

Bioactivity of Four Plant Extracts on Coleopterous Pests of Stored Cereals and Grain Legumes in Nigeria

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Abstract: The efficacy of ethanol extracts from four plants, *Dennettia tripetala* Baker, *Eugenia aromatica* Baillon, *Piper guineense* Thonn et Schum and *Anchomanes difformis* P. Beauv. as bioinsecticides for control of adult *Sitophilus zeamais* Motschulsky, *Tribolium castaneum* Herbst, *Callosobruchus maculatus* Fabricius, *Oryzaephilus mercator* Fauvel and *Lasioderma serricorne* Fabricius were determined at two concentrations (0.5% and 2.0%) in the laboratory. All extracts were toxic to beetles with *E. aromatica* being the most potent of four plant materials tested and had the least LT₅₀ value. This was followed by *A. difformis* extract. At 2.0% v/w extract concentration, percentage grain damage by insects in treated grains stored for 90 days was nil. Grains protected with *A. difformis* had the least percentage seed germination of 62.50% while those protected with *P. guineense* had the highest percentage germination (74.58%) at 2.0% extract concentration. The mean percentage germination in the control was 72.72%. Treatment of grains with plant extracts had no significant ($P > 0.05$) effect on its water absorption capacity.

Key words: Coleopterous pest; Plant extract; LT₅₀; Seed viability

四种植物淬取物对尼日利亚仓贮甲虫的生物活性

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关键词: 甲虫类害虫; 植物淬取物; LT₅₀; 种子发芽能力

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Acute food shortage due to the inability to protect and preserve crops from quality and quantity deterioration arising from microbial, vertebrate and insect pest infestations has been a primordial problem confronting Nigeria and other developing countries in the tropics (Talukder & Howse, 1994; Adedire, 2001).

Insect pests cause a great deal of losses of stored food products, especially in the tropics where food products usually are susceptible to attack during the storage phase of the crops (Sighamony et al, 1986). During storage, apart from the percentage losses incurred from the grain they feed on, they also render large quantities useless by contaminating them with their droppings, webs, and odours. Their biochemical

activities could lead to heat being generated which may eventually result in hot spot in bulk grain storage (Odeyemi & Daramola, 2000) thus, leading to caking of grains. Losses due to storage pests are therefore a major agricultural problem in the third world, which has led to the continued search for humanly safe, host specific, cost effective and ecologically tolerable means of managing these pests.

As part of the quest for an alternative to the use of chemical insecticides against insect pests, research efforts are currently being focused on the use of plant products, such as plant powder, extracts and oils, which are cheaper, safer and eco-friendly (Adedire & Ajayi, 1996).

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About 2,000 species of plants in the tropics have been reported to possess biopesticidal properties in their bioactive components (Ahmed et al, 1984). Several researchers have screened many plant products for the control of insect pests of stored cereal grains and comprehensive review on this subject had been undertaken by van Huis (1991), Lale (1995), Boeke et al (2002). Botanical insecticides tend to have broad-spectrum activity (Talukder & Howse, 1995). They are safe and relatively specific in their mode of action, easy to process and use (Sighamony et al, 1986; Rajapakse & Van Emden, 1997). The objectives of this study were: (1) to examine the efficacy of ethanol extracts of four plants, namely *Dennettia tripetala*, *Eugenia aromatica*, *Piper guineense* and *Anchomanes difformis* as bioinsecticides against adult *Sitophilus zeamais*, *Tribolium castaneum*, *Callosobruchus maculatus*, *Oryzaephilus mercator* and *Lasioderma serricorne*; (2) to evaluate the germination ability and water absorption capacity of grains treated with these plant products.

