able to achieve complete mortality of *R. dominica* within 48h of application. After 72h of exposure, the powder of *A. indica* and *Z. zanthoxyloides* at 1.0 g caused 100% mortality for the three tested insects. In addition , both previous powders at 0.8 g achieved 97.63 - 100% mortality for the three tested insects. However, *R. dominica* was the most sensitive one to the three powders, *A. indica* ,*Z. zanthoxyloides* and *A. occidentale* at 0.8 and 1.0 g (100% mortality) On the other hand, powder of *M. oleifera* was less potent on the three tested insects, mortality ranged between 30.00 to 72.24% at all the used concentrations.

Table 1. Percentage mortality of *S. oryzae, O. mecator* and *R. dominica* on paddy rice treated with plant powders

Plant materials	Dosage (g)	% Mortality (Mean ± SE)					
		S. oryzae		*O. mecator*		*R. dominica*	
		48 hrs.	72 hrs.	48 hrs.	72 hrs.	48 hrs.	72 hrs.
A. indica	0.4	54.00±0.24^{d}	76.00±0.84^{e}	49.40±2.40^{cd}	54.24±2.58^{c}	46.70±0.33^{c}	70.58±0.58^{d}
	0.6	76.00±0.88^{ef}	98.00±1.22^{gh}	56.00±1.28^{d}	80.58±0.58^{ef}	72.50±2.50^{e}	92.70±1.33^{f}
	0.8	85.24±0.67^{f}	100.00±0.00^{h}	59.27±0.88^{d}	95.30±0.33^{f}	80.30±0.67^{f}	100.00±0.00^{g}
	1.0	100.00±0.00^{g}	100.00±0.00^{h}	67.00±1.30^{e}	100.00±0.00^{fg}	91.00±0.66^{g}	100.00±0.00^{g}
Z. zanthoxyloides	0.4	50.00±0.58^{cd}	68.00±0.67^{de}	58.00±1.67^{d}	76.00±0.84^{e}	45.00±0.24^{c}	65.00±0.24^{cd}
	0.6	70.00±1.80^{e}	92.00±0.24^{g}	86.00±0.88^{f}	100.00±0.00^{g}	72.00±0.88^{e}	89.68±0.88^{ef}
	0.8	80.00±1.00^{f}	97.63±1.33^{gh}	92.67±2.44^{f}	100.00±0.00^{g}	79.86±2.67^{ef}	100.00±0.00^{g}
	1.0	86.67±0.33^{f}	100.00±0.00^{h}	100.00±0.00^{fg}	100.00±0.00^{g}	89.06±0.22^{fg}	100.00±0.00^{g}
A. occidentale	0.4	46.70±0.33^{c}	57.00±2.24^{cd}	40.25±0.67^{c}	55.00±0.24^{c}	46.00±0.88^{c}	68.00±0.28^{cd}
	0.6	56.70±0.88^{d}	66.00±2.24^{d}	53.00±2.43^{d}	65.25±0.88^{d}	73.23±1.67^{e}	93.00±0.24^{f}
	0.8	66.00±0.58d^{e}	88.24±1.00^{fg}	57.24±2.88^{d}	89.00±1.67^{f}	81.00±2.67^{f}	100.00±0.00^{g}
	1.0	72.70±0.88^{e}	90.00±0.88^{g}	67.12±0.88^{e}	97.86±2.24^{fg}	90.00±0.24^{g}	100.00±0.00^{g}
M. oleifera	0.4	30.20±2.44^{b}	44.00±0.28^{b}	30.00±4.08^{b}	43.08±0.28^{b}	31.00± 0.58^{b}	42.00±2.33^{b}
	0.6	42.24±0.88^{c}	48.59±2.45^{b}	37.50±2.50^{b}	46.00±0.58^{b}	49.30± 1.00^{c}	52.47±0.67^{b}
	0.8	57.24±2.88^{d}	63.00±1.87^{d}	49.00±2.89^{cd}	58.00±1.33^{c}	63.00± 1.00^{d}	66.00±0.24^{cd}
	1.0	59.12±0.67^{d}	69.10±2.67^{de}	56.50±1.33^{d}	69.82±2.67^{d}	68.67±0.33^{de}	72.24±0.88^{d}
Control	0.0	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}

Each value is a mean ± standard error of four replicates. Means followed by the same letter along the column are not significantly different ($P>0.05$) using New Duncan's Multiple Range Test.

