Phytochemical compositions and Adulticidal Effectiveness of Indian Borage, Coleus amboinicus Lour, against Maize Weevil, Sitophilus zeamais Motschulsky [Coleoptera: Curculionidae]

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Abstract

The use of synthetic chemical insecticides in the management of food grains pest have a serious adverse effect on consumer's health and the environment. Public awareness of the adverse effects of the synthetic chemical insecticides has called for the urgent need to replace this method with safer and cheap method. This research evaluated the adulticidal effects of *Coleus amboinicus* leaf, stem and root powders and crude extracts against *Sitophilus zeamais*. The plant powders were tested at dosage 0.1, 0.3, 0.6, 0.9 and 1.5 g per 20 grams, while extracts were tested at concentration 0.1, 0.2, 0.3, 0.4 and 0.5 ml per 20 grams of maize seeds. The results revealed that *Coleus amboinicus* leaf powder at dosage 1.5g caused 63% mortality of adult *S. zeamais* after a day of treatment. This followed by *C. amboinicus* stem that evoked 56% weevil mortality. This research showed that *C. amboinicus* extracts were more toxic than powders of the tested *Coleus amboinicus* parts. The lethal concentration of leaf, stem and root extracts which caused 50% mortality in the population of *S. zeamais* response after 96 hours of exposure were 0.13 ml, 0.27ml and 0.48ml respectively. *Coleus amboinicus* leaf proved to be the most toxic to maize weevil, followed by stem powder and extract. The study established *C. amboinicus* leaf, stem, and root contain varying levels of phytochemicals, such as alkaloids, saponin, flavonoids, and tannin, which are responsible for the adulticidal toxicity to the maize weevil.

1. Introduction

Maize is one of the major grains grown in large quantities in West Africa, particularly in Nigeria, most especially during the rainy season. According to Food and Agriculture Organization (1), maize grains is fourth most important food grain after sorghum, millet, and rice. Maize grains and its products are major component of meals consumed by millions of people worldwide (2, 3); it also server as raw material for many industries. The production of maize has enormous potential to fight poverty and the global food problem. Maize is a commercial crop in addition to being used as an industrial raw material (4). In addition, breweries and pharmaceutical companies use it. Maize is used in the manufacturing of starch, pulp abrasive, drinks, high fructose syrup, dextrose, infant cereals, animal feeds, biodegradable plastics, absorbent materials for diapers and nappies, drinks, drinks, crayons, soaps, and culinary additives in addition to nutritional supplements (5). Maize is also used industrially to produce fuel (6).

Despite its value, insect pests such as *Sitophilus zeamais*, *Rhizopertha dominica*, *S. oryzae*, *S. Granarious*, and numerous others have put this precious grain's production and storage at risk (7). The main insect pest of maize seeds is *Sitophilus zeamais* Motschulsky (8). For many years, synthetic chemical pesticides have been employed to reduce the threat posed by *S. zeamais* and other pests found in stored products, especially in large-scale production (9).

The use of synthetic chemicals has proved efficient in the control of maize weevil; however, this has resulted to insecticide resistance and its residue has been reported to be harmful to man and environment (10). Thus, there is need to research into environmentally friendly methods of control stored products insects. Several plant species have been shown to have the ability to act as insecticides, but

more plants need to be screened to establish those that can compete with synthetic insecticide. The study evaluates the insecticidal potency of Indian borage (*Coleus amboinicus*) for the control of maize weevil *S. zeamais*.

2. Materials and Methods

2.1 Collection of Maize Grains

Uninfested maize grains were collected from seed unit at Agricultural Development Project (ADP) in Akure and transported to Storage Entomology Postgraduate Research Laboratory, Biology Department, Federal University of Technology Akure (FUTA), Ondo State, Nigeria for subsequent processing. The maize grains were sorted and kept in the freezer at -10ºC for 4 weeks to remove any hidden infestation and then air dried before usage.

2.2 Collection of Plant Materials

The leaf, stem, and root, of Indian borage (*Coleus amboinicus*) was collected from unpolluted areas within Akure, Ondo state and were taken to the Crop, Soil and Pest Management Department, FUTA, Ondo State for authentication by a plant taxonomist. The plant part was cleansed and air dried in the laboratory for three weeks. They were then pulverized into coarse powders using pestle and mortar before grinding in an electric blender (Binatone Model BLG 400). The fine powders of each of the plant part was further sieved through 1\mm perforations before they were stored at room temperature in separate labelled air-tight plastics for further use.

