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EFFICACY OF SOME PLANT EXTRACTS AS POST HARVEST GRAIN PROTECTANTS AGAINST *CALLOSOBRUCHUS MACULATUS* (F.) AND *SITOPHILUS ZEAMAIS* MOTSCH.

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ABSTRACT
A study was conducted to estimate the efficacy of extracts of *Zanthoxylum zanthoxyloides, Aristolochia ringens, Colocasia esculenta* and *Morinda lucida* as post harvest protectants of maize and cowpea seeds against *Sitophilus zeamais* Mots. and *Callosobruchus maculatus* (F.) respectively. The study was conducted in the laboratory at ambient temperature of 28±2^{o}C and relative humidity of 75±5%. The extracts of these plants were made using ethanol as solvent and were prepared at concentrations of 1.0%, 1.5% and 2.0%. Untreated seeds and solvent treated seeds served as controls. At 2.0% concentration, all the extracts achieved high rate of insects mortality as they all achieved above 98% death of *S. zeamais* and *C. maculatus* within four days of exposure. The results obtained from this work showed that only the extract of *A. ringens* was able to prevent the emergence of adult *S. zeamais* and *C. maculatus* and therefore achieved 100% reduction at 1.0%, 1.5% and 2.0% concentrations. Also, only the extract of *A. ringens* was able to prevent damage to treated seeds by the insects and therefore achieved 0%WPI at all levels of concentration. The effect of *A. ringens* in terms of adult emergence, percentage reduction, percentage damage and weevil perforation index (WPI) was significantly ($p<0.05$) different from other extracts except extract of *Z. zanthoxyloides* which also prevented the adult emergence of the insects and damage of the treated seeds at 2.0% concentration. However, extract of *Z. zanthoxyloides* was also very effective on the insects as it achieved 100% mortality within one day of exposure at 2.0% and its effect was significantly ($p<0.05$) different from other extracts. The effectiveness of these extracts as grain protectants could be rated as follow *A. ringens*> *Z. zanthoxyloides*> *M. lucida*> *C. esculenta.* For effective protection and control of infestation by *S. zeamais* and *C. maculatus* in storage of maize and cowpea respectively extracts of *A. ringens* and *Z. zanthoxyloides* could be used on these food commodities.

Keywords: protectant, *Zanthoxylum zanthoxyloides, Aristolochia ringens, Colocasia esculenta, Morinda lucida* adult emergence, seed damage

INTRODUCTION

Post harvest losses of crops due to insect infestation especially during storage have been one of the major problems encountered in agriculture in developing countries like Nigeria. Cowpea, *Vigna unguiculata* and maize, *Zea mays,* are one of the major staple foods in Nigeria which had been attacked by *Callosobruchus maculatus* (F.) and *Sitophilus zeamais* Mots respectively. The control of these notorious insects had relied upon the use of synthetic insecticides because of their quick knock down action and high effectiveness (Udo, 2011). However, because of the adverse effects of these chemical insecticides on mammals and their environment, the search for alternative means of controlling these insect pests have been a major concern (Ashamo and Akinneye, 2009; Ashamo *et al*., 2013). Botanical insecticides have been encouraged since they are believed to be safer to the environment, generally less expensive, readily available, effective, easily processed and can be used by farmers and small scale industries (Nibber, 1994; Belmain *et al.,* 2001; Okosun and Adedire, 2010; Habib *et al.,* 2011; Ashamo *et al.,* 2011). Tropical regions are believed to be endowed with many plant species with insecticidal properties (Shaalan *et al.*, 2005). Therefore this study examined the efficacy of extracts of some plants as grain protectants against the cowpea seed beetle, *C. maculatus* and maize weevil, *S. zeamais*.

MATERIALS AND METHODS

Insect culture

The two insect pest species, *Callosobruchus maculatus* and *Sitophilus zeamais* were cultured in their food media, cowpea (*Vigna unguiculata* L. Walp) and maize (*Zea mays* L.) respectively in the laboratory. The insects were reared subsequently by replacing devoured and infested grains with fresh, clean, uninfested grains in 2 litre Kilner jars covered with muslin cloth to allow air circulation and prevent escape of insects. Insect rearing and the experiments were conducted at ambient temperature of 28±2^{o}C and relative humidity of 75±5% in the laboratory of Department of Biology, Federal University of Technology, Akure, Nigeria. One to two day old adults were obtained by sifting the culture a day before the experiment.