3.2. Effect of Plant Extracts on Mortality of S. oryzae, O. mercator and R. dominica

The effect of different plant extracts on mortality of *S. oryzae, O. mercator* and *R. dominica* was presented in Table 2. All the used plant extracts showed a higher mortality effect on the three insects than the powders and their effect increased as the period of exposure increased. The extracts of *A. indica* and *Z. zanthoxyloides* at all concentrations were able to achieve complete mortality of *S. oryzae* within 48h of exposure and their effect was significantly ($p<0.05$) different from other extracts, in addition, the extract of *A. occidentale* at 6% and 8% concentrations achieved 95% and 100% insect mortality of *S. oryzae* at the same time of examination, respectively. Moreover, all the extracts, at all tested concentrations, achieve 100% mortality of *S. oryzae* within 72h of exposure except extract of *M. oleifera* at 2 and 4 % which achieved 72% and 87.59% mortality, respectively. The extract of *Z. zanthoxyloides* at all tested concentrations was more active and able to achieve complete mortality of *O. mercator* within 48h and 72h post-treatment and its effect was significantly ($p<0.05$) different from other extracts. Also, the extract of *A. indica A. occidentale* at all concentrations significantly at $p\leq 0.05$ achieved 89.45 - 100% mortality of *O. mecator* within 72h of application. *R. dominica* again proved to be sensitive to the first three extracts and achieved 100% mortality within 72h post-treatment at lower concentration (2%) except the extract of *M. oleifera* which only achieved complete beetle mortality at 8% concentration. However, effect of all the plant extracts on the three insects was significantly ($p<0.05$) different from the controls.

Table 2. Percentage mortality of *S. oryzae, O. mecator* and *R. dominica* on paddy rice treated with plant oil extracts

Plant materials	Dosage (%)	% Mortality (Mean ± SE) in hours					
		S. oryzae		*O. mecator*		*R. dominica*	
		48 hr	72 hr	48 hr	72 hr	48 hr	72 hr
A. indica	2	100.00±0.00^{f}	100.00±0.00^{d}	79.27±0.88^{e}	100.00±0.00^{e}	91.00±0.66^{fg}	100.00±0.00^{e}
	4	100.00±0.00^{f}	100.00±0.00^{d}	87.00±1.30^{fg}	100.00±0.00^{e}	100.00±0.00^{h}	100.00±0.00^{e}
	6	100.00±0.00^{f}	100.00±0.00^{d}	100.00±0.00^{h}	100.00±0.00^{e}	100.00±0.00^{h}	100.00±0.00^{e}
	8	100.00±0.00^{f}	100.00±0.00^{d}	100.00±0.00^{h}	100.00±0.00^{e}	100.00±0.00^{h}	100.00±0.00^{e}
Z. zanthoxyloides	2	100.00±0.00^{f}	100.00±0.00^{d}	100.00±0.00^{h}	100.00±0.00^{e}	89.06±0.22^{ef}	100.00±0.00^{e}
	4	100.00±0.00^{f}	100.00±0.00^{d}	100.00±0.00^{h}	100.00±0.00^{e}	98.00±1.30^{gh}	100.00±0.00^{e}
	6	100.00±0.00^{f}	100.00±0.00^{d}	100.00±0.00^{h}	100.00±0.00^{e}	100.00±0.00^{h}	100.00±0.00^{e}
	8	100.00±0.00^{f}	100.00±0.00^{d}	100.00±0.00^{h}	100.00±0.00^{e}	100.00±0.00^{h}	100.00±0.00^{e}
A. occidentale	2	78.82±0.28^{cd}	100.00±0.00^{d}	69.45±0.24^{d}	89.45±0.67^{d}	75.56±3.40^{d}	100.00±0.00^{e}
	4	87.70±0.88^{de}	100.00±0.00^{d}	89.00±2.67^{fg}	100.00±0.00^{e}	83.23±1.88^{e}	100.00±0.00^{e}
	6	95.00±0.00^{ef}	100.00±0.00^{d}	92.28±0.24^{f}	100.00±0.00^{e}	89.00±0.33^{ef}	100.00±0.00^{e}
	8	100.00±0.00^{f}	100.00±0.00^{d}	99.20±0.02^{fg}	100.00±0.00^{e}	100.00±0.00^{h}	100.00±0.00^{e}
M. oleifera	2	68.88±0.24^{bc}	72.00±0.28^{b}	48.00±2.36^{b}	62.00±0.28^{b}	56.82± 0.88^{b}	66.00±0.67^{b}
	4	70.24±0.88^{c}	87.59±2.45^{c}	57.50±2.50^{c}	75.00±2.58^{c}	69.00± 1.67^{c}	72.47±0.43^{c}
	6	87.24±0.28^{de}	100.00±0.00^{d}	65.00±2.89^{d}	88.00±1.63^{d}	76.00± 2.20^{d}	96.80±0.88d^{e}
	8	93.12±0.28^{e}	100.00±0.00^{d}	82.50±1.33^{e}	100.00±0.00^{e}	88.63± 2.46^{ef}	100.00±0.00^{e}
Solvent control		0.00±0.00^{a}	3.30± 0.33^{a}	0.00±0.00^{a}	0.24±0.23^{a}	0.00±0.00^{a}	1.35±0.67^{a}
Untreated Control		0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}