2.3 Preparation of Plant Extract

Using the crude extraction method, ethanol extracts of the Indian borage (*C. amboinicus*) root, stem, and leaves were produced. In an extraction bottle with 600 ml of 100% ethanol, about 300g of the plant powders were separately steeped. The extraction process was stopped after three days, and the liquid was periodically agitated with a glass rod. The mixture obtained was filtered through two layers of Whatman No. 1 filter paper, and the solvent was removed using a rotary evaporator set at 30–40°C and rotating at a speed of 3–6 rpm for eight hours, as per the extraction protocol outlined by (11). Using a rotating evaporator vacuum, excess solvent was collected. After air drying, the resultant extract was concentrated to get rid of any remaining extraction solvent.

2.4 Quantitative Phytochemical Screening of C*oleus amboinicus*

Qualitative analysis was carried out on the ethanolic extracts of *C. amboinicus* leaves to determination the present of phytochemicals such as alkaloid, flavonoid, tannin, and saponin were determined using standard procedures as described by (12, 13).

2.5 Insect culture

The *S. zeamais* adults that were recently emerged and utilized in this investigation were taken from a culture that was already established at the Postgraduate Research Laboratory, FUTA. Two-liter plane glass kilner jars containing 500 g of *Zea mays*, acquired from the Agricultural Development Program and one hundred pairs of *S. zeamais* were introduced. A cage with an ambient temperature of 28 ± 2℃ and 75 ± 5% relative humidity was used to house the culture, which was kept in insect rearing jars.

2.6 Contact Toxicity of *C. amboinicus* Powder

A clean and uncontaminated twenty grams (20 g) of maize was measured in using an electronic weighing balance (Model JTC 2101N) and placed inside lidded plastic cups (250 ml). Thereafter, 0.1, 0.3, 0.6, 0.9 and 1.5 g dosages of *C. amboinicus* leaf, stem and root powders were carefully measured and was admixed separately with 20 g of the clean un-infested maize seeds in three replicates. The covered plastic cups containing the plant powders and the maize seeds were thoroughly shaken to ensure adequate mixing. Afterwards, ten copulating pairs (10 males: 10 females) of recently emerged (less than 7 day old) adults of *S. zeamais* was introduced into each of the lidded plastic cups holding the treated maize seeds. Only twenty grams of maize seeds and ten pairs of copulating adult *S. zeamais* were present in the control experiment. Insect mortality was assessed every day for 5 days. Dead weevils were those that did not move and did not respond to pin probing. At the end of 5 days post treatment, data on percentage adult mortality was corrected using (14) formula.

The insect rearing cage housed the insect bioassay setup, and daily observations were conducted until the emergence of the first filial generation adult.

2.7 Fumigant Toxicity of *C. amboinicus* Powder

Fumigant application method described by (15) was adopted with slight modification. Ten grammes of the maize seeds were weighed into 50ml plastic film tubes that had been cut opened at the bottom and sealed with mushlin cloth. *C. amboinicus* leaf, stem and root powders weighing 0.0 (untreated), 0.1, 0.3, 0.6, 0.9 and 1.5 g were put into another half-cut 50ml plastic film tubes. The 50ml tube and 25ml tube were then joined together with the aid of gum in corresponding orders. Ten pairs of unsexed adult *S. zeamais* (less than 7 days old) were introduced to the tube containing 10g of maize seeds and tight sealed. The experiments were set up in a Completely Randomized Design (CRD) and each treatment was replicated three times. Weevil mortality was assessed after 96 hours.

2.8 Contact Toxicity of *C. amboinicus* Crude Extracts

Twenty grammes (20 g) of clean uninfested maize grains was measured with the aid of an electronic weighing balance (Model JTC 2101N) and placed inside covered plastic cups (250 ml). Thereafter, different concentrations of *C. ambionicus* leaf, stem and root crude extract was admixed separately with 20 g of the clean uninfested maize seeds in three replicates. The covered plastic cups containing the plant extract and the maize seeds were thoroughly shaken to ensure adequate mixing. Then, ten copulating pairs (10 males: 10 females) of newly emerged (less than 7 days old) adults of *S. zeamais* were introduced into each of the covered plastic cups containing the treated maize seeds. The control

experiment had only 20 g of maize seeds and ten copulating pairs of adult *S. zeamais*. Insect mortality was assessed every day for 5 days. Dead weevils were those that did not move and did not respond to pin probing. At the end of 5 days post treatment, data on percentage adult mortality was corrected using (14) formula thus as described above. The insect bioassay set up was kept inside the insect rearing cage and daily observations were made until first filial generation adult emergence.

2.9 Fumigant Toxicity of *C. amboinicus* Crude Extract

Ten grammes of the maize seeds were weighed into 50 ml plastic film tubes that had been cut opened at the bottom and sealed with mushlin cloth. *Coleus ambionicus* leaf, stem and root crude extract weighing 0.0 (untreated), 0.1, 0.3, 0.6, 0.9 and 1.5 ml were placed in another half-cut 50ml plastic film tubes. The 50\ml tube and 25\ml tube were then joined together with the aid of gum in corresponding orders following the method described by (10). Ten pairs of unsexed adult *S. zeamais* (less than 7 days old) were introduced to the tube containing 10 g of maize seeds and tight sealed. The experiments were set up in a Completely Randomized Design (CRD) and each treatment was replicated three times. Weevil mortality was assessed after 96 hours as described above.

