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Entomocidal Properties of Selected Spices for Protecting Stored Paddy Rice Against *Sitophilus oryzae* (Coleoptera: Curculionidae)

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ABSTRACT

Background and Objective: The toxicity effects of seed powders and extracts of *Piper guineense*, *Aframomum melegueta*, and *Syzygium aromaticum* were evaluated for their insecticidal properties against the rice weevil, *Sitophilus oryzae*. The study aimed to assess the potential of these spices as eco-friendly protectants of stored paddy rice by determining their efficacy in controlling *S. oryzae* under laboratory conditions. **Materials and Methods:** Experiments were conducted at an ambient temperature of 28±2°C and 75±5% relative humidity. The seed powders were tested at doses of 0.2, 0.4, 0.6, 0.8, and 1.0 g/20 g of paddy, while the extracts were tested at concentrations of 0.2, 0.3, 0.4, and 0.5 mL/20 g of paddy. The parameters evaluated included adult mortality, weight loss, adult emergence, seed damage, and the weevil perforation index (WPI). Data were analyzed using ANOVA in SPSS 25.0, with Tukey's test for mean separation at $p \leq 0.05$. **Results:** The results indicated that *P. guineense* powder was the most potent, causing 60% adult mortality at 1.0 g/20 g after 24 hrs, followed by *A. melegueta* powder (50% mortality) and *S. aromaticum* powder (40% mortality). Extracts were more toxic than powders, with *P. guineense* extract causing 100% mortality at 0.4 and 0.5 mL/20 g of paddy after 24 hrs, followed by *A. melegueta* (90%) and *S. aromaticum* (80%). Extracts of *P. guineense* and *A. melegueta* completely prevented adult emergence, seed damage, and weight loss. The lethal dose (LD_{50}) and lethal concentration (LD_{90}) values confirmed the highest toxicity of *P. guineense*, with its effect continuing to increase over time. **Conclusion:** The study demonstrates the potential of *P. guineense*, *A. melegueta*, and *S. aromaticum* as effective biopesticides for controlling *S. oryzae* in stored paddy rice. Their application can enhance food security by preventing seed damage, reducing post-harvest losses, and ensuring viable seed storage.

KEYWORDS

Piper guineense, *Syzygium aromaticum*, *Aframomum melegueta*, *Sitophilus oryzae*, post-harvest loss, biopesticides

INTRODUCTION

Rice is a monocot plant classified as a cereal grain, characterized by a seed containing a single embryonic leaf. The two primary cultivated species are African rice (*Oryza glaberrima*) and Asian rice (*Oryza sativa*). With the rising global population, the demand for rice is expected to increase significantly, potentially

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surpassing production capacity[1]. In Nigeria, cereal grains occupy a prominent place in the nutrition of Nigerians because their edible seeds form a cheap alternative source of energy in diets. In Nigeria, the major cereal grains cultivated are rice, *Oryza sativa*, maize, *Zea mays*, wheat, *Triticum aestivum*, oat *Avena sativa*, and so on[2].

Rice weevil, which belongs to the Order Coleoptera, are segmented insects with three pairs of body parts[3]. Stored products like grains, rice, and flour are commonly infested by pests from the order Coleoptera, including the rice weevil (*Sitophilus oryzae*). These pests not only cause direct physical damage to stored products but also facilitate secondary infestations by pathogenic organisms like fungi and bacteria. Adult rice weevils possess a distinctive long snout with chewing mouthparts. Their developmental stages (egg, larva, and pupa) all occur inside the grain kernel. Upon reaching maturity, the adult weevil emerges by chewing through the kernel, leaving behind a partially consumed, "insect-damaged" kernel. The entire life cycle of the rice weevil takes approximately 35 days[4].

The climbing black pepper (*Piper guineense*), commonly known as West African black pepper, Ashanti pepper, Guinea cubeb, and Benin pepper, is indigenous to Africa's tropical rainforests, primarily thriving in the wild. However, it is partially cultivated in Southern Nigeria, where both its leaves and seeds are used to flavor soups. Notably, the seeds of *P. guineense*, in combination with parts of *Pterocarpus osun*, *Eugenia caryophyllata*, and *Sorghum bicolor*, are utilized to produce Niprisan[5].

Alligator pepper, *Aframomum melegueta* is a spice belonging to the family of perennial plants called Zingiberaceae. It is commonly known as grain majorly found in the South-South and South-East States in Nigeria[6]. The seeds of the alligator pepper are similar to the grains of paradise however, the difference between them is that the alligator pepper seeds are usually sold enclosed with pods while the grains of paradise are sold as single seeds[7].

Syzygium aromaticum, popularly known as clove, is a traditional spice that has been used for food preservation and also acts as a pharmacological agent. Several reports have documented the antibacterial, antiviral, anticarcinogenic, and antifungal activities[8].

The destructive activities of insects and other storage pests have been adequately subdued by chemical control methods comprising fumigation of stored commodities with carbon disulfide and phosphine dusting with malathion, carbaryl, or permethrin. These chemicals have been reported to be effective against rice weevils and other insect pests[6]. The problem of many synthetic insecticides includes resistance to pests and the killing of non-target insects, which can be avoided by the use of eco-friendly botanical control[9]. The use of botanicals in the control of stored is very effective especially for black pepper, the insecticidal functions of the *piper guineense* powder and extracts are supported by many previous reports that extracts from plants have been shown to possess insecticidal properties against insect pests, the plant can control the reproductive capacity, caused high mortality rate and prevent egg[10]. This study aimed to evaluate the insecticidal properties of seed powders and extracts of *Piper guineense*, *Aframomum melegueta*, and *Syzygium aromaticum* against the rice weevil, *Sitophilus oryzae*, in stored paddy rice. Specifically, the study assessed the toxicity levels of different doses of powders and concentrations of extracts by measuring adult mortality, seed damage, weight loss, adult emergence, and the weevil perforation index (WPI) under laboratory conditions.

MATERIALS AND METHODS

Study area: The study was carried out in the Department of Biology at the Federal University of Technology, Akure, between June to September, 2023.

Insect culture: Adult maize weevils of both sexes, *S. oryzae*, were supplied by the Storage Entomology Research Laboratory, Department of Biology, Federal University of Technology, Akure (FUTA), Nigeria. One hundred pairs of the weevils were introduced into a 1 L glass Kilner jar containing 800 g of rice grains obtained from a grain Merchant shop within Akure metropolis, Akure, Ondo State, Nigeria. The rice weevil colony was maintained under a constant temperature of 28±2°C and 75±5% of relative humidity.