Each value is a mean ± standard error of four replicates. Means followed by the same letter along the column are not significantly different ($P>0.05$) using New Duncan's Multiple Range Test.

3.3. Effect of plant powders on number of adult emergence and their inhibitory effect on progeny development of adult S. oryzae, O. mercator and R. dominica

All the plant powders significantly reduced the number of adult emergence of the three tested insects (Table 3). Powders of *A. indica, Z. zanthoxyloides* and *A. occidentale* at 0.8 and 1g were able to prevent the emergence of adult of the three tested insects being 97.86 - 100 % and 95.04 – 100 % adult reduction, respectively. *A. indica, Z. zanthoxyloides* and *A. occidentale* powders at 0.8 g were more potent on *R. dominica* (100% adult reduction). In contrast, the powders of *M. oleifera*, at the same concentration, were less potent on this beetle. Moreover, the effect of these plant powders was significantly (p<0.05) different from the controls.

Table 3. Effect of plant powders on the adult emergence of three stored product insect pests infesting rice

Plant materials	Dosage (g)	% Mortality (Mean ± SE)					
		S. oryzae		*O. mecator*		*R. dominica*	
		Mean number of adult emergence	%IR	Mean number of adult emergence	%IR	Mean number of adult emergence	%IR
A. indica	0.4	1.83±1.34[b]	96.87±0.01[f]	2.30±1.10[c]	91.24±0.22[d]	1.70±0.01[b]	96.79±0.06[c]
	0.6	1.20±0.01[b]	98.20±0.02[fg]	2.01±0.33[bc]	95.58±0.03[d]	1.20±0.01[b]	97.70±0.02[c]
	0.8	0.00±0.00[a]	100.00±0.00[g]	1.35±1.18[b]	97.30±1.02[e]	0.00±0.00[a]	100.00±0.00[e]
	1.0	0.00±0.00[a]	100.00±0.00[g]	0.89±0.01[a]	99.75±0.01[f]	0.00±0.00[a]	100.00±0.00[e]
Z. zanthoxyloides	0.4	2.35±0.55[c]	92.00±0.20[e]	1.73±0.32[b]	96.22±0.01[d]	1.89±0.02b[c]	94.00±0.21[c]
	0.6	1.92±1.30[b]	96.00±0.14[f]	0.89±0.02[a]	99.84±0.01[f]	1.02±0.08[b]	98.68±0.02d[e]
	0.8	0.88±0.01[a]	99.83±0.13[g]	0.00±0.00[a]	100.00±0.00[f]	0.00±0.00[a]	100.00±0.00[e]
	1.0	0.00±0.00[a]	100.00±0.00[g]	0.00±0.00[a]	100.00±0.00[f]	0.00±0.00[a]	100.00±0.00[e]
A. occidentale	0.4	2.70±0.34[c]	89.85±1.17d[e]	2.89±0.23[c]	89.40±0.01[cd]	2.03±0.88[c]	94.08±0.03[c]
	0.6	2.10±1.28[c]	92.00±0.32[e]	2.47±0.13[c]	91.49±0.22[d]	1.78±1.67[b]	96.20±0.15[c]
	0.8	0.13±0.01[a]	99.98±0.01[g]	1.44±2.04[b]	95.04±1.67[d]	0.00±0.00[a]	100.00±0.00[e]
	1.0	0.00±0.00[a]	100.00±0.00[g]	1.00±0.33[ab]	97.86±2.24[e]	0.00±0.00[a]	100.00±0.00[e]
M. oleifera	0.4	7.93±0.44[f]	81.60±0.08[b]	8.10±0.08[ef]	73.62±0.01[b]	6.95±0.23[e]	79.78±1.12[b]
	0.6	5.74±1.33[e]	83.79±1.43[b]	7.50±1.55[e]	77.08±0.22[b]	6.84±1.33[e]	80.47±0.79[b]
	0.8	4.44±2.03[d]	86.00±0.33[c]	4.87±3.02[d]	82.30±0.02[c]	5.47±2.03[d]	83.89±0.01[b]
	1.0	4.02±0.34[d]	86.95±1.77[c]	4.56±0.53[d]	85.82±1.02[c]	5.23±0.34[d]	84.97±2.67[b]
Control	0.0	35.26±2.06[g]	0.00±0.00[a]	38.26±3.02[g]	0.00±0.00[a]	37.21±2.45[f]	0.00±0.00[a]