2.10 Data Analysis

Data collected were subjected to analysis of variance (ANOVA) at 5% significance level. Means were separated using Duncan Multiple Range Test (DMRT). Probit analysis was carried out on percentage mortality of the adult *S. zeamais* to determine the 50% lethal dose (LD_{50}) and 90% lethal dose (LD_{90}).

3. Results

3.1 Quantitative analysis of phytochemical present in C. amboinicus The result of the phytochemical screening of ethanolic extracts of *C. amboinicus* leaf, stem, and root is presented in Table 1. The quantity of phytochemicals present in *C. amboinicus* leaf, stem, and root ethanolic extracts were significantly difference ($p < 0.05$). The quantity of alkaloid, tannin, and flavonoid was high in *C. amboinicus* leaf, with values of 9.67 mg/g, 4.79 mg/g, and 7.44 mg/g, respectively, while saponin was significantly high in *C. amboinicus* root with a value of 6.37 mg/g. The root had the lowest content of alkaloid (5.71 mg/g), flavonoids (4.12 mg/g), and tannins (2.99 mg/g), while the stem had the lowest saponin with 2.49 mg/g.

Table 1
Quantitative analysis of phytochemical present in *C. amboinicus*

Plant Parts	Phytochemicals (mg/g)			
	Alkaloid	Flavonoid	Tannin	Saponin
Leaf	9.67 ± 0.03^{c}	7.44 ± 0.02^{c}	4.79 ± 0.01^{c}	3.75 ± 0.02^{b}
Stem	7.19 ± 0.05^{b}	5.27 ± 0.01^{b}	4.54 ± 0.02^{b}	2.49 ± 0.14^{a}
Root	5.71 ± 0.03^{a}	4.12 ± 0.04^{a}	2.99 ± 0.02^{a}	6.37 ± 0.03^{c}

Means followed by the same superscript in column are not significantly different from one another ($p > 0.05$) using Duncan Multiple Range Test (DMRT)

3.2 Contact Toxicity Effect of *C. amboinicus* Powder on Adult *S. zeamais* Mortality

The toxicity of *C. amboinicus* leaf, stem, and root powders on adult *S. zeamais* at different dosage and days is presented in Table 2. The results obtained showed that *C. amboinicus* leaf, stem, and root powders significantly ($p < 0.05$) effective against adult maize weevils compared to untreated maize grains (control) after 48 hours post treatment. However, there is no significant difference ($p > 0.05$) in insecticidal effectiveness of root powder (3.33%) and the control (0.00%) after 24 hours of application. The mortality effect of *C. amboinicus* leaf powder was higher compared to stem and root powder treatments throughout the experimental periods. The lowest toxic *C. amboinicus* part was root powder. In addition, the toxic effect of *C. amboinicus* leaf powder at 0.9 g dosage after 120 hours post treatment yield 100%, 1.5 g of stem powder yield 100% mortality after 120 hours after treatment while 1.5 g root powder yield 86.67% after 120 hours of treatment application.

Table 2
Percentage mortality of adult *S. zeamais* on maize seed treated with *C. amboinicus* powder