Identification and sexing of adult *Sitophilus oryzae*: The identification and sexing of *S. oryzae* were carried out in the Entomology Research Laboratory, Department of Biology, FUTA. The weevils were identified to the species level according to features of genital morphology[11]. The adult weevils were characterized by the presence of reddish-brown oval markings on the elytra and circular punctures also present on the prothorax. Adults were sexed according to the length of the rostrum (the female has a comparatively longer rostrum than the male)[11].

Collection and preparation of plant powders: The seeds of *A. melegueta*, *P. guineense*, and *S. aromaticum* were purchased at Oja-Oba Market in Akure South Local Government Area of Ondo State, Nigeria. These seeds were, first of all, air dried naturally in the laboratory. The dried seeds were later ground into fine powder with the aid of an electric blender, JTC Omni Blender V (Model TM-800). The fine powders were sieved and allowed to pass through a 1 mm^2 perforation. The powders were then packed into an air-tight container and put in a refrigerator at 4°C to retain their good quality before application.

Collection of rice grains (paddy): The rice grains used for this research work were obtained from newly harvested stock of paddy in a farm at Ilara-Mokin, Ondo State, Nigeria. The grains were free from debris and other unwanted particles. The grains were first sterilized by putting them in a deep freezer and maintained at -5°C for 7 days to ensure that all existing insect developmental stages were killed. This process is carried out because all the life stages of insects, such as eggs, pupae, and larvae, are sensitive to cold[12]. The disinfested maize grains were later air-dried in the laboratory for 72 hrs to prevent mouldiness before they were stored in plastic containers with tight lids.

Preparation of ethanolic extracts: The seeds of *A. melegueta*, *P. guineense*, and *S. aromaticum* were extracted using absolute ethanol as solvent. About 300 g of the plant powders were soaked separately in an extraction bottle containing 600 mL of absolute ethanol. The mixture was stirred with a glass rod and extraction was terminated after 3 days. The resulting mixture was filtered using a double layer of Whatman No. 1 filter paper, and the solvent was regained by redistilling in a rotary evaporator at 30-40 with rotary speed of 3-6 rpm for 8 hrs[13]. The resulting materials were air-dried to remove traces of solvents (ethanol).

Phytochemical screening of the plants: Chemical tests were carried out on the ethanolic extracts of the seeds of *Piper guineense*, *Aframomum melegueta*, and *Syzycum aromaticum* for the quantitative determination of phytochemical constituents using standard procedures[14,15].

Quantitative analysis

Determination of saponin: Saponin quantitative was determined[15]. Five grams of each experimental plant was put into a 250 cm^3 conical flask that contained 20% ethanol. The content was heated with continuous stirring over hot water at a temperature of 55°C for 4 hrs. The residue obtained was re-extracted after filtration and heated with continuous stirring over hot water at a constant temperature for 4 hrs. Combined extract was evaporated to 40 cm^3 over a water bath at 90°C. To the concentrate, 20 cm^3 of diethyl ether was added in a separator funnel of about 250 cm^3, strongly agitated to recover the aqueous layer, and the ether layer was discarded. The purification procedure was repeated two times. The N-butanol (60 cm^3) was added to 5% sodium chloride (10 cm^3) and extracted two times. The sodium chloride layer was discarded, while the remaining solution was heated in a water bath for 30 min. The solution was transferred into a crucible before oven oven-dried to a constant. The saponin content was expressed in percentages as follows:

$$\text{Saponin (\%)} = \frac{\text{Weight of saponin}}{\text{Weight of sample}} \times 100$$

Determination of alkaloid: The analytical quantitative of alkaloids was determined[15]. Five grams (2.5 g) of each of the experimental plant powder was weighed into an extraction bottle, followed by the addition of 200 mL of 10% acetic acid in ethanol and the mixture was allowed to stand for 4 hrs before filtration with Whatman No. 1 filter paper and extract was concentrated to one-quarter of its original volume on a water bath. Fifteen drops of concentrated ammonium hydroxide were added dropwise to the extract until the precipitation was completed after the filtration process. The mixture was allowed to settle for 3 hrs, and the supernatant was discarded, and the precipitate were washed with 20 cm^3 of 0.1 M of ammonium hydroxide before filtration. The residue was oven-dried and weighed, and the percentage of alkaloid is expressed as follows:

$$\text{Alkaloid (\%)} = \frac{\text{Weight of alkaloid}}{\text{Weight of sample}} \times 100$$

Flavonoid determination: The analytical determination of flavonoids was done[15]. Fifty (50 cm^3) of ethanol was added to 2.5 g of the sample in a 250 cm^3 beaker with a lid and allowed to stand for 24 hrs. The supernatant was discarded, followed by the re-extraction of the residue three times. Whatman No. 1 filter paper was used in the filtration of all the experimental plants. Each of the experimental plant's filtrate was transferred into a crucible and allowed to evaporate to dryness over a water bath. The remaining content in the crucible was allowed to cool in a desiccator and weighed until a constant weight was achieved[14]:

$$\text{Flavonoid (\%)} = \frac{\text{Weight of flavonoid}}{\text{Weight of sample}} \times 100$$

Determination of tannin: Tannin quantity was determined[15]. An insoluble Polyvinylpolypyrrolidone (PVPP) that binds tannins was used for the determination of tannin content. As 1 mg/mL of each of the experimental plants was prepared in ethanol. This followed the determination of total phenolics through the mixing of 1 mL of each experimental plant extract with 100 mg of polyvinylpolypyrrolidone, vortexed, then centrifuged at 3000 rpm for 10 min. Pure supernatant non-tannin phenolics were determined using the methods of finding total phenolics. Tannin content was evaluated as a difference between total phenolic and non-tannin content[14].