Each value is a mean ± standard error of four replicates. Means followed by the same letter along the column are not significantly different (P>0.05) using New Duncan's Multiple Range Test.

3.4. Effect of plant extracts on number of adult emergence and their inhibitory effect on progeny development of adult S. oryzae, O. mercator and R. dominica

Table 4 shows the effect of the plant extracts on the emergence of adult *S. oryzae, O. mercator* and *R. dominica*. All extracts of tested plants show a greater effect on the emergence of the adult insects. The extracts of *A. indica* and *Z. zanthoxyloides* at all concentrations were able to inhabit completely the emergence of adult *S. oryzae* and *O. mercator* and 100% adult reduction. Meanwhile, at 4, 6 and 8% concentration, extracts of *A. occidentale* also inhabit almost emergence of the three tested adults species. In contrast, *M. oleifera* was less potent on the emergence of the three tested adults species (83.46- 94.97% adult reductions). All the tested extracts were significantly (p<0.05) different from the controls in their effects.

Table 4. Effect of plant oil extracts on the adult emergence of three stored product insect pests infesting rice

Plant materials	Dosage (%)	% Mortality (Mean ± SE)					
		S. oryzae		*O. mecator*		*R. dominica*	
		Mean number of adult emergence	%IR	Mean number of adult emergence	%IR	Mean number of adult emergence	%IR
A. indica	2	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}
	4	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}
	6	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}
	8	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}
Z. zanthoxyloides	2	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}
	4	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}
	6	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}
	8	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}
A. occidentale	2	1.45±0.33^{b}	97.35±0.08^{cd}	1.24±0.24^{b}	96.40±1.01^{c}	0.00±0.00^{a}	100.00±0.00^{d}
	4	0.00±0.00^{a}	100.00±0.00^{d}	0.87±2.33^{a}	99.49±0.31^{d}	0.00±0.00^{a}	100.00±0.00^{d}
	6	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}
	8	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}	0.00±0.00^{a}	100.00±0.00^{d}
M. oleifera	2	4.42±4.08^{e}	87.72±0.13^{b}	4.87±3.02^{d}	83.46±1.32^{b}	4.64±3.21^{d}	86.59±1.47^{b}
	4	3.14±1.33^{d}	89.85±4.34^{b}	4.56±0.53^{d}	85.82±0.33^{b}	3.44±1.08^{c}	88.21±0.24^{b}
	6	3.03±1.33^{d}	92.60±2.03^{b}	3.96±2.44^{c}	87.23±0.46^{b}	3.23±1.33^{c}	91.89±0.33^{bc}
	8	2.00±3.05^{c}	94.97±033^{bc}	3.06±0.53^{c}	90.41±1.33^{b}	2.46±2.24^{b}	93.68±2.67^{c}
Solvent control		35.87±3.21^{f}	0.00±0.00^{a}	37.68±0.24^{e}	0.00±0.00^{a}	37.54±4.06^{e}	0.00±0.00^{a}
Untreated Control		35.26±2.06^{f}	0.00±0.00^{a}	38.26±3.02^{e}	0.00±0.00^{a}	37.21±2.45^{e}	0.00±0.00^{a}

Each value is a mean ± standard error of four replicates. Means followed by the same letter along the column are not significantly different (P>0.05) using New Duncan's Multiple Range Test.