Plant parts	Dosage (g)	% Mortality (Mean ± S.E.)				
		24 hours	48 hours	72 hours	96 hours	120 hours
Leaf	0.1	20.00 ± 0.00^{de}	33.33 ± 3.33^{ef}	40.00 ± 0.00^{de}	50.00 ± 0.00^{d}	56.67 ± 3.33^{de}
Stem		10.00 ± 0.00^{bc}	23.33 ± 3.33^{cd}	33.33 ± 3.33^{cd}	40.00 ± 0.00^{c}	46.67 ± 3.33^{c}
Root		3.33 ± 3.33^{ab}	13.33 ± 3.33^{b}	23.33 ± 3.33^{b}	33.33 ± 3.33^{b}	40.00 ± 0.00^{b}
Leaf	0.3	26.67 ± 3.33^{ef}	36.67 ± 3.33^{efg}	46.67 ± 3.33^{ef}	56.67 ± 3.33^{e}	63.33 ± 3.33^{e}
Stem		16.67 ± 3.33^{cd}	30.00 ± 0.00^{de}	40.00 ± 0.00^{de}	50.00 ± 0.00^{d}	56.67 ± 3.33^{de}
Root		10.00 ± 0.00^{bc}	20.00 ± 0.00^{c}	30.00 ± 0.00^{c}	40.00 ± 0.00^{c}	50.00 ± 0.00^{cd}
Leaf	0.6	40.00 ± 0.00^{g}	50.00 ± 0.00^{h}	60.00 ± 0.00^{g}	70.00 ± 0.00^{g}	76.67 ± 3.33^{f}
Stem		26.67 ± 3.33^{ef}	40.00 ± 0.00^{fg}	50.00 ± 0.00^{f}	60.00 ± 0.00^{ef}	70.00 ± 0.00^{f}
Root		20.00 ± 0.00^{de}	30.00 ± 0.00^{de}	40.00 ± 0.00^{de}	50.00 ± 0.00^{d}	60.00 ± 0.00^{e}
Leaf	0.9	46.67 ± 3.33^{gh}	63.33 ± 3.33^{s}	73.33 ± 3.33^{h}	83.33 ± 3.33^{i}	100.00 ± 0.00^{h}
Stem		40.00 ± 0.00^{g}	60.00 ± 0.00^{i}	63.33 ± 3.33^{g}	73.33 ± 3.33^{gh}	90.00 ± 0.00^{g}
Root		30.00 ± 0.00^{f}	43.33 ± 3.33^{g}	53.33 ± 3.33^{f}	63.33 ± 3.33^{f}	73.33 ± 3.33^{f}
Leaf	1.5	63.33 ± 3.33^{j}	80.00 ± 0.00^{k}	90.00 ± 0.00^{i}	100.00 ± 0.00^{k}	100.00 ± 0.00^{h}
Stem		56.67 ± 3.33^{i}	73.33 ± 3.33^{j}	83.33 ± 3.33^{j}	90.00 ± 0.00^{j}	100.00 ± 0.00^{h}
Root		50.00 ± 0.00^{h}	60.00 ± 0.00^{i}	70.00 ± 0.00^{h}	76.67 ± 3.33^{h}	86.67 ± 3.33^{g}
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}

Mean follow by the same superlative in column are not significantly different from one another ($p > 0.05$) using Duncan Multiple Range Test (DMRT).

3.3 Lethal Dosage (LD) of *C. amboinicus* Part Powder against Adult *S. zeamais*

The lethal dosage (LD) of *C. amboinicus* leaf powder needed to achieve 50% (LD_{50}) and 90% (LD_{90}) mortality of *S. zeamais* is presented in Table 3. The amounts of *C. amboinicus* leaf powder needed to evoke 50% mortality (LD_{50}) of *S. zeamais* after a day, 2 days, 3 days, 4 days, and the 5th day of exposure were 0.95, 0.39, 0.24, 0.13, and 0.07 g, respectively. Lethal dosages of *C. amboinicus* leaf powder to achieve 90% mortality (LD_{90}) c of *S. zeamais* after different periods of exposure were 19.85, 7.03, 2.85, 3.06, and 4.89 g. The lethal doses of *C. amboinicus* stem powder required to kill *Sitophilus zeamais* within 1,2,3,4 and 5 days of exposure were 1.46, 0.61, 0.37, 0.23, and 0.15 g, respectively. The lethal doses needed to effectuate 90% mortality (LD_{90}) were 17.09 g, 8.41 g, 5.75 g, 2.83 g, and 1.67 g. The amounts of *C. amboinicus* root powder needed to evoke 50% (LD_{50}) mortality of *S. zeamais* after 24 h, 48 h, 72 h, 96 h, and 120 h of exposure were 1.85, 1.26, 0.71, 0.39, and 0.23 g, respectively. The lethal dosages of *C. amboinicus* root powder needed to achieve 90% (LD_{90}) mortality were 13.01, 17.35, 13.05, 8.87, and 3.46 g.

Table 3
Lethal Dosage (LD) of *Coleus amboinicus* Part Powder against Adult *S. zeamais*

Plant Powder	Exposure Period (days)	Intercept± S.E.	Slope± S.D.	R^2	LD_{50} (LCL - UCL)	LD_{90} (LCL - UCL)	*p* value
Leaf	1	5.02 ± 0.19	0.98 ± 1.02	0.93	0.95 (0.40–2.22)	19.85 (8.46–46.58)	0.74
	2	5.42 ± 0.18	1.05 ± 0.96	0.84	0.39 (0.18–0.87)	7.03 (3.19–15.48)	0.43
	3	5.76 ± 0.15	1.23 ± 0.81	0.84	0.24 (0.12–0.46)	2.85 (1.42–5.71)	0.50
	4	5.83 ± 0.20	0.95 ± 1.06	0.85	0.13 (0.05–0.32)	3.06 (1.23–7.61)	0.59
	5	5.81 ± 0.28	5.81 ± 1.46	0.88	0.07 (0.02–0.23)	4.89 (1.39–17.18)	0.15
Stem	1	4.80 ± 0.16	1.21 ± 0.83	0.94	1.46 (0.71–3.02)	17..09 (8.27–35.26)	0.58
	2	5.24 ± 0.16	1.14 ± 0.88	0.88	0.61 (0.29–1.27)	8.41 (4.06–17.44)	0.41
	3	5.48 ± 0.17	1.10 ± 0.91	0.83	0.37 (0.17–0.78)	5.75 (2.70–12.22)	0.47
	4	5.77 ± 0.16	1.21 ± 0.83	0.85	0.23 (0.11–0.47)	2.83 (1.40–5.75)	0.64
	5	6.04 ± 0.16	1.28 ± 0.79	0.80	0.15 (0.08–0.31)	1.67 (0.83–3.38)	0.55
Root	1	4.59 ± 0.14	1.52 ± 0.66	0.98	1.85 (0.99–3.46)	13.01 (6.96–24.31)	0.79