Preparation of Plant Extracts

The plant materials used for the experiments were obtained from the local markets in Akure and from the premises of the Federal University of Technology, Akure, Nigeria. They were cut into small pieces, air-dried and pulverized into very fine powder using an electric grinder. Table 1 shows the list of plants tested for insecticidal activity. Twenty five grammes of each pulverized plant material were weighed into 250ml conical flasks and 200ml of aqueous ethanol (90:10) v/v) was poured on the powder to soak for 72hrs. Aluminium foil and cotton wool were used to cover the flasks to prevent escape of solvent. The extracts were later sieved with muslin cloth and porcelain paper. Resulting extracts were concentrated *in vacuo* and the concentrates were further air-dried to remove traces of the solvent. The aliquots were later kept in sample bottles and kept inside refrigerator until needed. From this, different ethanolic concentrations of 1.0%, 1.5% and 2.0% were prepared.

Contact toxicity of extracts against *S. zeamais* and *C. maculatus* adults

Twenty five grammes of maize grains were weighed into 9 cm inner diameter Petri dishes and rubbed with 1.0ml of each plant extract, thoroughly mixed and air-dried for 1hr. Untreated and solvent- treated controls were set up for comparison. All treatments were replicated six times and arranged in a completely randomised manner in insect breeding cages in the laboratory. Twenty teneral adults (0-48hr old) of *S. zeamais*, randomly selected irrespective of sex, were introduced into the Petri dishes and examined daily for four days. Those weevils and beetles that do not respond to a pin probe of the abdomen were considered dead. The same procedure was followed for adult *C. maculatus* using cowpea grains. Adult mortality was recorded each day for four days for the two insects.

Adult emergence and Reduction effect of plant extracts

At the end of four days in the previous experiment, all dead and live adults of *S. zeamais* and *C. maculatus* were removed and the set up were examined daily for adult emergence. At the end of 49 days and 42 days in *S. zeamais* and *C. maculatus* respectively, the total number of adults that emerged were counted and recorded. From these values the percentage reduction was calculated using the formula below:

%Reduction

$$= 100 - \left[\frac{\text{No of } F_1 \text{ adults from treated sample}}{\text{No of } F_1 \text{ adults from control}}\right] x100$$

Damage effect and Weevil Perforation Index

The percentage damage (PD) and weevil perforation index (WPI) for each plant treatment on the grains were calculated using the formula below:

$$\text{PD} = \frac{\text{Total number of treated grains perforated}}{\text{total number of grains}} x100$$

WPI

$$= \frac{\text{percentage of treated grains perforated}}{\text{percentage of control grains perfoated} + \text{percentage grains perforated}} x100$$

Analysis of data

All the data in this work were subjected to one way analysis of variance at 0.05 significant level using the New Duncan's Multiple Range Tests (Zar, 1984).

RESULTS

Effect of plant extracts on adult mortality of *S. zeamais*

Table 2 presents the effects of the ethanolic plant extracts on adult *S. zeamais* within 4 days of exposure. The percentage weevil mortality varied with the period of exposure, type of plant extracts used and the concentration of the extracts. There were significant ($p<0.05$) differences in the effectiveness of the extracts. At 2.0% concentration, *Z. zanthoxyloides* extract was able to achieve 100% weevil mortality within 24hours of exposure but its effect was not significantly ($p<0.05$) different from *A. ringens* and *C. esculenta* which achieved 95% and 96.65% mortality of weevils respectively. However all the extracts achieved more than 50% weevil mortality after four days of exposure and their effects were significantly different from the controls.

