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Koomson CK
Department of Integrated Science Education, University of Education, Winneba, P.O. Box 25, Winneba, Central Region, Ghana

Corresponding Author:
Koomson CK
Department of Integrated Science Education, University of Education, Winneba, P.O. Box 25, Winneba, Central Region, Ghana

Entomopoison efficacy of Christmas bush, *Alchornea cordifolia* (Schum. & Thonn.) root powder against the maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae)

Koomson CK

Abstract
Root powders from *Alchornea cordifolia* were evaluated for their efficacy as contact insecticides on maize beetle, *Sitophilus zeamais* in the Integrated Science Education Department laboratory of the University of Education, Winneba, Central Region, Ghana, at a temperature of 30±2°C and 75±5% relative humidity. The powders were applied at 0.5g, 1g, and 1.5g to assess contact toxicity, damage assessment, progeny production, repellency and seed germination ability. Results indicated that the plant material was toxic to the insect ($P<0.05$). The root powder of *A. cordifolia* applied at 1.5g greatly induced the highest mortality of 99% after 21 days, repelled almost 98% of the weevils, significantly inhibited adult emergence and seed damaged by the weevils up to about 99% respectively compared to other concentrations ($P<0.05$). The root powder also had no effect on germination. This study revealed that root powders of *A. cordifolia* can used to efficiently control *S. zeamais* in stored grains and its incorporation into traditional storage pest management is strongly recommended in developing countries.

Keywords: Grain protection, *Sitophilus zeamais*, entomopoison, *Alchornea cordifolia*

1. Introduction

From the beginning of history, insects have been the major competitor of human on earth in term of food consumption. These insects ranging from coleoptera to lepidoptera to diptera attack human crops both on the field and in storage where their noxious activity is more prominent. Maize (*Zea mais*) one of the major food staples of the world. It is also one of the most important cereal crops grown widely throughout the world in diverse agro ecological environments [1]. Maize is known to be subject to depreciation by various pests which can cause severe qualitative and quantitative losses. In developing countries, percentage weight losses in storage can exceed 30% [2]. One of such insect pests is *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). It is the most widespread and major destructive insect pest of stored maize throughout the world [1]. It is an internal feeder causing considerable loss to cereals by affecting the quantity as well as quality of the grains [3]. The multivotine kind of reproduction of this important insect pest of maize makes its destructive activity to be more pronounced and popular throughout the year especially in the countries where environmental conditions are favourable [4].

Attempts at controlling this dreadful insect pest of maize has been overwhelmingly relied upon the use of synthetic insecticides. These synthetic products, however, are not without their hazards to human health and the environment [5]. Apart from the health and environmental hazards posed by synthetic insecticides, mis-use and over-use by applicators have led to serious problems, including development of insect resistant strains to insecticides, toxic residues on stored grains, health hazards to grain handlers, food poisoning, environmental pollution [6, 8]. These problems have stimulated research into plants with insecticidal properties grown locally that are readily available, effective, affordable, less poisonous and less detrimental to the environment [9]. Most plants are rich sources of compounds that have insecticidal properties [10], *Zanthoxylum xanthoxyloides* [11] and many others have been successfully used to control insect pests.

Alchornea cordifolia is an important medicinal plant in African traditional medicine and much pharmacological research has been carried out into its antibacterial, antifungal and antiprotozoal properties, as well as its anti-inflammatory activities, with significant positive results [12, 13] as well as [14] found out the leaves and bark of the plant was effective in controlling the stored products insect pests through suppressing oviposition and progeny development, contact toxicity and repellency activities. The objective of this study is therefore to evaluate the efficacy of the root powder of *Alchornea cordifolia* against *S. zeamais* in stored maize in the laboratory.

2. Materials and Methods

The research was carried out at the Integrated Science Education Department laboratory of the University of Education, Winneba, Central Region, Ghana, at a temperature of 30±2 ^{0}C and 75±5% relative humidity from December 2019 to January 2020.