Plant Powder	Exposure Period (days)	Intercept± S.E.	Slope± S.D.	R^2	LD_{50} (LCL - UCL)	LD_{90} (LCL - UCL)	*p* value
	2	4.89 ± 0.17	1.14 ± 0.88	0.92	1.26 (0.59–2.68)	17.35 (8.14–37.00)	0.55
	3	5.15 ± 0.18	1.03 ± 0.97	0.89	0.71 (0.32–1.59)	13.05 (5.82–29.25)	0.56
	4	5.39 ± 0.19	0.96 ± 1.04	0.89	0.39 (0.17–0.93)	8.87 (3.76–20.93)	0.69
	5	5.70 ± 0.17	1.11 ± 0.90	0.89	0.23 (0.11–0.12)	3.46 (1.61–7.43)	0.76

Note: R^2 = Statistical measure of mortality proportion in regression model

S. E. = Standard error

S. D. = Standard deviation

LD_{50} = Lethal dosage at which 50% population response

LD_{90} = Lethal dosage at which 90% population response

LCL = Lower confidence limit

UCL = Upper confidence limit

p value = Chi -square (X^2) Significant

3.4 Contact Toxicity Effect of *C. amboinicus* Extract on Mortality Response of Adult *Sitophilus zeamais*

The mortality of *S. zeamais* was recorded after exposure to extracts of *C. amboinicus* parts (Table 4). Mortality rates increased in subsequent time periods extract dosage. Control had no mortality (0.00%) recorded and was significantly different ($p < 0.05$) from all other treatments. *Coleus amboinicus* leaf extracts achieved at least 50% mortality of *S. zeamais* at 0.1 ml, stem extracts at 0.6 ml (60.00%), and root extracts at 0.9 ml (80.00%) within 24 hours of exposure. Absolute mortality (100.00%) was attained within a day with leaf extract, day 2 with stem extract, and day 3 with root extract at 1.5 ml treatments. *C. amboinicus* root was the least toxic, evoking 20% mortality of maize seed on day 1 after treatment. In day 1, the adulticidal effects of 0.1 ml of *C. amboinicus* leaf (50.00%), 0.3 ml of stem (46.67%), and 0.6

ml of root (46.67%) were not significantly different ($p > 0.05$). Likewise, 0.1 ml of *C. amboinicus* stem (3.33%) and 0.3 ml of root (36.67%), 0.3 ml of *C. amboinicus* leaf (60.00%) and 0.6 ml of stem (60.00%), 0.9 ml of *C. amboinicus* stem (80.00%) and 1.5 ml of root (76.67%), stem oil extracts of 0.9 ml (80.00%) and 1.5 ml (86.67%), and root extract of 0.9 ml (70.00%) and 1.5 ml (76.67%) were not significantly different ($p > 0.05$). After 48 h, 100% mortality was recorded for *C. amboinicus* leaf, stem and root extracts concentrations of 0.9 ml and 1.5 ml, except 0.9 ml root extract (90.00%) at 72 h.

Table 4
Effect of Contact Toxicity of *C. amboinicus* Crude Extracts on Mortality Response of Adult *Sitophilus zeamais* on Maize Seed