Insect bioassay

Toxicity of plant powders on adult mortality and adult emergence of *S. oryzae*: Twenty grams of clean, uninfested paddy grains were measured with the aid of an electronic weighing balance (Model JTC 2101N) in the laboratory and put inside plastic cups (250 mL). Thereafter, 0.2, 0.4, 0.6, 0.8, and 1.0 g dosages of the seed powders of *A. melegueta*, *P. guineense*, and *S. aromaticum* were carefully measured and admixed with 20 g of the clean uninfested maize grains separately. The plastic cups containing the powder and the maize grains were thoroughly shaken to ensure adequate mixing. Then, ten copulating pairs (10 males: 10 females) of newly emerged (less than four days old) adults of *S. oryzae* were introduced into each of the plastic cups containing the treated maize grains and covered with muslin cloths. The control experiment had only 20 g of maize grains and ten copulating pairs of adult *S. zeamais* (no plant powder was included in the control). Insect mortality was assessed every day for 5 days, dead weevils were those that did not move and did not respond to pin probing (response to sharp pin). At the end of the 5 days of post-treatment, data on the percentage of adult mortality was calculated using the Abbott formula[16]:

$$Pr = \frac{Po - Pc}{100 - Po} \times 100$$

Where:

Pr = Corrected mortality (%)
Po = Observed mortality (%)
Pr = Control mortality (%)

The insect bioassay setup was kept inside the insect-rearing cage, and daily observations were made until the first filial generation adult emergence. The number of adult emergences was counted and recorded.

Weight loss of the maize grains was expressed as percentage of loss in weight as follows[16]:

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

The numbers of damaged maize grains were evaluated in percentage of seed damaged as follows[16]:

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

The weevil perforation index (WPI)[16] was expressed as:

$$\text{WPI (\%)} = \frac{\text{Treated maize grains perforated}}{\text{Control maize grains perforated}} \times 100$$

The WPI value exceeding 50 was regarded as an enhancement of infestation by the weevil or negative protectability of the powders and extracts tested.

Toxicity of ethanolic extracts on adult mortality and adult emergence of *S. oryzae*: Twenty grams of clean, uninfested maize grains were weighed into 250 mL plastic cups.

Then, an aliquot of 0.2, 0.5, 1.0, and 2.0 mL of *A. melegueta*, *P. guineense*, and *S. aromaticum* were measured with the aid of a graduated syringe and mixed with 20 g of clean paddy grains inside the plastic cups. The mixture was thoroughly mixed with the aid of a small glass rod. The plastic cups were left open for 40 min to allow the solvent (ethanol) to escape into the air. Thereafter, ten copulating pairs (10 males: 10 females) of less than (4 days-old) adult *S. oryzae* were introduced to each of the plastic cups and covered with muslin cloths. Each treatment was replicated four times. The control experiment had only 20 g of maize grains and ten copulating pairs of adult *S. oryzae* (no plant extract was included in the control). Insect mortality was assessed every day for 5 days. Dead weevils were those that did not move and did not respond to pin probing (response to sharp pin). At the end of 5 days of post-treatment, data on the percentage of adult mortality was calculated. The experimental setup was kept inside the insect-rearing cage for a further 35 days to allow the new adults to emerge. The percentage of adult emergence, weight loss, seed damage, and weevil perforation index were calculated[17].

Data analysis: The data were analyzed using Analysis of Variance (ANOVA), and treatment means were separated using the Tukey's Test. The ANOVA was conducted with the aid of SPSS 25.0 software, and statistical significance was determined at $p \leq 0.05$.

RESULTS

Phytochemical composition (quantitative) of the experimental plants: The phytochemical analysis of the experimental plants is represented in Table 1. The phytochemicals present in *P. guineense* show that alkaloids (4.00) have the highest composition, followed by flavonoids (3.69), tannins (2.27), and the least is saponins (2.14). The highest concentration of alkaloids present leads to high mortality, low seed damage and prevents adult emergence of the rice weevil on paddy grains. The phytochemicals present in *A. melegueta* showed that alkaloids have the highest value (3.89), and for *S. aromaticum*, the value of alkaloids present is 3.69 and represents the highest concentration.

Mortality response of adult *S. oryzae* treated with some spice powders: The mortality response of adult *S. oryzae* treated with three botanical plants is represented in Table 2. The insects used represented our dependent factor against an independent factor, which is study dosage. The higher the concentration, the higher the mortality rate. The toxicity of the three powders was significantly ($p<0.05$) different from the control. The *P. guineense* seed powder was the most toxic to rice weevil, the powder caused 10.00, 23.33, 30.00, 43.33 and 56.67% mortality of *S. oryzae* at concentrations of 0.2, 0.4, 0.6, 0.8 and 1.0 g/20 g of rice grains after the first day of exposure, respectively. This was followed by *A. melegueta* powder that included 10.00, 13.33, 20.00, 30.00, and 43.33% mortality of *S. oryzae* at concentrations of 0.2, 0.4, 0.6, 0.8 and 1.0 g/20 g of rice grains after the first day of exposure, respectively. The least toxic seed powder was *S. aromaticum* which causes 3.33, 3.33, 13.33, 20.00 and 36.67% mortality of *S. oryzae* at concentrations of 0.2, 0.4, 0.6, 0.8 and 1.0 g/20 g of rice grains after the first day of exposure, respectively. The *P. guineense* evoked 100.00 and 100% mortality of rice weevils at rates 0.8 and 10 g/20 g of rice grains after the fifth day of exposure, respectively. The toxicity trend of the 3 botanical powders was dosage dependent and exposure time.

Lethal dose (LD) of some botanical powders against adult *S. oryzae*: The lethal dose of the three botanicals powder against *S. oryzae* is given in Table 3. The dosage calculated for the *P. guineense*, *A. melegueta*, and *S. aromaticum* powders to cause 50% (LD_{50}) and 90% (LD_{90}) mortality against the test insects calculated after the first day were 0.97 and 3.08 g, 1.66 and 13.57 g, 1.81 and 14.29 g, respectively. The results revealed a continuous decline in the values after the second, third, fourth, and fifth days of exposure. Calculations indicated that *Piper guineense* seed powder had the lowest lethal dose across all exposure periods. Additionally, the confidence limits varied, suggesting potential effectiveness beyond the calculated values.