2.1 Insect Culture

Initial stock used for the experiment was obtained from maize seeds that were bought from the Mandela market at Agona Swedru in the Central Region of Ghana. The maize seeds were put in different jars covered with net and adult *S. zeamais* were introduced into the jars. The jars were kept at room temperature in the Integrated Science Education Department laboratory of the University of Education, Winneba for the insects to breed and multiply under favourable laboratory conditions (temperature of 30±2 °C, and relative humidity of 70±5%) The moisture content of maize grain was adjusted to12 to 13% [15]. After three weeks of oviposition, the parent weevils were sieved out after oviposition. Later the grain were kept in the laboratory for adult emergence while the emerging generation of same age insects re-cultured at temperature of 30±2 °C, and relative humidity of 70±5%. The F1 generation was used for the experiment.

2.2 Collection and preparation of plant materials

Alchornea cordifolia plants were collected from the Gomoa Otapirow area of the Central Region of Ghana. The roots were uprooted, chopped into pieces, rinsed in clean water to remove sand and other impurities, air dried at room temperature in the laboratory for 15 days, after which they were pounded in a mortar with a pestle into smaller pieces, pulverised into very fine powder using an electric blender. The powders were further sieved to pass through 1mm^2 perforations. The powders were packed in plastic containers with tight lids to ensure that the active ingredients are not lost and stored in the laboratory prior to use.

2.3 Source of maize substrate

The uninfested maize (local variety) used for the experiment were procured from the Mandela market at Agona Swedru in the Central Region of Ghana. These were properly handpicked and sieved. Thus, ensuring that only whole and infestation-free seeds were used. Nevertheless, the maize seeds, with the exception of those to be used for the viability tests were then sterilized in the electric oven for an hour at 60 °C. The seeds were then cooled at room temperature. Twenty gram each of the uninfested maize seeds were weighed separately and kept at room temperature. The experiment was carried out in triplicate for each treatment.

2.4 Effect of contact toxicity of *Alchornea cordifolia* root powders on adult mortality, oviposition and progeny development of *Sitophilus zeamais*

a. Contact toxicity of *Alchornea cordifolia* root powder

Twenty pairs of *S. zeamais* were introduced into the a clean sterilized 250ml plastic containers containing 20g of uninfected sterilized maize seeds at 0, 0.5, 1.0, and 1.5g% (w/w) of *Alchornea cordifolia* root powder, while in the control treatment there was no plant material added. The *Alchornea cordifolia* root powder was weighed and added to the maize grain in each jar and shaken well for uniform coating. The jars were covered with muslin cloth and secured with rubber bands as a ventilated lid. The experiment was laid out in Randomized Compete Block Design (RCBD) with three replications. The treated grains in the jars were kept for about 21 days and mortality rate assessments were performed regularly every 1, 7, 14 and 21 days after exposure of *Alchornea cordifolia* root powder. Adults were considered dead when probed with sharp objects and there were no responses [10]. Percentage adult mortality was corrected using the [16] formula, thus:

$$P_T = \frac{P_o - P_c}{100 - P_o} \times \frac{100}{1}$$

Where P_T = Corrected mortality (%)
P_o = Observed mortality (%)
P_c = Control mortality (%)

b. Determination of effect of powder on progeny production

Grains treated with the root powders were kept inside the laboratory for further 30 days to assess for the emergence of the first filial generation (F1). The containers were sieved out and newly emerged adult *S. zeamais* were counted and recorded for one week. The percentage adult emergence was calculated using the method of [17].

$$\%\ \text{Adult emergence} = \frac{\text{Total number of adult emergence}}{\text{Total number of eggs laid}} \times \frac{100}{1}$$

c. Damage assessment

Percentage weight loss of the maize seeds was determined by re-weighing after 35 days and the% loss in weight was determined using the method of [18] as follows:

$$\%\ \text{Weight loss} = \frac{\text{Change in weight}}{\text{Initial weight}} \times \frac{100}{1}$$

After re-weighing, the numbers of damaged maize seeds were evaluated by counting wholesome seeds and seeds with weevil emergent holes. Percentage seed damaged was calculated using the method of [18] as follows:

$$\%\ \text{Seed damaged} = \frac{\text{Number of seeds damaged}}{\text{Total number of seeds}} \times \frac{100}{1}$$

