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Biopesticidal activities of three botanicals (*Ageratum conyzoides* L., *Petiveria alliacea* L. and *Hyptis suaveolens* L. Poit,) against *Sitophilus oryzae* L

Abstract

This study was carried out to evaluate the effectiveness of oil extracts from *Ageratum conyzoides* L., *Petiveria alliacea* L., and *Hyptis suaveolens* L. as biopesticides against Sitophilus oryzae in the Entomology Laboratory of Federal University of Technology Akure, Ondo State. The experiments were conducted at a temperature of 28±2°C and a relative humidity of 75±5%. Methanol was used as a solvent to extract the oil from the plants, and different concentrations (0.5%, 1.0%, 1.5%, 2.0%, and 2.5%) of each plant extract were prepared. The results demonstrated that the oil extracts from all three plants had a significant impact on the mortality of *Sitophilus oryzae*. Among them, the oil extract from *Hyptis suaveolens* proved to be the most effective, causing 100% mortality of *Sitophilus oryzae* at 2.0% and 2.5% concentrations within 96 hours of introduction. The LD50 (concentration required to cause 50% mortality) for *Hyptis suaveolens* was 0.53 (at 96 hours) and 0.36 (at 120 hours), while the LD90 (concentration required to cause 90% mortality) was 4.27 (at 96 hours) and 1.86 (at 120 hours) for *Sitophilus oryzae*. Furthermore, the oil extracts of all three plants significantly reduced adult emergence of the insects and prevented weight loss in the seeds. These effects were particularly prominent at concentrations of 2.0% and 2.5%. Statistical analysis indicated significant differences ($p < 0.05$) between the treatments and control groups for all the parameters assessed. In conclusion, the results of this study demonstrated that the leaf extract of *Hyptis suaveolens* was more effective than the extracts from the other plants in reducing *Sitophilus oryzae* populations, inhibiting adult emergence, and preventing weight loss in stored grains. Therefore, *Hyptis suaveolens* can be considered as a valuable addition to the range of botanicals used for *Sitophilus* oryzae control in food storage.

Keywords: *Hyptis suaveolens*, *Petiveria alliacea*, *Ageratum conyzoides*, Mortality and *Sitophilus oryzae*

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Introduction

The residual presence of synthetic chemicals has been found to cause some diseases in humans, as it is toxic to the final consumer. While it has been effective in the last ten years, its efficiency is declining due to side effects.[1,2] Additionally, many insects have developed resistance to synthetic insecticides, leading to an increase in pest populations and ultimately food insecurity. To address this problem, alternative methods used in the past, such as clay, ash, and plant powder, may be useful.[3] However, it's important to consider that the effectiveness of any pest control method depends on various factors, including pest type, infestation level, and environmental conditions, and a combination of methods may be necessary to achieve optimal results. Researchers are constantly searching for botanicals that can effectively control insect pests, as medicinal plants have been found to contain various chemical materials with insecticidal properties. The abundance of these plants in our environment has led to an increased interest in their potential use in insect pest control.[4,5] Plant products have been found to reduce the survival rate of insect larvae, pupae, and adults, and extracts, powders, oils, and essential oils from various potent plants have been reported to act as repellents against economically important stored product insect pests.[6–8]