Number of adult emergences of *S. oryzae* in paddy treated with some botanical powders: Table 4 illustrates the effectiveness of *P. guineense*, *A. melegueta*, and *S. aromaticum* against maize weevil adult emergence. The protection effectiveness of *P. guineense*, *A. melegueta*, and *S. aromaticum powders* against infestation of *S. oryzae* is significantly different ($p<0.05$) from the control. The highest seed protection was recorded from 0.8 g of *P. guineense* and 1.0 g of *A. melegueta* powder (0.0 adult emergence of *S. oryzae* was recorded. The seed protection ability of 0.8 g of *P. guineense* and 1.0 g of *A. melegueta* powders are not significantly different from 0.8 *A. melegueta* and *S. aromaticum* powders (0.33 and 0.67 adult emergence was recorded, respectively). The protection strength of 0.2 g of *S. aromaticum* seed powder (4.00) is significantly different ($p<0.05$) from the 0.2 g of *P. guineense* and *A. melegueta*; 1.33 and 3.33 were recorded, respectively, on the paddy in respect to paddy weevil adult emergence. There is a significant difference ($p<0.05$) in the seed protection ability against the adult emergence of rice weevil when comparing 0.2 g of *S. aromaticum* (4.00 was recorded), and 0.4 g of *P. guineense* and *A. melegueta* powder (1.00 and 1.33 weevil emergence were recorded, respectively).

Table 1: Phytochemical composition percentage (quantitative) of the experimental plants

Phytochemicals	Alkaloids	Saponins	Tannins	Flavonoids
P. guineense	4.00±0.41	2.14±0.29	2.27±0.03	3.69±0.03
A. melegueta	3.89±0.02	2.23±0.23	2.41±0.18	3.59±0.12
S. aromaticum	3.69±0.40	2.16±0.25	2.20±0.15	3.51±0.02

Table 2: Mortality response of adult *S. oryzae* treated with some botanical powders

		Percentage of mortality (Mean±SE)				
Spice powder	Dosage (g)	Day 1	Day 2	Day 3	Day 4	Day 5
P. guineense		10.00 ± 0.00^{a}	20.00 ± 0.0^{b}	36.67 ± 3.33^{b}	43.33 ± 3.33^{b}	50.00 ± 5.78^{b}
A. melegueta	0.2	10.00 ± 0.00^{b}	16.67 ± 3.33^{b}	23.33 ± 3.33^{b}	30.00 ± 0.00^{b}	40.00 ± 0.00^{b}
S. aromaticum		3.33 ± 3.33^{ab}	13.33 ± 3.33^{b}	16.67 ± 6.67^{ab}	20.00 ± 0.00^{b}	30.00 ± 0.00^{b}
P. guineense		23.33 ± 3.33^{cd}	30.00 ± 0.00^{b}	40.00 ± 0.00^{b}	53.33 ± 3.33^{bc}	70.00 ± 0.00^{c}
A. melegueta	0.4	13.33 ± 3.33^{a}	20.00 ± 0.00^{b}	30.00 ± 0.00^{b}	40.00 ± 0.00^{c}	60.00 ± 0.00^{c}
S. aromaticum		3.33 ± 3.33^{bc}	13.33 ± 3.33^{b}	23.33 ± 3.33^{b}	36.67 ± 3.33^{c}	53.33 ± 3.33^{c}
P. guineense		30.00 ± 0.00^{b}	43.33 ± 3.33^{c}	53.33 ± 3.33^{c}	63.33 ± 3.33^{c}	100.00 ± 0.00^{d}
A. melegueta	0.6	20.00 ± 0.00^{c}	26.67 ± 3.33^{b}	43.33 ± 3.33^{c}	50.00 ± 0.00^{d}	66.67 ± 3.33^{c}
S. aromaticum		13.33 ± 3.33^{bc}	23.33 ± 3.33^{bc}	33.33 ± 3.333^{bc}	53.33 ± 3.33^{d}	60.00 ± 0.00^{c}
P. guineense		43.33 ± 3.33^{c}	53.33 ± 3.33^{c}	73.33 ± 3.33^{d}	93.33 ± 3.33^{d}	100.00 ± 0.00^{d}
A. melegueta	0.8	30.00 ± 0.00^{d}	40.00 ± 0.00^{c}	56.67 ± 3.33^{d}	76.67±3.33e	96.67 ± 3.33^{d}
S. aromaticum		20.00 ± 0.00^{c}	30.00 ± 0.00^{c}	46.67 ± 3.33^{cd}	70.00±0.00e	90.00 ± 0.00^{d}
P. guineense		56.67 ± 3.33^{d}	80.00 ± 5.78^{d}	96.67 ± 3.33^{e}	100.00 ± 0.00^{d}	100.00 ± 0.00^{d}
A. melegueta	1.0	43.33 ± 3.33^{e}	56.67 ± 3.33^{d}	73.33 ± 3.33^{e}	86.67 ± 3.33^{f}	100.00 ± 0.00^{d}
S. aromaticum		36.67 ± 3.33^{d}	43.33 ± 3.33^{d}	63.33 ± 3.33^{d}	80.00 ± 0.00^{c}	96.67 ± 3.33^{d}
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 alphabet in column are not significantly different from one another (p>0.05) using Tukey's Test

Table 3: Lethal Dosage of some botanical powders against adult *S. oryzae*

Spice powder	Exposure period	Intercept±SE	Slope±SD	R2	LD_{50} (LCL-UCL)	LD_{90} (LCL-UCL)	p-value
P. guineense	Day 1	0.04±0.12	2.55±0.34	0.89	0.97 (0.82-1.25)	3.08 (2.07-6.33)	0.27
	Day 2	0.47±0.12	2.15±6.53	0.78	0.61 (0.52-0.73)	2.39 (1.65-4.62)	0.62
	Day 3	0.92±0.13	2.22±6.90	0.71	0.39 (0.28-0.49	1.46 (1.01-3.32)	0.04
	Day 4	1.39±0.15	2.62±1.59	0.69	0.29 (0.19-0.37)	0.91 (0.69-1.55)	0.02
	Day 5	1.82±0.81	2.84±7.43	0.81	0.23 (0.18-0.27)	0.65 (0.55-0.82)	0.13
A. melegueta	Day 1	0.31±0.12	1.40±3.95	0.82	1.66 (1.10-4.96)	13.57 (4.67-309.15)	0.99
	Day 2	1.65±0.17	1.81±7.32	0.88	0.91 (0.81-1.06)	3.08 (1.39-2.00)	0.90
	Day 3	0.39±0.11	1.86±3.45	0.83	0.61 (0.51-0.76)	3.00 (1.89-7.36)	0.89
	Day 4	1.39±0.15	2.59±10.31	0.93	0.54 (0.48-0.59)	1.04 (0.94-1.17)	0.62
	Day 5	0.04±0.12	2.55±6.44	0.89	0.51 (0.82-1.25)	1.00 (2.07-6.33)	0.27
S. aromaticum	Day 1	0.50±0.12	1.93±4.01	0.55	1.81 (1.26-4.47)	14.29 (3.71-70.15)	0.67
	Day 2	0.33±0.12	1.40±2.84	0.69	1.73 (1.13-5.35)	8.41 (4.84-339.19)	0.89
	Day 3	0.14±0.11	1.84±1.25	0.78	0.84 (0.69-1.15)	4.16 (2.41-12.86)	0.60
	Day 4	0.73±0.12	2.41±6.11	0.96	0.50 (0.43-0.58)	1.70 (1.29-2.69)	0.99
	Day 5	1.32±0.14	2.89±8.33	0.86	0.35 (0.29-0.40)	0.97 (0.81-1.27)	0.34