Weevil Perforation Index (WPI) used by [19], quoted by [20] was adopted for the analysis of damage. WPI was defined as follows:

$$\text{WPI} = \frac{\%\ \text{treated maize seeds perforated}}{\%\ \text{control maize seeds perforated}} \times \frac{100}{1}$$

WPI value exceeding 50 was regarded as enhancement of infestation by the weevil or negative protectability of the plant material tested.

d. Repellency test

The repellency effect of the plant root powder against maize weevil was assayed using the method of preferential zone on a filter paper described by [21] with some minor modifications. A petri dish was lined with a Whatman filter paper (No. 10). The paper was divided into 3 equal zones along the diameter of the petri dish using a line drown with an HB pencil. 10 unsexed adult insects were starved for 24hrs in a clean glass jar. 30g of sterilized maize seeds were placed at the center of the two extreme zones of the petri dish. Plant root powders (0, 0.5, 1.0, and 1.5g) were place at one heap of grain at one of the extreme zones in the petri dish. 10 starved adult maize weevils were placed at the center of the central zone of the divide and the number of insects moving into the two extreme zones was recorded after 10mins. The experiment was conducted in triplicate for each dose of the plant powders in CRD. The process was repeated for maize weevil using maize. Percent repellency was calculated using the formula proposed by [20];

$$PR = \frac{NC-NT}{NC+NT} \times \frac{100}{1}$$

Where: NC – number of insects in the controlled zone (no plant powder)

NT – number of insects in the treated zone (plant powders available)

PR – percent repellency. The PR was ranked in six different classes as described by [21] as shown below:

Percent Repellency (PR) classes ranked by [21].

Class	PR proportion (%)	Description
O	PR < 0.01	Not repellant
I	0.1 < PR ≤ 20	Fair repellant
II	20.1 ≤ PR ≤ 40	Moderate repellant
III	4.01 ≤ PR ≤ 60	Good repellant
IV	60.1 ≤ PR ≤ 80	Very repellant
V	80.1 ≤ PR ≤ 100.0	Perfect repellant

Source: [21]

Percent repellency less than one was considered zero [4]. Data from repellency test was analyzed using chi square test to assess the repellency activity of the various powder doses of *Alchornea cordifolia* root powder and the susceptibility of the weevils. PR_{50} was calculated using [22] method based on the probit regression of mortality as a function of the logarithm of plant powder doses. All analysis was done using SPSS (version 16.0).

e. Seed germination

The effect of maize treated with the root powders and their interactions on seed germination and viability was examined after 21 days of grain storage period. Seed germination was tested using 50 randomly picked seeds from undamaged grains after separation of damaged and undamaged grains in each jar according to the methods described in [23]. The 50 grain sub-samples were germinated on moistened filter paper (Whatman No. 1) in Petri dishes arranged in a RCBD with four replicates. The experiment was maintained under laboratory conditions. The number of germinated seedlings from each Petri dish was counted and recorded after 7 days. The percent germination was computed according to the methods of [24] as follows:

$$\text{Viability index (\%)} = \frac{NG \times 100}{TG}$$

Where NG = number of seeds that germinated, TG = total number of test seeds

2.5 Statistical Analysis

Data were subjected to analysis of variance (ANOVA) and treatment means were separated using the new Duncan's multiple Range Test. The ANOVA was performed with SPSS 16.0 software. While egg counts, damaged and undamaged seeds were subjected to square root transformation and percentages were arcsine transformed before analysis. Result means were separated using the LSD test ($p \leq 0.05$) [24].

3. Results

3.1 Contact toxicity of *A. cordifolia* root powder

The contact toxicity effect of *A. cordifolia* root powder on mortality of *S. zeamais* at different concentration and period is presented in Table 1. The percentage weevil mortality varied with period of exposure and the concentration of the powders. Significant ($p<0.05$) differences existed among all the treatments with the 1.5g *A. cordifolia* root powder giving the highest mortality after 21 days. Nonetheless, at all dosses, lower mortality was observed within one day after the exposure of weevils to root powders.