Studies have shown that *Ocimum gratissimum* and Vernonia amygdaline have strong insecticidal properties and are effective in controlling *Callosobruchus maculatus*. *Ageratum conyzoides* L., *Petiveria alliacea* L., and *Hyptis suaveolens* L. Poit are common medicinal plants found in tropical and subtropical regions, and while some research has been conducted on their insecticidal activities, they have not been fully explored in this regard, unlike other plants such as *Eugenia aromatic* and *Nicotiana* spp. Most of these plants have been evaluated for their effectiveness against coleopterans and lepidoptera that attack stored products.[9,2] FAO[10] reports that rice provides approximately 20% of the world's total energy supply, with wheat following closely at 19% and maize at 5%. More than 17 countries in Asia and the Pacific, 8 countries in Africa, and 9 countries in South and North America rely heavily on rice as a primary source of nutrition. Due to the significant increase in Africa's population, there has been a call for increased rice production in Africa and sub-Saharan Africa (WARDA, 2008). Many countries in Africa and sub-Saharan Africa import rice, including Nigeria (WARDA, 2007). Rice is not only a commonly consumed cereal for humans but also for hexapods such as insects. Insects compete with humans for this valuable food source due to its high nutritional value. The competition between humans and insects over rice has resulted in global food insecurity, as insects attack both rice fields and storage facilities. Insects such as *Sitophilus granarius* L, *Sitotroga cerealella* (Olivier), and *Ryzoperta dominica* F are known threats to stored products, and their fecundity can cause significant losses to agricultural commodities like rice, leading to reduced quantity and market value. In order to combat the primary infestation of stored grains by pests like Sitophilus oryzae, researchers are evaluating the effectiveness of botanicals like *A. conyzoides*, *P. alliacea,* and *H. suaveolens* as biopesticides. This study aims to join global entomologists in researching safe and effective ways to fight against stored grain pests like *Sitophilus oryzae*.

Methods

Experimental site

The study was conducted at the Postgraduate Entomology laboratory of the Biology Department, Federal University of Technology Akure, Nigeria. The temperature and relative humidity during the research were maintained at 27±2 oC and 75±5%, respectively. The laboratory had adequate ventilation and all windows were left open to facilitate the biological activities of the rice weevil (*Sitophilus oryzae*).

Rice cultivars

The rice cultivars utilized in this study were obtained from Erinoke Oriade local Government area of Osun State in Southwest Nigeria. The rice cultivar was subsequently identified at the African Rice section of the International Institute of Tropical Agriculture (IITA) in Ibadan. To ensure adequate ventilation, the identified rice was packed in portable hessian sacks and transported to the laboratory, where it was then stored in a net cage.

Insect collection and insect culture

The source culture of Sitophilus oryzae was obtained from the Food Storage Laboratory of the Department of Biology at the Federal University of Technology, Akure, Nigeria. The insects were fed uninfested FARO 58 grains and ten adult individuals were selected to initiate a pure culture raised on 100g of rice grains. The culture was kept in the laboratory at 28±2 ^{o}C and a relative humidity of 75±5%, with the insects being maintained by replacing the sifted grains with uninfected rice grains. The first-generation adults of S. oryzae used for subsequent experiments were obtained from the existing laboratory culture. The S. oryzae population used for this study was collected from the Storage Research Laboratory of the Biology Department at the Federal University of Technology, Akure, Ondo State, Nigeria.

Preparation of the plant extract

The leaves of *Agerantum conyzoides* L. (Goat weed (Imi esu)), *Petiveria alliacea* L. (Guinea hen weed (Awogba / Ojusaju)) and *Hyptis suaveolens* (L.) Poit (Pig nut (Arunfofo)) were collected from farms around the Federal University of Technology, Akure, Nigeria, air-dried, and ground into a fine powder using a 1mm2 perforation sieve. The powdered samples were stored in a sealed container until needed for the bioassay. The plant extracts were prepared using methanol as a solvent and a soxhlet apparatus. The extract contained both the oil and the solvent, which were separated using a rotary evaporator. The extracts were prepared at concentrations of 0.5%, 1.0%, 1.5%, 2.0%, and 2.5% (0.5%, 1.0%, 1.5%, 2.0%, and 2.5% extract mixed with 99.5%, 99%, 98.5%, 98%, and 97.5% solvent, respectively). The same solvent used for extraction (methanol) was used to dissolve the extract, and the solvent was allowed to evaporate before the introduction of insects.