Table 1. Plant materials tested for insecticidal activity

Scientific name	Local name	Common name	Family	Parts used
Zanthoxylum zanthoxyloides (Lam) Waterm	Ata	Sichuan/Chineese pepper	Rutaceae	Roots
Aristolochia ringens Vahl	Akogun	Gaping Dutchman's pipe	Aristolochiaceae	Roots
Colocasia esculenta (L.) Schott	Koko	Cocoyam	Araceae	Leaves
Morinda lucida Benth	Oruwo	Indian morus	Rubiaceae	Stem bark

Table 2: Effect of plant extracts on adult mortality of *Sitophilus zeamais*

Plant Powder	Concentration % (w/v)	Mean % Mortality (±S.E) / day post-treatment			
		1	2	3	4
Z. zanthoxyloides	1.00	40.00 ±5.77^{c}	76.65 ± 6.67^{d}	83.35± 3.33 ^{e}	100.00± 0.00^{f}
	1.50	63.35 ±3.33^{e}	83.33 ± 6.67^{de}	93.35 ± 3.33^{f}	100.00± 0.00^{f}
	2.00	100.00 ± 0.00^{i}	100.00 ±0.00^{f}	100.00±0.00^{g}	100.00± 0.00^{f}
A. ringens	1.00	76.66 ±1.67^{g}	98.35 ±1.67^{f}	100. 00 ± 0.00^{g}	100.00 ± 0.00^{f}
	1.50	88.33 ± 1.67^{h}	100.00 ± 0.00^{f}	100.00 ±0.00^{g}	100.00 ±0.00^{f}
	2.00	95.00 ±2.89^{hi}	100.00 ± 0.00^{f}	100.00 ± 0.00^{g}	100.00 ± 0.00^{f}
C. esculenta	1.00	26.65 ± 3.33^{b}	46.65 ± 3.33^{b}	50.00 ± 0.00^{b}	55.00 ±2.89^{b}
	1.50	53.35 ± 3.33^{d}	60.00 ± 0.00^{c}	63.35 ± 1.67^{c}	80.00 ± 2.89^{c}
	2.00	96.65 ±3.33^{hi}	98.35 ± 1.67^{f}	100.00 ±0.00^{g}	100.00 ± 0.00^{f}
M. lucida	1.00	65.00 ± 2.89^{ef}	75.00 ± 2.89^{d}	78.35 ± 1.67^{d}	85.00 ± 0.00^{d}
	1.50	73.35 ± 1.67^{fg}	86.66 ± 1.67^{e}	90.00 ± 2.89^{f}	91.65 ± 1.67^{e}
	2.00	76.65 ± 3.33^{g}	88.35 ± 1.67^{e}	95.00 ± 0.00^{fg}	98.35 ± 1.67^{f}
Solvent control	0.00	0.00±0.00^{a}	1.65 ± 1.67^{a}	5.00 ± 0.00^{a}	6.65 ±1.67^{a}
Control	0.00	0.00±0.00^{a}	0.00±0.00^{a}	1.65 ± 1.67^{a}	5.00 ± 0.00^{a}

Each value is the mean of three replicates. Means followed by the same letter along the column are not significantly different ($p>0.05$) from each other, using New Duncan's Multiple Range Test.

Table 3: Effect of plant extracts on adult mortality of *Callosobruchus maculatus*

Plant Powder	Concentration % (w/v)	Mean % Mortality (±S.E) / day post-treatment			
		1	2	3	4
Z. zanthoxyloides	1.00	50.00 ± 5.78^{c}	66.65 ± 4.41^{d}	80.00 ± 2.89^{d}	93.35 ± 4.41^{de}
	1.50	86.66 ± 3.33^{fg}	100.00 ± 0.00^{e}	100.00 ± 0.00^{e}	100.00 ± 0.00^{e}
	2.00	100.00 ± 0.00^{g}	100.00 ± 0.00^{e}	100.00 ± 0.00^{e}	100.00 ± 0.00^{e}
A. ringens	1.00	33.35 ± 3.33^{b}	43.35 ± 3.33^{b}	53.35 ± 1.67^{b}	66.65 ± 4.41^{b}
	1.50	80.00 ± 0.00^{ef}	93.35 ± 3.33^{f}	96.65 ± 3.33^{e}	100.00 ± 0.00^{e}
	2.00	93.35 ± 6.67^{fg}	96.65 ± 3.33^{f}	100.00 ± 0.00^{e}	100.00 ± 0.00^{e}
C. esculenta	1.00	30.00 ± 0.00^{b}	56.65 ± 3.33^{c}	68.35 ± 2.89^{c}	80.00 ± 2.89^{c}
	1.50	70.00 ± 0.00^{de}	78.35 ± 1.67^{e}	85.00 ± 0.00^{d}	88.33 ± 1.67^{cd}
	2.00	91.65 ± 6.00^{fg}	96.65 ± 3.33^{f}	98.35 ± 1.67^{e}	98.35 ± 1.67^{e}
M. lucida	1.00	65.00 ± 2.89^{d}	70.00 ± 0.00^{d}	83.35 ± 4.41^{d}	88.35 ± 4.41^{cd}
	1.50	91.00 ± 8.33^{fg}	96.65 ± 3.33^{f}	98.35 ± 1.67^{e}	98.35 ± 1.67^{e}
	2.00	93.35 ± 3.33^{fg}	96.65 ± 1.67^{f}	100.00 ± 0.00^{e}	100.00 ± 0.00^{e}
Solvent control	0.00	0.00 ± 0.00^{a}	1.65 ± 1.67^{a}	5.00 ± 0.00^{a}	6.65 ± 1.67^{a}
Control	0.00	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	1.65 ± 1.67^{a}	5.00 ± 0.00^{a}