1 Materials and Methods

1.1 Preparation of insect cultures

The parent stock of *Sitophilus zeamais* Motschulsky, *Tribolium castaneum* Herbst, *Callosobruchus maculatus* Fabricius and *Oryzaephilus mercator* Fauvel were obtained from infested grains in 'Oba' market, Akure, Nigeria while *Lasioderma serricorne* Fabricius was obtained from International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. The insects were cultured in the laboratory under ambient temperature of 28 ± 2 °C and $75 \pm 5\%$ relative humidity. The food media used for insect culture were: maize for *S. zeamais*; maize grits for *T. castaneum*, cowpea for *C. maculatus* and *L. serricorne* and wheat for *O. mercator*. The food media were disinfested in a deep freezer for 72 hours and later air dried to prevent mouldiness Adedire & Ajayi (1996). About 750 g of each food medium were weighed into glass jars. Twenty unsexed adult insect species were introduced into each culturing medium and covered with muslin cloth held tightly in place by rubber bands. The jars were then kept in wooden insect cages.

1.2 Plant materials

The plants used were *Dennettia tripetala* Baker (fruit), *Eugenia aromatica* Baillon (fruit), *Piper guineense* Thonn et Schum (fruit) and *Anchomanes difformis* P. Beauv. (rhizome). They were bought fresh from 'Oba' market in Akure, Nigeria except *A. dif-*

formis, which was collected from Teaching and Research Farm of the Federal University of Technology Akure (FUTA), Nigeria. The plant parts used were collected fresh and air-dried in the laboratory at ambient tropical conditions. They were pulverized into fine powder using Kenwood electric blender and sieved with a 10-micron sieve. The fine plant powders were kept in airtight containers until required.

1.3 Ethanol extract formulation

Twenty grams of pulverized fruits of *D. tripetala*, *E. aromatica*, *P. guineense* and rhizome of *A. difformis* were soaked in 200 mL of 95% ethanol for 24 hours and filtered using the porcelain filter with fine pored muslin cloth. The extracts were kept in brown bottles until required.

1.4 Effect of plant extracts on beetle mortality

To 20 g of grains an aliquot of 1 mL of 0.5% and 2.0% v/w of ethanol extracts of plant materials were added and thoroughly mixed with the grains. The Petri-dishes were exposed for about 20 minutes to allow the ethanol to dry off, after which 20 teneral adult beetles *S. zeamais*, *T. castaneum*, *C. maculatus*, *O. mercator* and *L. serricorne* were introduced into the Petri-dishes. Mortality was recorded daily for four days. Control tests were set up by introducing the adult beetles into grains treated with absolute ethanol. Also, another experiment containing untreated seeds only was setup. Damage by the beetles to grains was assessed 90 days after treatment using the number of perforated grains in the treatments as index. Each treatment was replicated four times.

1.5 Effect of ethanol extract on water absorption capacity of grains used

Twenty grams each of grains were put in 9 cm diameter Petri-dishes and admixed with 0.4 mL of plant extract to give a concentration of 2% v/w. A treatment without plant extract was included in the set up. Each treatment was carried out in four replicates. The control treatment comprised solvent-treated grains and the test insects. Grains from all the treatments were later soaked in water and observed at 1, 3, 6 and 24 hours interval. On each occasion, the seeds were dried with paper towel and then reweighed.

1.6 Effect of ethanol extract on seed viability

An aliquot of 1 mL each of plant extracts of 2% concentration were mixed with 20 g each of grains in 9 cm diameter Petri-dishes. They were air-dried for 30 – 60 minutes and then covered and left in the laboratory for 90 days. The seeds were then planted in moist sawdust growth medium. Seed germination was recorded

from 3 to 5 days after planting. Four replicates were prepared for each treatment.

1.7 Data analysis

Data obtained were subjected to two-way stepwise Analysis of Variance (ANOVA) and where significant differences existed between the means, they were separated using Duncan’s New Multiple Range Test (DNM-RT). The lethal time required for 50% of the insects to die (LT₅₀) values was calculated based on the mean percentage mortality of test beetles against logarithm of concentration of plant materials used. Dose response was calculated as regression co-efficient estimated by simple regression (Finney, 1971).