Assessment of mortality of adult S. oryzae

To begin the experiment, 10 grams of local rice was weighed and put into 250 ml plastic containers. The botanical oil extracts were then added to the rice in varying percentages of 0.5%, 1.0%, 1.5%, 2.0%, and 2.5% V/V, while a control group with 2ml methanol was also included. This was done for four replicates. Ten newly hatched adults of S. oryzae were introduced to each treated sample and left in the breeding cage in the laboratory. The mortality of *S. oryzae* was recorded at 24, 48, 72, 96, and 120 hours after treatment. The experiment was carried out in a Completely Randomized Design with each treatment replicated three times. Dead and live insects were removed after 120 hours and the number of mortalities was counted and recorded. The control mortality was determined using Abbott's formula (1925), and the LC50 and LC90 values were calculated using Probit analysis.[11]

Adult emergence of sitophilus oryzae

Twenty grams of paddy rice treated with different concentrations of oil extracts from plant parts were placed in small plastic containers, along with control treatments as in the mortality experiment. The oil extract setup was left for 10 minutes so that the solvent could evaporate, leaving only the oil extract on the seeds. Ten 0-24 hour old Sitophilus oryzae were introduced into each container containing the treated rice grains. The containers were covered with perforated lids and muslin cloth to allow for ventilation. The experiment was set up in four replicates for each concentration of *Ageratum conyzoides* L., *Petiveria alliacea* L., and *Hyptis suaveolens* L. Poit. The emergence of adult Sitophilus oryzae was monitored weekly for 7 weeks in each container and recorded. Percentage adult emergence, seed damage, and weight loss were calculated using the following formulas.

Statistical analysis

The collected data was analyzed using one-way analysis of variance at a significance level of 5%. Duncan's Multiple Range Tests of SSPS version 21 was used to distinguish between the means. The data obtained from the mortality experiment was subjected to regression analysis to obtain LD50 and LD90 of the extracts after application using probit analysis.[11]

Results

Percentage mortality of *Sitophilus oryzae*

The percentage mortality of Sitophilus oryzae on the botanical treated FARO 58 (Rice used) is presented in Table 1. The percentage mortality of Sitophilus oryzae in each of the treatment was varied based on the plant extract, concentration and exposure time to the botanicals (*A. conyzoides, P. alliacea* and *H. suaveolens*). At 0.5 concentration, 6.67% of S. Sitophilus was recorded in all the botanicals at 24hrs. The values were no significantly different from one another ($p < 0.05$) and the control. With the same concentration, as the time of exposure increase the percentage mortality increase, At 48hrs *A. conyzoide* (13.33%), *P. alliacea* (13.33%) and *H. suaveolens* (26.67%). There were no statistically significant difference among the value at $p < 0.05$ and the control. At 72hrs *A. conyzoide* (20.00%), *P. alliacea* (23.33%) and *H. suaveolens* (30.00%). The values were not significantly different from one another. At 120hrs *A. conyzoide* (53.33%), *P. alliacea* (53.33%) and *H. suaveolens* (50.00%). There were no statistically significant difference among the values. At 1.00 concentration, At 24hrs *A. conyzoide* (3.33%), *P. alliacea* (20.00%) and *H. suaveolens* (20.00%). There is no statistically significant difference among the values. After 48hrs *A. conyzoide* cause 16.67%, *P. alliacea* (30.00%) and *Hyptis suaveolens* (36.67%). There is a statistically significant difference between the value *A. conyzoide* and *H. suaveolens* but no significant difference in *A. conyzoides* and the control. For 2.5% concentration, at 24hrs *Agerantum conyzoide* have 20.00%, *Petiveria alliacea* (10.00%) and *Hyptis suaveolens* (33.33%)

mortality of Sitophilus oryzae. There is no statistically significant difference among the value *A. conyzoide*, *P. alliacea* and the control but there is a significant difference the mortality recorded on the treatment of *H. suaveolens*, *P. alliacea* and the control.