Each value is the mean of three replicates. Means followed by the same letter are not significantly different (P >0.05) from each other, using New Duncan's Multiple Range Test.

Table 4: Emergence of adult *S. zeamais* and Percentage of reduction of extracts

Plant	Concentration % (w/v)	Mean No. of adults counted (± S.E)	% of reduction (± S.E)
Z. zanthoxyloides	1.00	14.00 ± 0.67^{b}	50.58 ± 2.03^{d}
	1.50	4.33 ± 0.33^{a}	84.72 ± 1.17^{e}
	2.00	0.00 ± 0.00^{a}	100.00 ± 0.00^{f}
A. ringens	1.00	0.00 ± 0.00^{a}	100.00 ± 0.00^{f}
	1.50	0.00 ± 0.00^{a}	100.00 ± 0.00^{f}
	2.00	0.00 ± 0.00^{a}	100.00 ± 0.00^{f}
C. esculenta	1.00	18.67 ± 0.33^{b}	34.10 ± 1.17^{b}
	1.50	14.00 ± 0.67^{b}	50.58 ± 2.03^{d}
	2.00	4.67 ± 0.33^{a}	83.52 ± 1.17^{e}
M. lucida	1.00	16.67 ± 0.67^{b}	41.16 ± 2.35^{c}
	1.50	14.67 ± 0.33^{b}	48.22 ± 1.17^{d}
	2.00	5.00 ± 0.67^{a}	82.35 ± 2.03^{e}
Solvent control	0.00	28.33 ± 0.33^{c}	0.00 ± 0.00^{a}
Control	0.00	30.25 ± 0.33^{c}	0.00 ± 0.00^{a}

Means followed by the same letter are not significantly different (P >0.05) from each other, using New Duncan's Multiple Range Test.

Table 5: Emergence of adult *C. maculatus* and percentage of reduction of extracts

Plant	Concentration % (w/v)	Mean No. of adults counted (± S.E)	% of reduction (± S.E)
Z. zanthoxyloides	1.00	8.33± 1.00[b]	88.31 ± 1.23[d]
	1.50	0.67± 0.33[a]	99.06 ± 0.47[f]
	2.00	0.00 ± 0.00[a]	100.00 ±0.00[f]
A. ringens	1.00	3.00 ± 0.67[a]	95.79± 0.81[e]
	1.50	0.00± 0.00[a]	100.00 ± 0.00[f]
	2.00	0.00 ± 0.00[a]	100.00 ± 0.00[f]
C. esculenta	1.00	23.67 ± 0.67[c]	66.82 ± 0.93[b]
	1.50	18.66 ± 1.00[bc]	73.83 ± 1.23[c]
	2.00	4.67 ± 1.00[a]	93.45 ± 1.23[e]
M. lucida	1.00	24.00 ±0.67[c]	66.35 ± 0.81[b]
	1.50	9.33 ± 0.67[b]	86.91 ± 0.93[d]
	2.00	4.00 ±0.67[a]	94.39 ± 0.81[e]
Solvent control	0.00	71.33 ± 1.33[d]	0.00 ± 0.00[a]
Control	0.00	74.39 ± 0.67 [d]	0.00 ± 0.00 [a]

Means followed by the same letter are not significantly different (P >0.05) from each other, using New Duncan's Multiple Range Test.