2 Results

2.1 Effect of ethanol extracts on adult beetles

Tab. 1 shows the time required for ethanol extracts of *D. tripetala*, *E. aromatica*, *P. guineense* and *A. difformis* at 0.5% and 2% v/w to achieve 50% mortality (LT₅₀) in test beetles population. The extracts of the four plant species significantly (*P* < 0.05) affected adult mortality of all the test beetles. There were significant differences between the LT₅₀ values observed in the control and the plant extracts. At 0.5% of the extracts, *S. zeamais* was the most susceptible beetle with an LT₅₀ of 2.02 days in grains treated with *E. aromatica* followed by *A. difformis* with an LT₅₀ 2.11 days.

Based on lower fiducial limits of *A. difformis* (0.52 to 3.70) as against (0.63 to 3.41) obtained in *E. aromatica*, *A. difformis* extract produced the lowest LT₅₀ on *S. zeamais*. The least effective of the four-plant extract at 0.5% v/w application rate was *P. guineense* (LT₅₀ 5.59) followed by *D. tripetala* (LT₅₀ 3.83). A similar trend was recorded in *C. maculatus* and *L. serricorne*. On *O. mercator*, *D. tripetala* was the most effective with the lowest LT₅₀ 4.13 days. For *T. castaneum*, *A. difformis* was most effective with LT₅₀ of 4.70 days followed by *E. aromatica* LT₅₀ of 4.78 days while the highest LT₅₀ of 6.18 days was observed in *P. guineense*. At 2.0% v/w of plant extract there were significant differences between the LT₅₀ values observed in the treatments and the controls (solvent control and untreated). However, none of the data obtained gave a value beyond the tested time range at 2.0% v/w application rate as was observed in 0.5% v/w plant extract treatments.

E. aromatica gave the lowest LT₅₀ value of 1.50 days on *S. zeamais* followed by *A. difformis* LT₅₀ 1.51 thereby making these plant extracts most effective on *S. zeamais* at 2.0% v/w concentration. The least effective at the same concentration was *P. guineense* (LT₅₀ 2.62) followed by *D. tripetala*. On *T. castaneum*, similar trend was observed with *P. guineense* being the least toxic with the highest LT₅₀(2.34) while

Tab. 1 LT₅₀ of 0.5% and 2.0% ethanolic extract concentration of four plant materials on five stored product insect pests

Plant extract	Concentration (%)	LT ₅₀ (d)				
		<i>S. zeamais</i>	<i>C. maculatus</i>	<i>T. castaneum</i>	<i>O. mercator</i>	<i>L. serricorne</i>
<i>D. tripetala</i>	0.0	171.40 (171.12 – 171.90)	60.15 (59.01 – 61.32)	74.12 (72.40 – 76.20)	98.79 (98.06 – 98.96)	135.15 (134.21 – 135.90)
	0.5	3.83 (2.14 – 5.52)	4.43 (2.72 – 6.14)	5.45 (4.25 – 6.65)	4.13 (2.47 – 5.78)	7.95 (6.68 – 9.22)
	2.0	1.69 (0.38 – 3.00)	1.69 (0.38 – 3.00)	1.63 (0.47 – 2.79)	2.25 (0.63 – 3.87)	2.26 (0.60 – 3.92)
<i>E. aromatica</i>	0.0	170.10 (169.24 – 170.77)	57.14 (57.02 – 57.96)	74.50 (72.10 – 75.00)	112.00 (111.70 – 112.71)	133.33 (130.10 – 134.40)
	0.5	2.02 (0.63 – 3.41)	4.28 (2.82 – 5.74)	4.78 (3.23 – 6.33)	4.76 (3.14 – 6.38)	4.52 (2.88 – 6.12)
	2.0	1.50 (1.09 – 1.91)	1.50 (1.50 – 2.50)	1.50 (1.18 – 1.82)	1.55 (0.65 – 2.45)	1.55 (0.69 – 2.41)
<i>P. guineense</i>	0.0	169.00 (168.41 – 169.72)	57.97 (55.11 – 58.52)	81.24 (81.03 – 81.75)	110.28 (109.00 – 111.10)	130.34 (130.10 – 133.33)
	0.5	5.59 (4.08 – 7.10)	5.00 (3.47 – 6.53)	6.18 (4.81 – 7.55)	5.28 (3.70 – 6.86)	4.85 (3.29 – 6.41)
	2.0	2.62 (1.08 – 4.16)	1.93 (0.53 – 3.33)	2.34 (0.79 – 3.89)	2.88 (1.27 – 4.49)	2.82 (1.20 – 4.44)
<i>A. difformis</i>	0.0	173.21 (172.60 – 175.00)	59.20 (57.96 – 61.13)	79.64 (78.41 – 79.92)	109.53 (107.00 – 111.21)	129.66 (129.12 – 132.06)
	0.5	2.11 (0.52 – 32.70)	4.36 (2.82 – 5.90)	4.70 (3.13 – 6.27)	4.97 (3.38 – 6.56)	4.85 (3.29 – 6.41)
	2.0	1.51 (0.99 – 2.03)	1.24 (0.40 – 2.08)	1.52 (1.03 – 2.01)	1.64 (0.47 – 2.81)	1.61 (0.54 – 2.68)