At 48hours *A. conyzoide* have 26.67.00%, *P. alliacea* (26.67%) and *H. suaveolens* (60.00%) mortality of Sitophilus oryzae. The value of *H. suaveolens* shows a significant difference from the control while other control is not significant different from the control. At 72hrs A. *conyzoide* have 36.67%, *P. alliacea* (43.33%) and *H. suaveolens* (73.33%) mortality of *Sitophilus oryzae*. The value of *H. suaveolens* was significantly different from that of the control and other two botanicals. At 96hours, 60.00% mortality of S. oryzae was recorded on *A. conyzoide*, 66.67% on *P. alliacea* while 100.00% mortality was recorded on *H. suaveolens*. There is a significant difference in the value recorded on *H. suaveolens* and other botanicals with the control. At 120hrs with the same concentration (2.5%), 80% mortality of O. surinamensis on *A. conyzoide*, 80% was recorded on *P. alliacea* while 100.00% mortality was recorded on *H. suaveolens*. The value from the three botanical *A. conyzoides*, *P. alliacea* and *H. suaveolens* was significantly different from the control. *H. suaveolens* showed the highest mortality of S. oryzae at concentration of 2.5% and 120hrs, although the value increase as the time of exposure increases. 3.2 Lethal Dosage of three botanicals Required to cause 50% and 90% Mortality of Sitophilus oryzae.

The lethal dosage (LD) of three botanicals extract against adult Sitophilus oryzae are presented in Table 2. The required concentration of *Ageratum conyzoides* needed to achieve 50% (LD50) mortality of Sitophilus oryzae after 24hours, 48hours, 72hours, 92 hours and 120 hours exposure were 15.93, 11.86, 8.85, 2.34 and 1.45 respectively. The concentration required to achieve 90% (LD90) mortality of Sitophilus oryzae using *Ageratum conyzoides* are 93.15, 39.33, 27.24, 13.15 and 8.52 for 24,48, 72, 96 and 120 hours of exposure respectively. The regression linear (R2) calculated for the 24 hours, 48 hours, 72 hour, 96 hours and 120 hours were 0.97, 0.79, 0.96, 0.52 and 0.58 respectively. The concentration of *Petiveria alliacea* extract needed to cause 50% (LD50) mortality Sitophilus oryzae for 120 hours of exposure were 6.79, 4.25, 3.87, 2.14 and 0.73 respectively. The lethal concentration of *P. alliacea* leaf needed to achieve 90% (LD90) mortality of Oryzaephilus surinamensis after 24hrs,48hrs, 72hrs, 96hrs and 120hrs of exposure were 47.29,36.04, 25.07, 19.21 and 8.69 respectively. The regression linear (R2) calculated for the 24hours, 48hours, 72 hour, 96 hours and 120 hours were 0.94, 0.95, 0.92, 0.55 and 0.92 respectively. The concentration of *Hyptis suaveolens* leave extract that required to cause 50% (LD50) mortality of *Sitophilus oryzae* for 120hrs exposure were 16.08, 2.35, 1.06, 0.53and 0.36 respectively. The lethal dose of *Hyptis suaveolens* leave extract that required to cause 90% (LD90) mortality of Sitophilus oryzae after 120 hours were 68.62, 33.90, 19.30, 4.27 and 1.85 respectively. The regression linear (R2) calculated for the 24hours, 48hours, 72hour, 96hours and 120hours were 0.96, 0.98, 0.91, 0.99 and 0.97 respectively.

Lethal dosage of three botanicals required to cause 50% and 90% mortality of *Sitophilus oryzae*