Table 6: Damage by *S. zeamais* to grains (after 49 days of storage)

Plants	Concentration % (w/v)	Total No of grains	No of grains damaged	Grains undamaged	% damage	*WPI
Z. zanthoxyloides	1.00	232	12	220	5.17	12.68
	1.50	234	4	230	1.70	4.56
	2.00	235	0	235	0.00	0.00
A. ringens	1.00	232	0	232	0.00	0.00
	1.50	229	0	229	0.00	0.00
	2.00	239	0	239	0.00	0.00
C. esculenta	1.00	235	24	211	10.21	22.30
	1.50	227	12	215	5.28	12.92
	2.00	227	5	222	2.20	5.82
M. lucida	1.00	232	17	215	7.32	17.06
	1.50	237	14	223	5.90	14.22
	2.00	232	6	226	2.58	6.76
Control	0.00	236	84	152	35.59	50.00

*Weevil Perforation Index: A value above 50 is an index of negative protectant ability or enhancement of infestation by bruchid.

Table 7: Damage by *C. maculatus* on grains (after 42 days of storage)

Plants	Concentration % (w/v)	Total No of grains	No of grains damaged	Grains undamaged	% damage	*WPI
Z. zanthoxyloides	1.00	320	7	313	2.19	9.50
	1.50	332	1	331	0.30	1.42
	2.00	317	0	317	0.00	0.00
A. ringens	1.00	322	2	320	0.62	3.00
	1.50	340	0	340	0.00	0.00
	2.00	338	0	338	0.00	0.00
C. esculenta	1.00	312	24	288	7.70	27.00
	1.50	323	18	305	5.57	21.07
	2.00	318	6	312	1.90	8.35
M. lucida	1.00	311	22	289	7.07	25.31
	1.50	330	7	323	2.12	9.23
	2.00	315	2	313	0.63	2.93
Control	0.00	350	73	277	20.86	50.00

*Weevil Perforation Index: A value above 50 is an index of negative protectant ability or enhancement of infestation by bruchid.

Effect of plant extracts on adult mortality of *C. maculatus*

Table 3 showed the effects of the plant extracts on adult mortality of *C. maculatus*. The percentage beetle mortality varied with the period of exposure, type of plant extracts used and the concentration of the extracts. At 1.5% concentration, all the extracts evoked more than 60% beetle mortality within one day of exposure and their effects were significantly ($p<0.05$) different from each other. However, at 2.0% concentration only *Z. zanthoxyloides* achieved 100% beetle mortality but its effect was not significantly ($p>0.05$) different from other extracts. At 1.0% concentration all the extracts achieved above 60% beetle mortality within four days of exposure with *Z. zanthoxyloides* having the highest effect of 93.35% beetle mortality and its effect was significantly ($p<0.05$) different from others. All the extracts evoked 100% beetle mortality within four days of treatment at 2.0% concentration and their effects were significantly ($p<0.05$) different from the controls.

Emergence and percentage reduction of adult *S. zeamais* on treated seeds

The percentage emergence and percentage reduction of adult *S. zeamais* on treated seeds are presented in Table 4. Compared to the controls, all the extracts significantly ($p<0.05$) reduced the emergence of adult *S. zeamais*. At all levels of concentration, extract of *A. ringens* prevented the emergence of *S. zeamais* and achieved 100% reduction. The effect of *A. ringens* on emergence of *S. zeamais* was significantly ($p<0.05$) different from other extracts except at 2.0% concentration where extract of *Z. zanthoxyloides* was also found to prevent the emergence of the weevil and achieved 100% reduction. The effect of all the extracts was significantly ($p<0.05$) different from the controls.

Emergence and percentage reduction of adult *C. maculatus* on treated seeds.

The percentage emergence and percentage reduction of adult *C. maculatus* on treated seeds are presented in Table 5. All the extracts significantly reduced or prevented the emergence of adult *C. maculatus*. Only the extract of *A. ringens* prevented the emergence of adult *C. maculatus* at 1.5% concentration and its effect was significantly ($p<0.05$) different from other extracts and the control except the extract of *Z. zanthoxyloides* which achieved 0.67% adult emergence. At 2.0% concentration, only the extracts of *A. ringens* and *Z. zanthoxyloides* were able to achieve 0.00% adult emergence and 100% reduction. However, at all levels of concentrations, all the extracts were significantly ($p<0.05$) different from the controls.