Table 1: Percentage mortality of adult *S. zeamais* treated with *A. cordifolia* root powders

Dose (g) of *A. cordifolia* root powder	Mean% Mortality + SE on Days after treatment			
	1	7	14	21
Control	0.00 ± 0.00^a	0.00 ± 0.00^a	0.00 ± 0.00^a	0.00 ± 0.00^a
0.5	31.00 ± 1.00^b	38.10 ± 2.40^b	73.00 ± 3.04^b	97.30 ± 2.01^b
1.0	39.21 ± 3.19^{bc}	56.20 ± 1.67^{bc}	88.16 ± 2.36^{bc}	98.10 ± 2.17^{cd}
1.5	44.14 ± 2.79^c	86.21 ± 2.13^d	95.00 ± 3.41^d	99.21 ± 3.11^b

Each value is a mean ± standard error of four replicate means within column followed by the same letters (s) are not significantly different at ($P>0.05$) using New Duncan's Multiple Range Test

3.2 Protection ability of the *A. cordifolia* root powder on maize seeds

Grains treated with *A. cordifolia* root powders showed significant difference ($p<0.05$) in the reduction of damage caused by *S. zeamais* and (Table 2). The 1.5g *A. cordifolia* root powder provided the highest protection (weight loss and seed damage) and prevented the perforation of the maize seeds by the weevils and the 0.5g *A. cordifolia* root powder provided the lowest protection (weight loss and seed damage) and provided the lowest perforation index.

Table 2: Protectability of *A. cordifolia* root powder on maize seeds

Dose (g) of *A. cordifolia* root powder	Mean total number of seeds	Mean total number of damaged seeds	Mean total number of damaged seeds	% weight loss	Weevil perforation index
Control	99.50	46.70 ± 2.13^{b}	47.23 ± 3.10^{b}	80.01 ± 1.34^{b}	56.32 ± 0.20^{c}
0.5	99.00	0.84 ± 0.05^{a}	1.24 ± 0.14^{a}	1.41 ± 1.10^{a}	1.17 ± 1.21^{b}
1.0	98.50	0.04 ± 0.03^{a}	0.51 ± 0.03^{a}	0.21 ± 0.11^{a}	0.02 ± 1.12^{b}
1.5	99.50	0.01 ± 0.06^{a}	0.02 ± 0.02^{a}	0.01 ± 0.21^{a}	0.01 ± 0.10^{a}

Each value is a mean ± standard error of four replicate means within column followed by the same letters (s) are not significantly different at (*P*>0.05) using New Duncan's Multiple Range Test

3.3 Fecundity of *S. zeamais* treated with *A. cordifolia* root powder on maize seeds

In Table 3, the oviposition and percentage progeny development of *S. zeamais* after being exposed to various dosses of plant powders as contact insecticide. Progeny development was significantly suppressed by various plant powders with the 1.5g dose almost completely inhibiting the emergence of *S. zeamais.*

Table 3: Fecundity of *S. zeamais treated with A. cordifolia* root on maize seeds

Dose (g) of *A. cordifolia* root powder	Oviposition	% number of progeny development
Control	49.05 ± 0.24^{c}	83.11 ± 2.20^{c}
0.5	2.31 ± 0.324^{b}	3.10 ± 1.06^{b}
1.0	0.01 ± 0.12^{ab}	0.03 ± 0.02^{b}
1.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}

Each value is a mean ± standard error of four replicate means within column followed by the same letters (s) are not significantly different at (*P*>0.05) using New Duncan's Multiple Range Test

3.4 Effects of *A. cordifolia* root powder on viability of stored maize seeds

The percentage of maize seeds that germinated after treatment with powder of *A. cordifolia* root powder is presented in Table 4. At the end of seven-day germination period, all the treated seeds recorded high germinability. The untreated maize seeds and seeds treated with *A. cordifolia* root powders all had 100% percentage germination.