R^2: Statistical measure of mortality proportion in regression model, SE: Standard error, SD: 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 (χ^2) significant

Table 4: Number of adult emergences of *S. oryzae* in paddy treated with some spice powders

Spice powder	Dosage (g)	Adult emergence
P. guineense		1.33 ± 0.67^{a}
A. melegueta	0.2	3.33 ± 0.67^{a}
S. aromaticum		4.00 ± 0.00^{b}
P. guineense		1.00 ± 0.58^{a}
A. melegueta	0.4	1.33 ± 0.33^{a}
S. aromaticum		2.00 ± 0.00^{ab}
P. guineense		0.33 ± 0.33^{a}
A. melegueta	0.6	1.00 ± 0.00^{a}
S. aromaticum		1.33 ± 0.33^{ab}
P. guineense		0.00 ± 0.00^{a}
A. melegueta	0.8	0.33 ± 0.33^{a}
S. aromaticum		0.67 ± 0.33^{a}
P. guineense		0.00 ± 0.00^{a}
A. melegueta	1.0	0.00 ± 0.00^{a}
S. aromaticum		0.00 ± 0.00^{a}
Control	0.0	63.00 ± 1.53^{b}

Mean follow by the same alphabet in column are not significantly different from one another (p>0.05) using Tukey's Test

Table 5: Protectant effect of some botanical powders on paddy seed damage, weight loss, and weevil perforation index (WPI) against rice weevil

Spice powder	Dosage (g)	Total number of seed	Seed damage (%)	Weight loss (%)	WPI
P. guineense	0.2	605.00±1.15[a]	0.22±0.11[a]	3.33±0.17[b]	0.23±0.01[a]
	0.4	602.67±1.76[a]	0.17±0.95[a]	3.33±0.17[b]	0.20±0.00[a]
	0.6	607.33±0.88[a]	0.53±0.05[a]	3.17±0.44[b]	0.01±0.01[a]
	0.8	604.00±0.58[a]	0.00±0.00[a]	2.00±0.00[a]	0.00±0.00[a]
	1.0	603.00±1.15[a]	0.00±0.00[a]	1.50±0.00[a]	0.00±0.00[a]
A. melegueta	0.2	607.33±0.67[a]	0.55±0.11[b]	2.50±0.00[b]	0.05±0.10[b]
	0.4	606.00±3.06[a]	0.22±0.55[a]	3.17±0.60[c]	0.23±0.00[a]
	0.6	604.67±1.45[a]	0.17±0.00[a]	3.50±0.29[c]	0.20±0.00[a]
	0.8	603.67±0.88[a]	0.57±0.57[a]	1.33±0.17[a]	0.01±0.01[a]
	1.0	605.67±2.40[a]	0.00±0.00[a]	1.00±0.00[a]	0.00±0.00[a]
S. aromaticum	0.2	604.00±2.08[a]	0.66±0.03[c]	3.50±0.00[d]	0.06±0.00[d]
	0.4	604.33±2.08[a]	0.33±0.00[c]	4.00±0.00e	0.03±0.00[c]
	0.6	606.67±2.84[a]	0.22±0.57[bc]	2.17±0.17[c]	0.23±0.00[b]
	0.8	608.00±1.54[a]	0.11±0.55[ab]	1.50±0.00[b]	0.01±0.01[b]
	1.0	604.67±0.88[a]	0.00±0.00[a]	1.00±0.00[a]	0.00±0.00[a]
Control	0.0	605.67±2.96[a]	10.403±0.29[b]	6.50±0.58[c]	10.40±0.29[b]

Mean follow by the same alphabet in column are not significantly different from one another ($p>0.05$) using Tukey's Test

Protectant effect of some spice powders on paddy damage, weight loss, and weevil perforation index against rice weevil: Percentage seed damage, weight loss, and weevil perforation index are presented in Table 5. Paddy treated with 0.4 g of *P. guineense* and 0.4 g of *A. melegueta* powder gave 0.17 and 0.22% seed damage, respectively. There was no significant difference ($p>0.05$) between the aforementioned powders when compared with *S. aromaticum* powder, which caused 0.33% seed damage at 0.4 g. The highest percentage of seed damage (0.66%) was observed in paddy treated with 0.2 g of *Syzygium aromaticum*, which was significantly lower ($p<0.05$) compared to the control (10.40%). Conversely, the lowest seed damage (0.00%) was recorded in treatments with 0.8 g of *Piper guineense*, 1.0 g of *Aframomum melegueta*, and 1.0 g of *Syzygium aromaticum* their protective effect was not significantly different ($p>0.05$) from 0.8 g of *A. melegueta* (0.57), 0.8 g of *S. aromaticum* (0.11), 0.6 g of *P. guineense* (0.53) and 1.0 g of *S. aromaticum* (0.00). The highest weight loss was recorded with paddy treated with 0.2 g of *S. aromaticum* powder (3.50); this was significantly different ($p<0.05$) from what was recorded from the control (6.50). The weevil perforation index recorded from the seeds treated with 0.2 g of *P. guineense* (0.23) was the highest, followed by 0.4 g of the same powder with 0.23.