Damage to treated maize seeds by *S. zeamais* and the weevil perforation index (WPI)

Table 6 showed damage caused by *S. zeamais* on the treated maize seeds. At all levels of concentration, only the extract of *A. ringens* was able to prevent damage of treated seeds and no weevil perforation. The effect of *A. ringens* was significantly ($p<0.05$) different from other extracts except that of *Z. zanthoxyloides* which also achieved 0% damage and WPI at 2.0% concentration. Moreover, all the extracts significantly reduced damage and their effects were significantly ($p<0.05$) different from the controls.

Damage to treated cowpea seeds by *C. maculatus* and the weevil perforation index (WPI)

There was no grain damage by *C. maculatus* in the treated seeds at 1.5 and 2.0% concentration in *A. ringens* and at 2.0% concentrations in *Z. zanthoxyloides* (Table 7). However, some damages by the bruchids were inflicted on the grains treated with the extracts of *C. esculenta* and *M. lucida*. The effect of *Z. zanthoxyloides* and *A. ringens* extracts were significantly different from other extracts in all the treatments. All the extracts significantly reduced damage and their effects were significantly ($p<0.05$) different from the controls.

DISCUSSION

The results obtained from this research showed that the extract from *A. ringens*, *Z. zanthoxyloides, C. esculenta* and *M. lucida* had a distinct effect on the mortality of *S. zeamais* and *C. maculatus* on treated maize and cowpea seeds respectively. *Aristolochia ringens* was able to cause 100% mortality of *S. zeamais* at day 3 and 4 at all concentrations of 1.0, 1.5 and 2.0%. This same plant extract was also able to cause 100% mortality of *C. maculatus* at day 4 at 1.5 and 2.0% concentrations. In a related manner, *Z. zanthoxyloides* was able to cause 100% mortality of *C. maculatus* at day 2, 3 and 4 using concentrations of 1.5 and 2.0%. The two plants, *A. ringens and Z. zanthoxyloides* were able to cause 100% reduction of the two insects. A good way of controlling lepidopterous and coleopterous insect pests of stored cereals and grain legumes is by coating such seeds with plant oil and powders because of their persistence and insecticidal action against virtually all stages in the life cycle of insects (Lale, 1995; Ashamo *et al*., 2011; Ileke *et al*., 2013). Powders, extracts and oil of aromatic medicinal plants have been shown to reduce oviposition and adult emergence of *C. maculatus* and *C. chinensis* (Adedire, 2002; Okosun and Adedire, 2010). In this study, mortality was probably caused by contact of the extracts with the spiracles. Most insects breathe by means of trachea which usually opens at the surface of the body through spiracles. These spiracles might have been blocked by these extracts thereby leading to suffocation of the insects.The extracts from *A. ringens* and *Z. zanthoxyloides* however had the highest mortality on these insects. Insecticidal property of any plant material would depend on the active constituents of the plant material. One of the constituent secondary metabolites, Zanthoxylol has been identified as a phenolic compound responsible for insecticidal activity of *Z. zanthoxyloides* (Udo, 2011). The result of this research was in agreement with the work of Udo (2011) in which the powder of *Z. zanthoxyloides* was found to evoke high mortality on adult *C. maculatus*. The extract of *A. ringens* and *Z. zanthoxyloides* showed a greater protectant ability than others against *S. zeamais* and *C. maculatus* as they both prevented the adult emergence of the insects as well as preventing damage to the treated seeds. The inability of the insects to emerge may be due to the death of the insect larval which might have been caused by inability of the larval to fully cast off their exoskelecton which typically remained linked to the posterior part of their abdomen (Trindade *et al*., 2008; Okosun and Adedire, 2009; Oigiangbe *et al*., 2010, Ashamo *et al*., 2013).

This agreed with the work of Udo (2011) in which the extract of *Z. zanthoxyloides* was found to reduce adult emergence of *C. maculatus. Zanthoxylum. zanthoxyloides* and *A. ringens* showed a good insecticidal effect on these insect pests. However, all the extracts have low weevil perforation index when compared with the control. Therefore, since extract of *Z. zanthoxyloides* and *A. ringens* appeared to be most effective among the plant extracts tested and the fact that they are cheap and readily available, they could be incorporated into pest management programmes. These two plant extracts were able to protect and effectively control infestation by *S. zeamais* and *C. maculatus* in storage of maize and cowpea respectively.

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