Plant parts	Extract (ml)	% Mortality (Mean ± S.E.)				
		24 hours	48 hours	72 hours	96 hours	120 hours
Leaf	0.1	50.00 ± 0.00^{d}	60.00 ± 0.00^{d}	70.00 ± 0.00^{d}	80.00 ± 0.00^{ef}	86.67 ± 3.33^{d}
Stem		33.33 ± 3.33^{c}	50.00 ± 0.00^{c}	60.00 ± 0.00^{c}	70.00 ± 0.00^{c}	76.67 ± 3.33^{c}
Root		20.00 ± 0.00^{b}	36.67 ± 3.33^{b}	46.67 ± 3.33^{b}	56.67 ± 3.33^{b}	66.67 ± 3.33^{b}
Leaf	0.3	60.00 ± 0.00^{e}	70.00 ± 0.00^{e}	83.33 ± 3.33^{f}	93.33 ± 3.33^{g}	100.00 ± 0.00^{f}
Stem		46.67 ± 3.33^{d}	60.00 ± 0.00^{d}	70.00 ± 0.00^{d}	83.33 ± 3.33^{f}	93.33 ± 3.33^{e}
Root		36.67 ± 3.33^{c}	46.67 ± 3.33^{c}	60.00 ± 0.00^{c}	73.33 ± 3.33^{cd}	80.00 ± 0.00^{c}
Leaf	0.6	66.67 ± 3.33^{ef}	80.00 ± 0.00^{f}	90.00 ± 0.00^{g}	100.00 ± 0.00^{h}	100.00 ± 0.00^{f}
Stem		60.00 ± 0.00^{e}	66.67 ± 3.33^{e}	76.67 ± 3.33^{e}	90.00 ± 0.00^{g}	100.00 ± 0.00^{f}
Root		46.67 ± 3.33^{d}	60.00 ± 0.00^{d}	70.00 ± 0.00^{d}	76.67 ± 3.33^{de}	90.00 ± 0.00^{de}
Leaf	0.9	86.67 ± 3.33^{i}	100.00 ± 0.00^{h}	100.00 ± 0.00^{h}	100.00 ± 0.00^{h}	100.00 ± 0.00^{f}
Stem		80.00 ± 0.00^{hi}	86.67 ± 3.33^{g}	100.00 ± 0.00^{h}	100.00 ± 0.00^{h}	100.00 ± 0.00^{f}
Root		70.00 ± 0.00^{fg}	80.00 ± 0.00^{f}	90.00 ± 0.00^{g}	100.00 ± 0.00^{h}	100.00 ± 0.00^{f}
Leaf	1.5	100.00 ± 0.00^{j}	100.00 ± 0.00^{h}	100.00 ± 0.00^{h}	100.00 ± 0.00^{h}	100.00 ± 0.00^{f}
Stem		86.67 ± 3.33^{i}	100.00 ± 0.00^{h}	100.00 ± 0.00^{h}	100.00 ± 0.00^{h}	100.00 ± 0.00^{f}
Root		76.67 ± 3.33^{gh}	86.67 ± 3.33^{g}	100.00 ± 0.00^{h}	100.00 ± 0.00^{h}	100.00 ± 0.00^{f}

Plant parts	Extract (ml)	% Mortality (Mean ± S.E.)				
		24 hours	48 hours	72 hours	96 hours	120 hours
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[s]

Mean follow by the same superlative in column are not significantly different from one another ($p > 0.05$) using Duncan Multiple Range Test (DMRT).

3.5 Lethal Concentration (LC) of *C. amboinicus* Extract against Adult *Sitophilus zeamais*

The lethal concentration (LC) of *C. amboinicus* leaf extract needed to achieve 50% (LC_{50}) and 90% mortality (LC_{90}) of *S. zeamais* is presented in Table 5. The amounts of *C. amboinicus* leaf extract needed to evoke 50% mortality (LC_{50}) of *S. zeamais* after 24, 48, 72, 96, and 120 hours of exposure were 0.13, 0.05, 0.03, 0.02, and 0.02 ml, respectively. Lethal dosages of *C. amboinicus* leaf extract to achieve 90% mortality (LC_{90}) of *S. zeamais* after different days of exposure were 2.64, 2.65, 0.61, 0.21, and 0.13 ml. The lethal dosages of *C. amboinicus* stem extracts required to cause 50% mortality (LC_{50}) of *S. zeamais* within 120 h of exposure were 0.27, 0.12, 0.04, 0.03 and 0.03 ml, respectively. The lethal doses needed to effectuate 90% mortality (LC_{90}) were 5.07 ml, 2.44 ml, 1.50 ml, 0.61 ml, and 0.22 ml. The amounts of *C. amboinicus* root extracts needed to evoke 50% mortality (LC_{50}) of *S. zeamais* after 24, 48, 72, 96, and 120 hours of exposure were 0.48, 0.25, 0.15, 0.05, and 0.04 ml, respectively. The lethal dosages of *C. amboinicus* root extracts needed to achieve 90% mortality (LC_{90}) were 4.19, 2.93, 2.60, 1.62, and 0.66 ml.