Mortality response of adult *S. oryzae* treated with some botanical extracts: The mortality response of adult *S. oryzae* treated with three botanical plants is represented in Table 6. The insects used represented our dependent factor against an independent factor, which is our dosage. The higher the concentration, the higher the mortality rate. The toxicity of the three extracts was significantly ($p<0.05$) different from the control. The *P. guineense* seed extract was the most toxic to rice weevil; the extract caused 73.33, 83.33, 100.00, and 100.00% mortality of *S. oryzae* at concentrations of 0.2, 0.3, 0.4 and 0.5 mL/20 g of rice grains after the first day of exposure, respectively. This was followed *A. melegueta* extract that included 60.00, 70.00, 73.33, and 90.00% mortality of *S. oryzae* at concentrations of 0.2, 0.3, 0.4 and 0.5 mL/20 g of rice grains after the first day of exposure, respectively. The least toxic seed extract was *S. aromaticum* which caused 50.00, 60.00, 66.67, and 83.88% mortality of *S. oryzae* at concentrations of 0.2, 0.3, 0.4, 0.5 mL/20 g of rice grains after the first day of exposure, respectively. The *P. guineense*, *A. melegueta*, and *S. aromaticum* evoked 100.00% mortality of rice weevils at the rate of 0.4 and 0.5 mL/20 g of rice grains after the fifth day of exposure, respectively. The toxicity trend of the 3 botanical extracts was dosage dependent and exposure time.

Table 6: Mortality response of adult *S. oryzae* treated with some botanical extracts

		Percentage of mortality (Mean±SE)				
Spice extract	Concentration (mL)	Day 1	Day 2	Day 3	Day 4	Day 5
P. guineense		73.33±3.33^b	86.67±3.33^b	100.00±0.00^c	100.00±0.00^c	100.00±0.00^c
A. melegueta	0.2	60.00±0.00^b	70.00±0.00^b	86.67±3.33^b	96.67±3.33^b	100.00±0.00^b
S. aromaticum		50.00±0.00^b	60.00±0.00^b	70.00±0.00^b	86.67±3.33^b	90.00±0.00^b
P. guineense		83.33±3.33^c	100.00±0.00^c	100.00±0.00^c	100.00±0.00^c	100.00±0.00^c
A. melegueta	0.3	70.00±0.00^b	83.33±3.33^b	93.33±3.33^b	100.00±0.00^b	100.00±0.00^b
S. aromaticum		60.00±0.00^b	70.00±0.00^{bc}	76.67±3.33^b	86.67±3.33^{bc}	96.67±3.33^c
P. guineense		100.00±0.00^d	100.00±0.00^c	100.00±0.00^c	100.00±0.00^c	100.00±0.00^c
A. melegueta	0.4	73.33±3.33^b	26.67±3.33^b	93.33±3.33^b	96.67±3.33^b	100.00±0.00^b
S. aromaticum		66.67±3.33^b	73.33±6.67^{bc}	83.33±6.67^b	90.00±5.78^{bc}	100.00±0.00^c
P. guineense		100.00±0.00^d	100.00±0.00^c	100.00±0.00^c	100.00±0.00^c	100.00±0.00^c
A. melegueta	0.5	90.00±0.00^c	96.67±3.33^c	100.00±0.00^b	100.00±0.00^b	100.00±0.00^b
S. aromaticum		83.88±8.82^c	90.00±10.00^c	100.00±0.00^c	100.00±0.00^c	100.00±0.00^c
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 alphabet in column are not significantly different from one another (p>0.05) using Tukey's Test

Table 7: Lethal concentration (LC) of some spice's extracts against adult *S. oryzae*

Spice extracts	Exposure period	Intercept±SE	Slope±SD	R^2	LD_{50} (LCL-UCL)	LD_{90} (LCL-UCL)	p-value
P. guineense	Day 1	1.82±0.18	2.84±7.43	0.31	0.35 (0.18-0.27)	0.65 (0.55-0.82)	0.13
	Day 2	6.89±1.91	14.42±3.07	0.30	0.35 (0.24-0.36)	0.49 (0.38-0.46)	0.11
	Day 3	4.210.58±	9.49±7.46	0.31	0.34 (0.25-0.42)	0.49 (0.39-0.82)	0.01
	Day 4	4.07±0.54	9.49±7.46	0.33	0.33 (0.27-0.41)	0.47 (0.41-0.77)	0.03
	Day 5	4.43±0.54	9.49±7.46	0.30	0.23 (0.31-0.37)	0.41 (0.43-0.52)	0.33
A. melegueta	Day 1	1.32±0.14	3.89±9.43	0.64	0.46 (0.38-0.54)	0.98 (0.80-1.38)	0.01
	Day 2	1.84±0.17	4.68±10.13	0.61	0.40 (0.32-0.47)	0.78 (0.64-1.00)	0.00
	Day 3	2.94±0.27	6.26±10.08	0.06	0.35 (0.22-0.44)	0.54 (0.42-0.92)	0.00
	Day 4	3.03±0.28	6.58±9.94	0.41	0.35 (0.26-0.42)	0.54 (0.45-0.75)	0.00
	Day 5	6.67±2.75	14.65±2.13	0.40	0.34 (0.07-0.38)	0.43 (0.40-0.97)	0.99
S. aromaticum	Day 1	1.01±0.13	3.58±7.86	0.85	0.52 (0.47-0.58)	1.19 (1.01-1.52)	0.07
	Day 2	1.32±0.14	3.89±9.54	0.41	0.46 (0.36-0.55)	0.98 (0.78-1.49)	0.00
	Day 3	1.93±0.18	4.88±10.11	0.45	0.40 (0.33-0.47)	0.74 (0.62-0.97)	0.00
	Day 4	2.44±0.22	5.46±10.24	0.03	0.36 (0.27-0.43)	0.61 (0.51-0.84)	0.00
	Day 5	4.84±0.56	9.84±7.95	0.34	0.32 (0.24-0.38)	0.44 (0.37-0.59)	0.00

R^2: Statistical measure of mortality proportion in regression model, SE: Standard error, SD: 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 (χ^2) significant

Lethal concentration (LC) of some botanical extracts against adult *S. oryzae*: The lethal dose of the three botanical extracts against *S. oryzae* is given in Table 7. The dosage calculated for the *P. guineense*, *A. melegueta*, and *S. aromaticum* extracts to cause 50% (LD_{50}) and 90% (LD_{90}) mortality against the test insects calculated after the first day were 0.35 and 0.65 mL, 0.46 and 0.98 mL, 0.52 and 1.19 mL, respectively. The results showed a continuous decline in values after the second, third, fourth, and fifth days of exposure. Based on the calculations, *Piper guineense* extract had the lowest lethal dose across all exposure periods. Additionally, the confidence limits varied, indicating potential effectiveness beyond the calculated values.