The lethal dosage (LD) of three botanicals extract against adult *Sitophilus oryzae* are presented in Table 2. The required concentration of *Ageratum conyzoides* needed to achieve 50% (LD_{50}) mortality of *Sitophilus oryzae* after 24hours, 48hours, 72hours, 92 hours and 120 hours exposure were 15.93, 11.86, 8.85, 2.34 and 1.45 respectively. The concentration required to achieve 90% (LD_{90}) mortality of *Sitophilus oryzae* using *Ageratum conyzoides* are 93.15, 39.33, 27.24, 13.15 and 8.52 for 24,48, 72, 96 and 120 hours of exposure respectively. The regression linear (R^2) calculated for the 24 hours, 48 hours, 72 hour, 96 hours and 120 hours were 0.97, 0.79, 0.96, 0.52 and 0.58 respectively. The concentration of *Petiveria alliacea* extract needed to cause 50% (LD_{50}) mortality *Sitophilus oryzae* for 120 hours of exposure were 6.79, 4.25, 3.87, 2.14 and 0.73 respectively. The lethal concentration of *P. alliacea* leaf needed to achieve 90% (LD_{90}) mortality of *Oryzaephilus surinamensis* after 24hrs,48hrs, 72hrs, 96hrs and 120hrs of exposure were 47.29,36.04, 25.07, 19.21 and 8.69 respectively. The regression linear (R^2) calculated for the 24hours, 48hours, 72 hour, 96 hours and 120 hours were 0.94, 0.95, 0.92, 0.55 and 0.92 respectively. The concentration of *Hyptis suaveolens* leave extract that required to cause 50% (LD_{50}) mortality of *Sitophilus oryzae* for 120hrs exposure were 16.08, 2.35, 1.06, 0.53and 0.36 respectively. The lethal dose of *Hyptis suaveolens* leave extract that required to cause 90% (LD_{90}) mortality of *Sitophilus oryzae* after 120 hours were 68.62, 33.90, 19.30, 4.27 and 1.85 respectively. The regression linear (R^2) calculated for the 24hours, 48hours, 72hour, 96hours and 120hours were 0.96, 0.98, 0.91, 0.99 and 0.97 respectively.

Effect on adult emergence

There was no adult emergence from treated samples with all the plants at week 3 and week 4 of *P.* alliacea and *H. suaveolens*. As the week increase, insect began to emerge in all the treatment except in at 2.0% and 2.5% oil extract concentrations of *Hyptis suaveolens*. Nevertheless, there was adult emergence in the 0.5% (0.00%-26.30%), 1% (0.00%- 12.00%), 1.5% (0.00%- 11.00%) of all plant parts respectively. There was higher emergence in the control 0.5% (15% (week 1), 56% (week 5) (98% (week 6) and 99.9% control (week 7). The effect of plant extract concentration was significantly ($p<0.05$) different from other concentrations and the controls (Table 3).

Percentage weight losses caused be Sitophilus oryzae infestation

The infestation of *Sitophilus oryzae* cause weight loss which is converted to percentage, Table 4. All the plants extract prevented the grain of rice from excessive weight loss, as a result of protection of the grains from *Sitophilus* attack. Although the grain of rice loss substantial with may be as a result of dryness of the grains as the storage time increases. The percentage weight loss was higher (90.25%) in the control compare to the experimental.

Table 1 Effects oil extract on Mortality of *Sitophilus oryzae* on FARO 58a treated with plant extract