Table 5
Lethal Concentration (LC) of *C. amboinicus* Crude Extract against Adult *Sitophilus zeamais* (LC_{50} and LC_{90})

Plant Extract	Exposure Period (hours)	Intercept± S.E.	Slope± S.D.	R^2	LC_{50} (LCL - UCL)	LC_{90} (LCL - UCL)	*p* value
Leaf	24	5.89 ± 0.19	1.00 ± 0.99	0.78	0.13 (0.05–0.30)	2.64 (1.11–6.30)	0.61
	48	5.97 ± 0.27	0.74 ± 1.35	0.97	0.05 (0.02–0.16)	2.65 (0.79–8.89)	0.33
	72	6.49 ± 0.24	0.96 ± 1.03	0.99	0.03 (0.01–0.08)	0.61 (0.21–1.79)	0.81
	96	7.22 ± 0.22	1.38 ± 0.72	1.00	0.02 (0.01–0.06)	0.21 (0.08–0.57)	-
	120	7.63 ± 0.25	1.52 ± 0.66	1.00	0.02 (0.01–0.05)	0.13 (0.04–0.39)	-
Stem		5.77 ± 0.14	1.34 ± 0.74	0.93	0.27 (0.14–0.51)	5.07 (1.19–21.41)	0.72
	24	6.08 ± 0.17	1.18 ± 0.85	0.92	0.12 (0.06–0.26)	2.44 (1.29–4.62)	0.74
	48	5.85 ± 0.34	0.61 ± 1.65	0.99	0.04 (0.01–0.17)	1.50 (0.69–3.22)	0.20
	72	6.49 ± 0.24	0.97 ± 1.03	0.99	0.03 (0.01–0.09)	0.61 (0.21–1.79)	0.81
	96	7.35 ± 0.19	1.62 ± 0.62	1.00	0.03 (0.01–0.08)	0.22 (0.09–0.52)	-
Root	24	5.44 ± 0.14	1.36 ± 0.73	0.95	0.48 (0.26–0.89)	4.19 (2.26–7.79)	0.77
	48	5.77 ± 0.15	1.27 ± 0.79	0.90	0.25 (0.13–0.49)	2.93 (0.89–9.69)	0.64

Plant Extract	Exposure Period (hours)	Intercept± S.E.	Slope± S.D.	R^2	LC_{50} (LCL - UCL)	LC_{90} (LCL - UCL)	*p* value
	72	6.06 ± 0.16	1.26 ± 0.79	0.82	0.15 (0.07–0.30)	2.60 (1.33–5.11)	0.66
	96	5.94 ± 0.27	0.74 ± 1.35	0.95	0.05 (0.02–0.18)	1.62 (0.79–3.31)	0.29
	120	6.48 ± 0.21	1.07 ± 0.93	0.98	0.04 (0.02–0.11)	0.66 (0.26–1.73)	0.78
Note: R^2 = Statistical measure of mortality proportion in regression model							
S. E. = Standard error							
S. D. = Standard deviation							
LC_{50} = Lethal concentration at which 50% population response							
LC_{90} = Lethal concentration at which 90% population response							
LCL = Lower confidence limit							
UCL = Upper confidence limit							
p value = Chi -square (X^2) Significant							

3.6 Fumigant Toxicity Effect of *C. amboinicus* Powder and Extract on *S. zeamais* Adult Emergency

The fumigant toxic effects of *C. amboinicus* leaf powder and extract were significantly higher ($p < 0.05$) compared to all other extract treatments throughout the experimental period (Table 6). The fumigant effect of leaf power and extract achieved 100% mortality of *S. zeamais* at 0.6 g and 0.6 ml, respectively. At all treatment levels, the fumigant effects of stem and leaf powder and extract on *S. zeamais* mortality were not significantly different ($p > 0.05$) from each other, except for extract at 0.9 ml. The untreated *S. zeamais* showed no fumigant effect.

Table 6
Toxicity Effect of *C. amboinicus* Powder and Extract on *S. zeamais* Adult Emergency

Plant Part	Dosage (g) or (ml)	Adult Mortality (%) after 96 hours	
		Powder	Extracts
Leaf	0.1	63.33 ± 26.67^{de}	100.00 ± 0.00^{h}
Stem	0.1	40.00 ± 0.00^{bc}	50.00 ± 0.00^{bcd}
Root	0.1	30.00 ± 0.00^{b}	43.33 ± 3.33^{b}
Leaf	0.3	83.33 ± 3.33^{ef}	100.00 ± 0.00^{h}
Stem	0.3	50.00 ± 0.00^{bcd}	53.33 ± 3.33^{cde}
Root	0.3	46.67 ± 3.33^{bcd}	46.67 ± 3.33^{bc}
Leaf	0.6	100.00 ± 0.00^{f}	100.00 ± 0.00^{h}
Stem	0.6	60.00 ± 0.00^{cd}	56.67 ± 3.33^{def}
Root	0.6	53.33 ± 3.33^{cd}	50.00 ± 0.00^{bcd}
Leaf	0.9	100.00 ± 0.00^{f}	100.00 ± 0.00^{h}
Stem	0.9	63.33 ± 3.33^{de}	63.33 ± 3.33^{fg}
Root	0.9	56.67 ± 3.33^{cd}	53.33 ± 3.33^{cde}
Leaf	1.5	100.00 ± 0.00^{f}	100.00 ± 0.00^{h}
Stem	1.5	66.67 ± 3.33^{de}	66.67 ± 3.33^{g}
Root	1.5	60.00 ± 0.00^{cd}	60.00 ± 0.00^{efg}
Control	0.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}

Mean follow by the same superlative in column are not significantly different from one another ($p > 0.05$) using Duncan Multiple Range Test (DMRT).