Values in parenthesis represent fiducial limits.

E. aromatica is the most potent with the lowest LT₅₀ (1.50). *A. difformis* was the most potent extract on *C. maculatus* as it was able to achieve 50% mortality in *C. maculatus* within 1.24 days. On *O. mercator* and *L. serricorne*, *E. aromatica* was most potent with the LT₅₀ of 1.55 days.

Based on LT₅₀ values, *S. zeamais* and *C. maculatus* had the same level of susceptibility to *D. tripetala* extract (Tab. 1). All the test beetles were highly susceptible to 2% v/w *E. aromatica* extract. *C. maculatus* (LT₅₀ 1.93) was the most susceptible beetle to *P. guineense*.

2.2 Effects of plant extracts on grain damage

The toxicity of all the plant extracts at 2.0% v/w concentration was persistent because after 90 days post treatment, there was zero percentage damage in all treated grains except *D. tripetala* extract where 0.62% damage was observed after 90 days post treatment (Tab. 2). In contrast, high percentage seed damage was observed in the untreated maize grains infested with *S. zeamais*, cowpeas with *C. maculatus* and *L. serricorne* respectively (Tab. 2).

However, some levels of damage were recorded for all the plant extracts at a sub-lethal dose of 0.5% v/w, *L. serricorne* in seeds protected with *A. difformis* produced the highest mean percentage seed damage. Percentage seed damage ranging from 48.42% to 89.63% was observed in the control. *L. serricorne* appears the least susceptible of all the test beetles used in this investigation.

2.3 Effect of plant extracts on water absorption capacity of treated grains

The water absorption rate of maize grains treated with 2.0% v/w concentration of ethanol extracts of *D. tripetala*, *E. aromatica*, *P. guineense* and *A. difformis* is presented in Tab. 3. The rates of absorption of water by treated seeds varied with seed type, the period of submergence and the plant extract used.

At 2.0% v/w plant extract concentrations, the percentage water absorption of grains increased with increase in the interval of submergence. After one-hour interval, grains pre treated with *D. tripetala* had the highest water absorption (9.23%) followed by *E. aromatica* (9.13%), the control and the untreated seeds had 8.73% and 8.80% respectively. At 3 hours interval of submergence, grains treated with *E. aromatica* have 14.12% absorption, while the least water absorption of 12.03% was obtained in seeds treated with *A. difformis* extract. At 6 hours interval, grains treated with *P. guineense* was observed to have the highest percentage water absorption and at the end of 24 hours, *A. difformis* has the least. Generally, the rate of water absorption of cowpea grains is higher than that of maize at both extract.