Botanicals	Concentration	24hrs	48hrs	72hrs	96hrs	120hrs
A. conyzoide		6.67±6.67ab	6.67±6.67a	33.33±3.33bcde	36.67±6.67b	40.00±5.77b
P. alliacea	0. 5	3.33±3.33a	10.00±5.77a	16.67±3.33ab	33.33±3.33ab	43.33± 3.33b
H. suaveolens		26.67±8.82ab	33.33±3.33bcd	50.00±5.77ef	50.00±5.77bc	60.00±5.77bcd
A. conyzoide	1	13.33±6.67ab	23.33±3.33abc	30.00±0.00bcd	36.67±3.33b	43.33±3.33b
P. alliacea		23.33±3.33ab	23.33±5.77abc	33.33±3.33bcde	40.00±5.77b	56.67±3.33bcd
H. suaveolens		23.33±12.02ab	23.33±3.33abc	50.00±0.00bcde	63.33±3.33cd	76.67±8.82def
A. conyzoide	1.5	13.33±8.82aab	20.00±5.77ab	26.67±6.67abc	36.67±6.67b	46.67±8.81bc
P. alliacea		13.33±8.82ab	16.67±8.82ab	26.67±6.67abc	40.00±10.00b	73.33±3.33bcd
H. suaveolens		23.33±12.02ab	40.00±0.00cd	43.33±3.33cdef	73.33±14.53d	90.00±10.00f
A. conyzoide	2	16.67±8.82ab	23.33±6.67ab	30.00±5.77bcd	33.33±3.33ab	46.67±8.82bc
P. alliacea		16.67±12.02ab	20.00±10.00ab	30.00±10.00bcd	40.00±10.00b	60.00±11.55bcd
H. suaveolens		30.00±5.77b	50.00±5.77d	60.00±5.77f	80.00±5.77d	93.33±3.33f
A. conyzoide	2.5	10.00±5.77ab	20.00±5.77ab	26.67±3.33abc	40.00±5.77b	66.67±8.82f
P. alliacea		20.00±10.00ab	33.33±3.33bcd	46.67±3.33def	63.33±3.33cd	83.33±3.33ef
H. suaveolens		30.00±5.77b	50.00±5.77d	56.67±12.02f	83.33±12.02d	90.00±5.77f
Control	0	6.67±3.33ab	10.00±0.00a	10.00±0.00a	13.33±3.33a	13.33±3.33a

Table 2 Percentage Mortality of *Sitophilus oryzae* on FARO 58a (Probit)

Plant Extract	Exposure Period	Intercept± S.E.	Slope± S.D.	R^2	LC50 (LCL - UCL)	LC90 (LCL -UCL)	P value
	24 hours	3.72±0.32	0.73±1.37	0.97	15.93 (10.4 – 23.43)	93.15(55.58-123.32)	0.99
	48 hours	3.93±0.21	1.01±0.99	0.79	11.86 (4.61 – 20.51)	39.33(13.04 - 61.5.)	0.45
A. conyzoide	72 hours	4.35±0.34	0.56±1.79	0.96	8.85 (3.20 – 18.89)	27.24 (14.21-45.78)	0.99
	92 hours	4.70±0.22	0.81±1.24	0.52	2.34 (0.86 – 6.39)	13.15 (3.17 -25.38)	0.36
	120 hours	4.88±0.24	0.74±1.35	0.58	1.45 (0.49 – 4.28)	8.52 (2.53 – 14.24)	0.67
	24 hours	3.73±0.15	1.54±0.65	0.94	6.79 (3.54 – 13.06)	47.29 (24.62 – 90.8)	0.74
	48 hours	3.98±0.28	0.73±1.33	0.95	4.25 (2.07 – 9.86)	36.04 (20.16 –78.91)	0.97
P. alliacea	72 hours	4.35±0.17	1.11±0.90	0.92	3.87 (1.79 – 8.33)	25.07 (15.56 - 39.18)	0.85
	92 hours	4.74±0.23	0.79±1.26	0.55	2.14 (0.77 – 5.93)	19.21 (12.55 - 31.02)	0.48
	120 hours	5.17±0.15	1.19±0.84	0.92	0.73 (0.36 – 1.45)	8.69 (4.35 – 17.36)	0.01
	24 hours	4.30±0.33	0.58±1.73	0.96	16.08 (3.61 – 71.74)	68.62 (60.21- 88. 50)	0.99
H. suaveolens	48 hours	4.59±0.17	1.11±0.91	0.98	2.35 (1.12 – 4.94)	33.90 (16.12 - 71.32)	0.98
	72 hours	4.99±0.31	0.57±1.76	0.91	1.06 (0.26 – 4.37)	19.30 (14.69 - 45.70)	0.99
	92 hours	5.39±0.71	1.41±0.71	0.99	0.53 (0.29 – 0.97)	4.27 (2.55 – 8.67)	0.99
	120 hours	5.80±0.12	1.82±0.55	0.97	0.36 (0.21 – 0.62)	1.85 (1.08 – 3.18)	0.99

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.