Number of adult emergences of *S. oryzae* in paddy treated with some botanical extracts: Table 8 illustrates the effectiveness of *P. guineense*, *A. melegueta* and *S. aromaticum* extract against maize weevil adult emergence. The protection effectiveness of *P. guineense*, *A. melegueta*, and *S. aromaticum* powders against infestation of *S. oryzae* is significantly different (p<0.05) from the control (60.67). The highest seed protection was recorded from 0.2, 0.3, 0.4 and 0.5 mL of *P. guineense*, *A. melegueta* and *S. aromaticum* extracts (0.0 adult emergence of *S. oryzae* was recorded). The seed protection ability of *P. guineense* was not significantly different from *A. melegueta* and *S. aromaticum* extracts.

Table 8: Number of adult emergences of *S. oryzae* in paddy treated with some botanical extracts

Spice powder	Concentration (mL)	Adult emergence
P. guineense		0.00±0.00[a]
A. melegueta	0.2	0.00±0.00[a]
S. aromaticum		0.00±0.00[a]
P. guineense		0.00±0.00[a]
A. melegueta	0.3	0.00±0.00[a]
S. aromaticum		0.00±0.00[a]
P. guineense		0.00±0.00[a]
A. melegueta	0.4	0.00±0.00[a]
S. aromaticum		0.00±0.00[a]
P. guineense		0.00±0.00[a]
A. melegueta	0.5	0.00±0.00[a]
S. aromaticum		0.00±0.00[a]
Control	0.0	60.67±1.20[b]

Mean follow by the same alphabet in column are not significantly different from one another (p>0.05) using Tukey's Test

Table 9: Protectant effect of some botanical extracts on paddy seed damage, weight loss, and weevil perforation index against rice weevil

Spice extracts	Concentration (mL)	Total number of seed	Seed damage (%)	Weight loss (%)	WPI
P. guineense	0.2	605.00±1.15[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
	0.3	602.67±1.76[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
	0.4	607.33±0.88[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
	0.5	604.00±0.58[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
A. melegueta	0.2	607.33±0.67[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
	0.3	606.00±3.06[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
	0.4	604.67±1.45[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
	0.5	603.67±0.88[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
S. aromaticum	0.2	604.00±2.08[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
	0.3	604.33±1.45[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
	0.4	606.67±2.85[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
	0.5	608.00±1.15[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
Control	0.0	604.00±2.96[a]	10.02±0.25[b]	7.20±0.35[b]	10.02±0.43[b]

Mean follow by the same alphabet in column are not significantly different from one another (p>0.05) using Tukey's Test

Protectant effect of some botanical extracts on paddy damage, weight loss, and weevil perforation index against rice weevil: The percentage seed damage, weight loss, and weevil perforation index were presented in Table 9. Paddy treated with 0.2, 0.3, 0.4, and 0.5 mL of *P. guineense* extract gave 0.00% of seed damage, the same thing for 0.2, 0.3, 0.4, and 0.5 mL extracts of A. *melegueta* and *S. aromaticum*, respectively. There was no percentage weight loss recorded for the paddy treated with 0.2, 0.3, 0.4, and 0.5 mL of the three botanical extracts (0.00%); this was significantly different ($p<0.05$) from what was recorded from the control (7.20%). The weevil perforation index recorded from the seeds treated with 0.2, 0.3, 0.4, and 0.5 mL extracts of *P. guineense*, *A. melegueta*, and *S. aromaticum* was 0.00%, and only the control showed the highest (10.02).

Relationship between phytochemicals in *P. guineense, A. melegueta* and *S. aromaticum* powders and *S. oryzae* adult emergence, paddy grain damage, and weight loss: The correlation matrices illustrated the interaction among the composition of phytochemicals and biological activities of *S. oryzae* in Table 10. The correlation analysis shows that for *P. guineense*, there was a weak and negative correlation between the alkaloids and grain damage ($r = -0.288$). There was a positive and weak correlation between saponins and flavonoids ($r = 0.327$). The relationship between saponins to adult emergence ($r = 5.00$), grain damage ($r = 0.575$), and weight loss ($r = 517$) were positive and moderate.

The correlation analysis shows that for *A. melegueta*, the relationship between alkaloids to saponins ($r = -0.911$) and grain damage ($r = -0.971$) were negatively and positively strong, respectively. The relationship between saponins and adult emergence was weak and moderate ($r = -0.619$).

Table 10: Correlation between phytochemicals in *P. guineense*, *A. melegueta*, and *S. aromaticum* powders and *S. oryzae* adult emergence, paddy grain damage, and weight loss

	Alkaloids	Saponins	Tannins	Flavonoids	Adult emergence (%)	Grain damage (%)	Weight loss (%)
P. guineense							
Alkaloids	1.000	0.619	0.976	0.945	0.99	-0.288	0.992
Saponins		1.000	0.434	0.327	0.500	0.575	0.517
Tannins			1.000	0.993	0.997*	-0.488	0.995
Flavonoids				1.000	0.982	-0.585	0.978
Adult emergence (%)					1.000	-0.421	1.000*
Grain damage (%)						1.000	-0.403
Weight loss (%)							1.000
A. melegueta							
Alkaloids	1.000	-0.911	0.933	-0.721	0.24	-0.971	0.693
Saponins		1.000	-0.702	0.371	-0.619	0.786	-0.929
Tannins			1.000	-0.922	-0.125	-0.992	0.388
Flavonoids				1.000	0.500	0.866	0.000
Adult emergence (%)					1.000	0.000	0.866
Grain damage (%)						1.000	-0.500
Weight loss (%)							1.000
S. aromaticum							
Alkaloids	1.000	-0.262	-0.028	-0.929	-0.371	-0.614	-0.990
Saponins		1.000	-0.957	-0.115	0.993	0.923	0.397
Tannins			1.000	0.397	-0.918	-0.771	-0.114
Flavonoids				1.000	0.000	0.277	0.866
Adult emergence (%)					1.000	0.961	0.500
Grain damage (%)						1.000	0.720
Weight loss (%)							1.000

The correlation analysis shows that for *S. aromaticum*, the relationship between alkaloids and adult emergence was weak and negative ($r = 0.371$), and saponins to grain damage was positive and strong ($r = 0.923$).