2.4 Ethanol extracts effect of plant materials on seed viability

The percentage of maize seeds that germinated after treatment with 0.5% and 2.0% v/w concentrations of plant extracts are presented in Tab. 4. At the end of five days planting period, virtually all the treated seeds show germinative ability. And at 0.5% plant extract maize seeds treated with *P. guineense* has the highest percentage germination (88.57%) followed by *E. aromatica* and untreated grain samples which had 83.33% and 81.42% respectively. 75.76% germination was observed in the control while grains treated with *D. tripetala* and *A. difformis* produced 79.41% and 75.00% germination respectively. The higher concentration of plant extract treatment (2.0% v/w) led a lower percentage germinative ability of maize grains when compared to the results obtained in 0.5% plant extract concentration. Grains protected with *A. difformis* have the least percentage germination (62.50%) while the untreated maize grains has the highest percentage germination (76.14%). The mean percentage germination in the control was 72.72%. The germina

Tab. 2 Percentage damaged grains after 90 days post treatment with 2.0% plant extract

Protectant	Grain damaged (%)				
	<i>S. zeamais</i>	<i>C. maculatus</i>	<i>L. serricorne</i>	<i>T. castaneum</i> *	<i>O. mercator</i> *
Control	73.77 ± 3.50 ^b	88.81 ± 1.44 ^b	47.53 ± 2.04 ^b	22.18 ± 5.25 ^b	6.35 ± 3.14 ^b
<i>D. tripetala</i>	0.00 ± 0.00 ^a	0.62 ± 1.25 ^a	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a
<i>E. aromatica</i>	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
<i>P. guineense</i>	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
<i>A. difformis</i>	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 the percentage of mean ± SE of four replicates. Means followed by the same letter(s) are not significantly different at *P* < 0.05 according to Duncan's New Multiple Range Test.
* Percentage grits damage.

Tab. 3 Effect of 2.0% plant extracts on water absorption of maize grains

Protectant	Water absorption (%)			
	1 h	3 h	6 h	24 h
Maize				
Untreated	8.80 + 2.15 ^a	13.08 + 3.04 ^a	21.06 + 1.44 ^{ab}	31.14 + 1.25 ^{ab}
Control	8.73 + 2.50 ^a	13.01 + 3.08 ^a	20.98 + 2.00 ^{ab}	31.35 + 4.23 ^b
<i>D. tripetala</i>	9.23 + 1.25 ^a	13.51 + 2.15 ^a	19.41 + 2.04 ^a	29.30 + 2.50 ^a ^b
<i>E. aromatica</i>	9.13 + 1.50 ^a	14.12 + 1.25 ^a	18.93 + 2.23 ^a	29.43 + 1.44 ^{ab}
<i>P. guineense</i>	8.64 + 1.55 ^a	12.36 + 1.50 ^a	22.18 + 5.25 ^a	30.86 + 1.25 ^{ab}
<i>A. difformis</i>	7.84 + 3.14 ^a	12.03 + 3.50 ^a	21.70 + 4.20 ^b	28.50 + 2.50 ^a
Cowpea				
Untreated	14.03 + 3.14 ^b	18.31 + 4.23 ^b	26.29 + 2.04 ^{cd}	43.93 + 2.50 ^e
Control	13.56 + 2.50 ^b	17.84 + 3.42 ^b	25.82 + 2.04 ^e	43.46 + 2.35 ^e
<i>D. tripetala</i>	14.04 + 1.40 ^b	18.32 + 2.04 ^b	27.30 + 3.50 ^{cd}	41.30 + 5.08 ^e
<i>E. aromatica</i>	13.63 + 2.39 ^b	17.91 + 1.25 ^b	28.48 + 2.15 ^d	42.89 + 3.14 ^e
<i>P. guineense</i>	13.56 + 1.25 ^b	17.06 + 3.14 ^b	25.60 + 1.25 ^e	43.50 + 4.12 ^e
<i>A. difformis</i>	11.78 + 1.44 ^b	18.46 + 4.15 ^b	26.84 + 4.23 ^{cd}	42.36 + 1.44 ^e

Each value is the percentage of mean ± SE of four replicates. Means followed by the same letter(s) are not significantly different at P < 0.05 according to Duncan’s New Multiple Range Test.