Table 4: Effects of *A. cordifolia* root powder on viability of stored maize seeds

Dose (g) of *A. cordifolia* root powder	% Viability
Control	100.00 ± 0.00^{a}
1.0	100.00 ± 0.01^{a}
2.0	100.00 ± 0.00^{a}
3.0	100.00 ± 0.00^{a}

Each value is a mean ± standard error of four replicate means within column followed by the same letters (s) are not significantly different at (*P*>0.05) using New Duncan's Multiple Range Test

3.5 Repellent action of *A. cordifolia* root powder to *S. zeamais.*

Table 5 shows the mean (±SD) of maize weevil repelled by different doses of *A. cordifolia* root powder after 10 minutes of exposure. The chi-square test was conducted on counts. The result reveals that the highest concentration (1.5g) of *A. cordifolia* root powder had a strong repellent effect of 98% for the maize weevil described according to [21] as perfectly repellent whiles the 0.5g dose recorded the lowest repellence of 59%.

Table 5: Repellency caused by *A. cordifolia* root powder against *S. zeamais* after 10mins in petri test of preferential zone

Dose (g) of *A. cordifolia* root powder	Mean (± SE) number of insects in controlled zone	Mean (± SE) number of insects in treated zone	% Repelled
Control	9.30 ± 0.40^{c}	9.00 ± 0.50^{c}	0
0.5	8.56 ± 0.14^{b}	2.34 ± 0.12^{b}	59
1.0	9.60 ± 1.48^{ab}	0.71 ± 0.11^{ab}	86
1.5	9.93 ± 1.03^{a}	0.21 ± 0.11^{a}	98

Each value is a mean ± standard error of four replicate means within column followed by the same letters (s) are not significantly different at (*P*>0.05) using New Duncan's Multiple Range Test

4. Discussion

According to [4], for an insecticide to be accepted, it will depend on its ability to prevent or reduce infestation by insects and also to have less or no adverse effect on the human and environmental health. Since botanical insecticides however remain the most accessible source of insect control for both poor and mechanize farmers, their method of application still remain a major challenge which need to be tackled [25]. In the current study, mortalities were recorded when the maize was treated with the plant material. The result obtained from this research showed that the root powders of *A. cordifolia* had a significant effect on the survival of the *S. zeamais* when compared to the controls. This suggests the promising potential of the plant material for controlling *S. zeamais*.

Furthermore, regardless of the plant part used, *A. cordifolia* root powder reduced the oviposition and adult emergence of *S. zeamais* at higher concentrations when compared to the controls. This inability of the insect to lay more eggs could be due to the ovicidal properties in the plant which had affected the respiratory rate of the insects and in turn affected the rate of mating among the insects. Also, the high rate of mortality could also be responsible for the low rate of oviposition. The low adult emergence of the insects could be due to inability of the larvae to emerge as they may not be able to fully castoff their exoskelecton which remain joined to their abdomen [26, 25]. This may also be due to the allelochemicals present in the root powder of this plant [12]. This further suggests that *A. cordifolia* root powder may have an obvious effect on the post embryonic survival of the weevils, which, in turn, prevents and significantly reduces adult emergence from treated maize grains when compared to control [27].

The reduced weight loss and damage of the maize protected by the root powders of *A. cordifolia* could be due to reduced adult emergence as suggested by [28, 29]. These authors opined that the higher the rate of adult that emerge from a stored commodity the higher will be the rate of weight loss of the commodity. This significant reduction in percentage seed damage and weight loss also indicates that the plant material was effective in reducing the normal growth and developmental processes of *S. zeamais* and found to be seed protective as the spoilage of seeds were reduced to a significant extent. The efficacy of the root powder of the plant in reducing percentage seed damage weight loss is probably attributable to the strong pungent odour of the freshly prepared plant product. This agrees with the findings of [13] and [14].

Moreover, the result obtained in this work agreed with the work of above mention authors which reported that the leaves and bark powders were more effective in protecting grains against insect pests.

5. Conclusion

The present study has therefore shown that t *Alchornea cordifolia* root powder has entomopoison properties against *S. zeamais* and thus could go a long way in the quest of providing alternatives to the use of chemical insecticides for protecting maize grain in storage and for increasing seed germination and seedling emergence. Furthermore, these plants are readily available in Ghana and so can be integrated into integrated pest management strategies in developing countries because they are locally available, potentially less expensive to the traditional farmer and relatively less harmful to human health and the environment. Since the plant powders could lead to qualitative losses through discolouration of the grains, further studies on the plants extracts of the various parts of the plant could be tested against stored product pests to determine its efficacy.

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