Table 3 Emergence of *Sitophilus oryzae* from week 3-7

Plant extract	Concentrations %	Week 3	Week 4	Week 5	Week6	Week 7
Ageratum conyzoide	0.5	0.00±0.00a	14.02±0.00b	23.10±0.00b	24.02±0.70b	26.30±0.03b
	1	0.00±0.00a	10.40±0.05a	11.06±0.02a	10.70±0.50ab	12.00±0.12ab
	1.5	0.00±0.00a	8.00±3.00a	8.00±0.35a	9.00±0.05a	11.00±0.06ab
	2	0.00±0.00a	7.00±0.00a	8.00±0.00a	10.00±0.00a	10.00±0.00a
	2.5	0.00±0.00a	0.00±0.00a	0.00±0.00a	3.00±0.80a	10.00±1.05a
Petiveria Alliacea	0.5	0.00±0.00a	2.00±0.00a	2.00±0.49a	3.40±0.05a	12.60±0.09a
	1	0.00±0.00a	0.00±0.00a	2.00±0.00a	5.20±0.08	6.40±0.05a
	1.5	0.00±0.00a	0.00±0.00a	2.30±0.02a	3.20±0.09	4.00±0.07a
	2	0.00±0.00a	0.00±0.00a	4.50±0.03a	4.60±0.06	6.00±0.00
	2.5	0.00±0.00a	0.00±0.00a	3.02±0.05a	3.03±0.05	3.00±0.05a
Hyptis suaveolens	0.5	0.00±0.00a	0.00±0.00a	1.00±0.05a	3.20±0.05a	3.36±0.05a
	1	0.00±0.00a	0.00±0.00a	1.00±0.05a	6.23±0.05a	7.20±0.05a
	1.5	0.00±0.00a	0.00±0.00a	6.03±0.00a	6.00±0.00a	10.00±0.00a
	2	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	2.5	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	Control	0.00±0.00a	15.00±0.02b	56.00±0.14c	98.00±0.23cd	99.00±0.10d

Note: each value in the mean ± standard error of 4 replicates. Mean followed by the same letter within the same column are not significantly ($p > 0.05$) different from each other.

Table 4 Percentage weight loss caused by *Sitophilus oryzae* infestation on rice treated with *Ageratum conyzoides, Petiveria alliacea* L. and *Hyptis suaveolens* L. extracts

Concentration %	*Ageratum conyzoides L.*	*Petiveria alliacea L.*	*Hyptis suaveolens L.*
0.5	22.02±1.00d	28.02±0.00d	7.24±0.32a
1	19.67±0.10b	20.47±0.10b	10.00±0.89a
1.5	28.67±0.10b	29.00±0.10b	21.00±0.10a
2	15.00±0.00b	15.00±0.00b	21.00±0.00a
	13.00±0.00a	15.00±0.00b	10.00±0.00a
Control	90.25±2.04d	90..25±2.04d	90.25±2.04d

Note: Each value is the mean ± standard error of 4 replicates. Mean followed by the same letters within the same column are not significantly ($p > 0.05$) different from each other

Discussion

Biopesticides are gaining more attention as potent preservative against insect pest both in the developed and underdeveloped countries. Many of these countries are banning the use of synthetic chemicals as food preservatives because of the reported poisonous residual.[12,1] The assessment of the three botanicals (*Ageratum conyzoides, Petiveria alliacea* L. and *Hyptis suaveolens* L. Poit) showed effects on the *Sitophilus* oryzae adult mortality and emergence. Also, the percentage weight loss caused by the infestation of *Sitophilus* oryzae. All the plants extract are potent to cause mortality of *Sitophilus oryzae*. The three botanicals significantly reduce the emergence of Adult *Sitophilus oryzae*. *A.* conyzoides also show a moderate potency against Sitophilus oryzae. This agreed with the work of Ito and Utebor[13] who reported the potency of *A. conyzoides* against *Dermestes maculatus* on fish. The potency of these plant extracts to reduce or prevent emergency of *Sitophilus oryzae* as a result of the blockage that the oil extract caused to the chorion in the breathing channel egg.[14] Phytochemical's constituent of *Ageratum conyzoides, Petiveria alliacea* L. and *Hyptis suaveolens* L. Poit are parts of the content that make the botanicals to be active biopesticides which could help in preserving products storage.[15] *Ageratum conyzoides* extract at concentration of 2.5% after 120 h caused 66.67% *Sitophilus oryzae.* This corelated with the work of Kamboj and Saluja 2008 who reported on the insecticidal and pesticidal activities of *Ageratum conyzoides* against weevil.