Tab. 4 Percentage germination after five days in seeds treated with 2.0% plant extract (%)

Protectant	Maize seed		Cowpea seed	
	Germination	Germination relative to control	Germination	Germination relative to control
Untreated	76.14 ± 2.39 ^d	104.70	72.50 ± 1.44 ^b	95.85
Control	72.72 ± 3.15 ^b	100.00	75.64 ± 1.25 ^d	100.00
<i>D. tripetala</i>	69.65 ± 1.44 ^b	95.78	72.50 ± 2.39 ^b	95.85
<i>E. aromatica</i>	73.00 ± 3.15 ^{bc}	100.39	74.30 ± 3.15 ^{cb}	98.23
<i>P. guineense</i>	74.58 ± 2.39 ^c	102.56	75.00 ± 1.25 ^d	99.15
<i>A. difformis</i>	62.50 ± 1.25 ^a	85.95	71.08 ± 2.39 ^a	93.97

Each value is the percentage of mean ± SE of four replicates. Means followed by the same letter(s) are not significantly different at P < 0.05 according to Duncan’s New Multiple Range Test.

tive ability of cowpea grains was higher than that of maize (Tab. 4). Cowpea grains treated with 0.5 % *E. aromatica* has the highest percentage germination 89.18% after 5 days, followed by grains protected with *P. guineense* (87.56%) and *A. difformis* (80.00%). In the control, the germination was 79.00%. As for cowpea grains protected with 2. 0% plant extracts, grains treated with *P. guineense* gave 75.00% germination while the least mean percentage germination was observed in *A. difformis* (71.08).

3 Discussion

Peasant farmers in many parts of Africa frequently mix plant materials with stored grains to prevent insect pests damage (Caswell, 1976; Ofuya, 1990). The results obtained from this study suggested that ethanol extracts of *D. tripetala*, *E. aromatica*, *P. guineense* and *A. difformis* were effective as contact biorationals against *S. zeamais*, *T. castaneum*, *C. maculatus*, *O. mercator* and *L. serricorne*. However, their effective-

ness was dependent on dosage and exposure periods. The differences in the response by the different insect pest species, could be attributed to the morphological and behavioural differences between the insects (Tanpondju et al, 2002).

The insecticidal activity of *D. tripetala* could be attributed to β-phenylnitroethane an active principle characterized by Agbakwuru et al (1978). Egwunyenga et al (1997) found out that the powder, acetone and ethanol extracts of *D. tripetala* caused 40.1% to 60% repellency when used to protect dry fish from fish beetles, *Dermestes maculatus* (Degeer).

Extracts of *E. aromatica* and *A. difformis* were the most effective of the four plant extracts used for contact toxicity because all the beetles were susceptible to *E. aromatica* plant extract treatment although the susceptibility varies among insect species with *L. serricorne* being the most resistant. *E. aromatica* is known to have pungent smell and contains eugenol, sesquiterpene and caryophylline (Ho et al, 1994). Eugenol is

toxic and inhibit growth in insects. The extract of *E. aromatica* evoked up to 90% mortality in *S. zeamais* (Ho et al, 1994; Javid & Poswal, 1995). The action of *E. aromatica* on these beetles could be as a result of stomach poisoning (Ahmed et al, 1984; Lajide et al, 1998), through picking lethal doses of the plant extract by the beetles while feeding on whole or fragmented grains. Therefore, the high toxic effect of *E. aromatica* on *S. zeamais* which is known to have thick exoskeleton that should give them some level of resistance, could probably be due to the feeding habits of these pests during which lethal dose of the plant material might have been taken up (Wasserman & Asami, 1985). The result obtained in this study tallies with the findings of Javid & Poswal (1995) who reported that 2.0% (w/w) cloves powder admixed with cowpea, prevented further population increase of cowpea bruchid, *C. maculatus* and also caused mortality of the adult beetles.