4. Discussion

The use of botanicals in place of synthetic chemical in the control of crop and stored products pest is currently gaining recognition. Some plant products have been researched on and proved ability in mitigating damages caused by insect pest on agricultural products with no toxicity effect on consumers and environment (16, 17). The present study has shown the adulticidal potency of *C. amboinicus* powder

and crude extract against adult maize weevil with the emphasis on the leaf part of the plant as the most potent.

In this study, the quantity of alkaloids, tannins, flavonoids, and saponins present in the plant leaf, stem, and root varies with the leaf extract having the highest content of alkaloid, tannin, and flavonoid while the root most saponins. These phytochemicals have been reported in *C. amboinicus* extract by (18, 19); however, (10) did not saponins in leaf extract. The disparities in phytochemical contents can be attributed to geographical location, climate, and different stages of plant material collection (20). These phytochemicals are not harmful to human but serve has anticonvulsive and antiepileptic medicine (21, 22). Secondary metabolites such as phenolic compounds, saponins, alkaloids, flavonoids, and terpenoids have been identified to exhibit strong activities against several pathogens and insect pests (23).

The effectiveness of *C. amboinicus* leaf, stem, and root is dosage and time dependent; the outcome of this study showed that both the powder and extracts of *C. amboinicus* leaf, stem, and root is toxic against adult maize weevils either as contact or fumigant plant-based insecticide. These findings conformed to the findings of (24) and (25) who reported the effectiveness of some plant powders in the control of storage insect pest population. Wanna and Krasaetep (16) have also reported the insecticidal effect of crude extract from *Plectranthus amboinicus* a synonymous plant to *C. amboinicus* in the management of *S. zeamais* population. In another study carried out by (26), *C. amboinicus* powder when admixed with maize resulted in high mortality of adult *S. zeamais*. This was in support of our current study and the insecticidal activities of the plant materials is attributed to the natural chemical components of the plant which serve as antifeedant against the adult weevil (27). Findings from the current study, the leaf *C. amboinicus* contain the higher composition of phytochemicals and evoked higher adult weevil mortality compared to parts understudied. This observation was in conformity with the findings of (28), who reported that the leaf is richer in volatile or essential constituents, which show ovicidal, toxic, and deterrent effects on the stored product insect. The toxicity and antifeedant effects of alkaloids on stored products insect pests have been reported by (29). Also, insecticidal potency of saponin has been reported by (30) documented anti-inflammatory, antiviral, antifungal, insecticidal, molluscicidal, piscidal, and antibacterial activities of saponin. We also observed that the estimated dosage of *C. amboinicus* plant materials required to protect stored maize grain against maize weevils depend on period storage to the amounts of the plant materials applied. However, a relatively high amount of *C. amboinicus* plant powder and crude is required to evoked higher population of adult maize weevil mortality on short period storage of highly infested maize grains.

5. Conclusion

The insecticidal potency of *Coleus amboinicus* plant against maize weevil has been established in the study. The plant leaf, stem, and root of the plant contains different levels of phytochemicals such as alkaloids, saponin, flavonoid, and tannin which are responsible for the insecticide toxicity, antifeedant and oviposition deterrence to the maize weevil with no report of environmental and human health

implications. This study shows the strong insecticidal activity of *C. amboinicus* leaf extracts and its potential role as a fumigant in the management of adult maize weevil *S. zeamais*. The effectiveness of the *C. amboinicus* plant material as botanical insecticide is dosage-dependent. Thus, this plant can be adopted replace synthetic chemical insecticides. Furthermore, the use of *C. amboinicus* leaf, stem, and root as safe bio-insecticides in the management of insects of stored grains and farm crops among food merchants and farmers should be advocated.

Declarations

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Authors' contributions

MOA Conceptualization, Methodology, Formal analysis, writing – reviewing & editing.
KDI Conceptualization, Methodology, Data curation, Formal analysis, writing – original draft. **OSY,** Data curation, Investigation. All authors have read and approved the manuscript.

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Data Availability

All the data collected are presented in tables in the manuscript and further inquiries can be directed to the corresponding author.

Ethics approval and consent to participate

Coleus amboinicus was collected at Aponmu farm in Akure, Ondo State. The plant materials were identified by a Plant Taxonomist, Dr. F. A. Ologundudu, and avoucher specimen was deposited at Biology Department Herbarium, FUTA with voucher ID #562.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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