The finding also agreed with the work of Singh et al.,[16] and Ito and Ighere[18] who documented the insect toxicity caused by *Ageratum conyzoides* against *D. maculates*. *Petiveria alliacea* L. (Phytolaccaceae), is one of the several plants that possessed insecticidal properties.[18] *P. alliacea* possessed odour which contain sulfide compound which have insecticidal activities against insects.[19,20] LD 50 (0.73 (0.36 – 1.45) LD 90 (8.69 (4.35 – 17.36). *Petiveria alliacea* L. caused 73.33% mortality of *Sitophilus oryzae* after 120h at 2.5% concentration. This is closed to the report of García-Mateos et al.,[21] who reported mortality of adult greenhouse whitefly (*Trialeurodes vaporariorum* WEST) after treatment with *Petiveria alliacea* L as 86.6 %. Nevertheless, *Petiveria alliacea* and *Hyptis suaveolens* showed more insecticidal activities than *Ageratum conyzoides*. *H. suaveolens* showed to be more effective in the control of *Sitophilus oryzae*. *H. suaveolens* is a known aromatic medicinal herb with a great insecticidal potential in control of insect pest this correlated with the work of Edeoga et al.,[22] who compared *H., suaveolens* with *occimum gratissimum*. *H., suaveolens* contained diversity of phytochemicals such as essential oils, phenolics, di and triterpenoids, steroids, flavonoids, etc. that constitute the chemical profile of the plants. H. suaveolens contain high amount oil glands, alkaloids, flavonoids, tannins, phenolics, and saponins. Edeoga et al.,[22] reported the potency of extract of H. suaveolens as possessed larvicidal ability against yellow fever mosquito Aedes aegypti (L), Aedes albopictus larvae. Sharma et al.,[23] also reported Larvicidal activity of Hyptis suaveolens in controlling moquitoes. This is may be due to compounds like alpha-pinene, beta-pinene, sabinene, terpinolene, betacaryophyllene, and 4-terpineol that it contains.[24–28]

Conclusion

The results showed that methanolic extract of these plants are potent in prevention and control of *Sitophilus oryzae* on stored rice. Increased mortality of *S. oryzae*, reduction in emergence adult *S. oryzae* on and decrease in percentage weight loss of rice grains were recorded when compared the plant extract treatment with the control. *Hyptis suaveolens* caused highest mortality of *S. oryzae*.and reduce the emergence of the insect Both percentage of mortality and the median lethal concentration for *Hyptis suaveolens was* 0.36 (LC50) and 1.85 (LD90). All of the plant extracts studied were significantly different from the control treatments. Therefore, the mortality, reduction in emergence and reduction in weight loss was caused by the extracts of the botanicals. The potency of *Hyptis suaveolens* may be due to the presence of compounds like alpha-pinene, beta-pinene, sabinene, terpinolene, betacaryophyllene, and 4-terpineol in which most of them has been reported for insecticidal in controlling insect. *Hyptis suaveolens* which is the most effective of all the plant extract used can be recommended for the protection of rice grains in the stores.

Declarations

Ethics approval and consent to participate "Not applicable"

Consent for publication.

Availability of data and materials: Not Applicable

Competing interests: The authors declare that there is no competing interests

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Conflicts of Interest

None.

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