The comparatively lower susceptibility of *O. mercator* and *L. serricorne* to *E. aromatica*, might be due to the size of the insect and their feeding habits. Adult *O. mercator* is very small 2.3 mm in size and flattened (Munro, 1966). During the experiment, it was observed that about 90% of the insects clustered round a spot (a grain) thereby reducing the chances of making contact with the plant materials.

P. guineense also acted as a very good protectant. High percentage mortalities were recorded in all the beetles introduced into Petri-dishes containing grains treated with *P. guineense* extract. However, the mortality recorded was not as high as those recorded in the treatments with *E. aromatica*, *A. difformis* and *D. tripetala*. Similar observations were made by Okonkwo & Okoye (1996) who reported that *D. tripetala* was more effective than *P. guineense*, *Monodora myristica* (Houtt.) and *Xylopi aethiopica* against *S. zeamais* and *C. maculatus*. However, Mbata & Ekpandu (1992) had earlier observed that 0.1 g/20 g of hexane extract of *P. guineense*, when admixed with either maize, cowpea or bambara, resulted in 100% adult mortality of *S. zeamais*, *C. maculatus* and *C. subinnotatus*. The fruit of *P. guineense* contains the amides piperine, chavicine, N-iso-butyloctadeca-trans-2-trans-4-dienamide, sylvatine, a β -dihydro piperine and trichostachine (Oliver-Bever, 1986). The biological activities of the extract have been linked to the presence of these active principles in the plant because some of these compounds, especially chavicine and piperine

have contact toxicity and fumigant action on insects.

The ethanol extract of *A. difformis* though has not been reported as being effective against storage beetles, appears to be very effective as control agent for all the test beetles. Results from these investigations revealed that extracts from *A. difformis* significantly ($P < 0.05$) reduced the population of all the storage beetles. The action of *A. difformis* on these beetles could be due to contact toxicity of the plant powder to the insects, or stomach poisoning during feeding. Since mortality increases as the exposure period increases, it shows that the toxic components of *A. difformis* have some level of persistence. This result is in agreement with reports of Niber (1994) and Adedire & Lajide (2003) who reported that some tropical plants could be admixed with grains in storage in order to protect them from storage beetles.

Grains protected with 2.0% plant extract, gave better protection against *S. zeamais* than 0.5% as zero index was recorded in virtually all the grains protected with 2.0% plant extracts, as against the control where percentage damaged grains were relatively higher. It could be inferred that the extracts of all the plant materials at 2.0% concentration have long-term protectant effect in preserving grains from attack by storage beetles. Therefore, if grains should be stored for an upward of 90 days, it is advisable to use plant extract as surface protectant.

The maize grains treated with ethanol extracts of *D. tripetala*, *E. aromatica*, *P. guineense* and *A. difformis* did not show any negative water absorption capacity when compared with the control and the untreated seeds. However, seeds treated with varying plant materials gave different percentage rates of water absorption and this may be due to the physiology of the individual seeds, hard seed coat and seed type. However, it was observed that seeds treated with higher percentage plant extract have lower water absorption capacity than seeds treated with lower concentrations. The results also showed that the amount of water absorption by seeds could be directly proportional to the period of submergence. Ashamo & Odeyemi (2001) had reported that seed extracts of *A. melegueta* K. schum., *P. guineense*, *Jatropha gossypifolia* L., *Arachis hypogea* L., *Elaeis guineensis*, Jacq., at 1%, 2%, and 3% concentration did not affect the water absorption capacity of maize grains.

Though there were marked differences between the

mean percentage germination in the some treated seeds from mean percentage germination in the control and the untreated seeds, the seed viability of grains pre-treated with 0.5% and 2.0% v/w plant extract concentration showed that the treatments did not negatively affect seed germination. This is suggestive that the plant extracts did not adversely hamper germination of seeds.

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