4. Discussion

Botanical source insecticides may serve as alternatives to popularly used synthetic chemical insecticides as many of them have often been used against a number of species of stored product insect pests, including Coleoptera and Lepidoptera (Nathan *et al.,* 2007). They are believed to be easily biodegradable and not toxic to none target organisms. Moreover, prior to the discovery of the organochlorine and organophosphate insecticides in the late 1930s and early 1940s, botanical insecticides have remained an important weapon in the farmers armory in managing insect pests of their farm produce (Forim *et al.,* 2012). Many Nigerian plant species are medicinal and they are proved to be effective against different a wide range of insect pests (Akinkurolere *et al.,* 2006; Ileke and Olotuah, 2012; Akinneye and Ogungbite, 2013).

In this study, the oil extracts of *A. indica* and *Z. zanthoxyloides* show a higher effectiveness than the oil of *A. occidentale* and *M. oleifera* as they presented 100% mortality of *S. oryzae* within 48h of application at all concentrations. Moreover, the extract of *Z. zanthoxyloides* shows the greatest mortality of *O. mercator* as it was the only one that achieved 100% mortality within 48h at all concentrations. The powders of these four botanicals also show greater a mortality effect on the three insects tested, but their effect was less than their oil extracts. The high mortality effect of these botanical oil extracts and powders could be due to the inability of the insects to feed on the paddy rice that has been coated with these botanicals, thereby leading to their starvation. The oils and powders of these botanicals may have also disrupted the normal respiratory activities of these insects leading to the asphyxiation and death. The oils and the powders may have also blocked the spiracles of these insects which therefore led to suffocation. This results agree with the previous studies in which powders and oils of *A. indica, Z. zanthoxyloides, A. occidentale* and *M. oleifera* have been used as protectant against different storage insects (Onu and Baba, 2003; Ileke and Oni, 2011; Ileke and Olotuah, 2012; Akinneye and Ogungbite, 2013).

The toxicity of *A. indica* to these three insects could be attributed to the presence of many chemical ingredients such as triterpenoids, which includes azadirachtin, salanin, meliantriol, etc. (Ileke and Oni, 2011). The toxic effect of *Z. zanthoxyloides* could be related to the presence of secondary phenolic compound known as zanthoxylol and this had been reported to have mortality and ovicidal effect on stored product insect pests (Udo, 2011; Akinneye and Ogungbite, 2013). Also, the high mortality, effect evoked by the oils and powders of *A. occidentale,* could be linked to the occurrence of anacardic acid, cardinal, quercetin and kaempferol glycosides as suggested by Oparaeke and Bunmi (2006).

All the concentrations of the extract of *A. indica* and *Z. zanthoxyloides* prevented the emergence of the adults of these insects and also showed 100% inhibition rate while only the extract of *A. occidentale* at higher concentrations was able to prevent the emergence of these insects and achieved complete inhibition of the insects. However, both the extract and powder of *M. oleifera* could not completely inhabit (100%) the emergence of the three insects. However, the oil and powder of *M. oleifera* greatly reduced the emergence of these insects and achieved greater inhibition rate when compared to the controls.

The inability of these insects to emerge may be due to the death of the insect larvae which may occur due to inability of the larvae to fully cast off their exoskeleton which remained linked to the posterior part of their abdomen. This is in agreement with the observation made by Oigiangbe *et al*. (2010) who worked on insecticidal properties of an alkaloid from *Alstonia boonei*. Also, different chemical compositions of these plants as mentioned earlier could be responsible for the in ability of the adult insects to emerge as they are found to disrupt growth and reduced larval survival as well as disruption of life cycle of insects (Mordue-Luntz and Nisbet, 2000; Yang *et al.,* 2006).

This result agrees with the work of various researchers in which the extracts and powders of *A. indica, Z. zanthoxyliodes, A. occidentale* and *M. oleifera* were used to prevent the emergence of adult insects as well as the inhibition of their development (Udo, 2005; Ileke and Oni, 2011; Udo, 2011; Akinneye and Ogungbite, 2013). The powders and oil extracts of the four used botanicals are medicinal and risk-free to mammals. Therefore, they could be integrated with other insect pest management system.

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