DISCUSSION

The results obtained from this study justified the use of *P. guineense*, *A. melegueta*, and *S. aromaticum* powders and extracts in the protection and preservation of paddy grains against damage by storage insect pests. The treatment applied has been observed to greatly reduce the ability of adult rice weevils to feed and lay eggs on the body of the protected grains, which can lead to serious damage on the grain. The efficacy of these plant products against *S. oyzae* on stored paddy could be attributed to the contact toxicity of the powders to the weevil.

From the result obtained from the analysis, it could be observed that the treatment controlled the rice weevil reproduction almost 100% for the two months. The mechanism of the plant action might be to their antifeedant nature; a natural or synthetic substance that stops or inhibits feeding by a pest and especially an insect, they are pesticides derived from plants such as the black pepper, which act as antifeedants and repellents and render the food unpalatable[18]. The effect of this antifeedant or repellent on the result of analysis of variance, damage, percentage grain weight loss, and weevil perforation index of both powders and extracts were significantly reduced by using these botanical products. The use of oil in insect control is very efficacious against all the life stages of insects due to their contact toxicity on the insects[19].

The screening test carried out in this research work has revealed that the three botanical powders and extracts used are very effective and highly toxic to rice weevil when compared to the control. From the lethal dose result, the lowest value of 50 and 90% of *P. guineense* on *S. oryzae* shows its highest toxicity level, while *S. aromaticum* had the highest lethal dosage of 50 and 90%, which shows that it has the least toxicity. The research conducted also showed that the insect mortality rate continues to increase as the exposure days increase, in which *P. guineense* has the highest mortality rate in both powders and extracts. With the black pepper used in the treatment of bean weevil (adults), the mortality was dose-dependent, with higher dosages leading to 100% mortality. The number of eggs laid on the treated seeds was significantly reduced. Progeny emergence and feeding damage were completely inhibited at higher dosages. The seed oil has no adverse effect on cowpea seed viability. The results show that *P. guineense* seed extract has protectant ability against insect pest damage in storage and is a good alternative to synthetic insecticides in the control of insect pests in stored products[20]. Alkaloids, which are natural products present in *P. guineense* 'Uziza' are made up of heterocyclic nitrogen that possess insecticidal activities, and also the presence of flavonoids, on the other hand, is remarkable for their countless benefits[7]. From this recent study, it was observed that the seeds and extracts of *P. guineense* have the highest mortality percentage, followed by *A. melegueta*, while *S. aromaticum* has the least toxicity; the toxicities were based on exposure periods. The toxicities of these powders and extracts could be linked to the fact that the active ingredients of the materials have been concentrated during the extraction process[17]. The biological activity of *P. guineense* could be attributed to the presence of Chavin and piperine, an unsaturated amide, and the effectiveness of *P. guineense* powder against storage pests may also cause physical abrasion on the cuticle of weevils with a resultant loss of body fluids or blockage of spiracles[21]. The results from this research showed that all the leaves and extracts evaluated for the insect's toxicity significantly reduced seed damage in which plant extracts were more toxic than plant powders because there was no adult emergence, weight loss, weevils perforation index, and seed damage in paddy-treated with the seed extracts. The ability of the plant powders and extracts to completely cause zero damage to paddy could be due to the high mortality effect of the botanicals or the lack of weevils to lay eggs on the grains[17]. The results obtained from this study demonstrate the active potentials of these plant products as plant-derived insecticides against paddy weevil and provide a scientific solution to the use of plant-based insecticides as an alternative to synthetic insecticides in post-harvest storage. The disadvantages of using synthetic chemicals in the control of rice weevils are due to the high cost of the chemicals, toxic build-up residue in foods, resistance to pests, destruction of natural enemies, and harm to non-targeted organisms[9]. The three plants used in this project indicate their efficacy for replacing synthetic pesticides; not only do they prevent environmental pollution but also prevent insect resistance against pesticides, and they are biodegradable pesticides with greater selectivity.

CONCLUSION

The main reason for protecting our foods against insect damage is to ensure a continuous supply of foods for future use. The research used botanical materials in the management of *S. oryzae* on paddy grain infestation. The plant materials obtained from three different plants, *P. guineense*, *A. melegueta*, and *S. aromaticum*, were effective in the control of rice weevils against grain damage, especially the plant extracts. The potential of these plants should be put into consideration towards their development and exploitation. The botanical plants are biodegradable, not synthetic; therefore, they are known as eco-friendly, less toxic to the environment, and less resistant to insect pests.

SIGNIFICANCE STATEMENT

This study highlights the potential of *Piper guineense*, *Aframomum melegueta*, and *Syzygium aromaticum* as eco-friendly, sustainable alternatives to synthetic pesticides for controlling *Sitophilus oryzae* in stored paddy rice. By reducing seed damage, preventing weight loss, and minimizing adult weevil emergence, these botanicals can enhance food security, reduce post-harvest losses, and promote safer storage practices. The findings contribute valuable insights to sustainable agriculture, supporting efforts to minimize chemical pesticide dependence while safeguarding stored grains against insect infestations.

REFERENCES

1. Rajeswari, R. and M.R. Srinivasan, 2019. Efficacy of different botanicals against rice weevil, *Sitophilus oryzae* L. (Coleoptera: Curculionidae) in stored paddy seeds. Madras Agric. J., 106: 533-536.
2. Rismayani, I.M. Trisawa, A. Jufri, M. Syakir and Wiratno, 2023. Effect of botanical insecticide application on the population of brown planthopper and its natural enemies and the growth and production of rice plants. IOP Conf. Ser.: Earth Environ. Sci., Vol. 1208. 10.1088/1755-1315/1208/1/012009.
3. Seni, A., 2019. Impact of certain essential oils and insecticides against major insect pests and natural enemies in rice. J. Cereal Res., 11: 252-256.
4. Prakash, B., A. Kumar, P.P. Singh, S. Das and N.K. Dubey, 2021. Prospects of Plant Products in the Management of Insect Pests of Food Grains: Current Status and Future Perspectives. In: Natural Bioactive Compounds: Technological Advancements, Sinha, R.P. and D.P. Häder (Eds.), Academic Press, Massachusetts, United States, ISBN: 978-0-12-820655-3 pp: 317-335.
5. Ameh, S.J., O.O. Obodozie, U.S. Inyang, M.S. Abubakar and M. Garba, 2011. Climbing Black Pepper (*Piper guineense*) Seeds as an Antisickling Remedy. In: Nuts and Seeds in Health and Disease Prevention, Preedy, V.R., R.R. Watson and V.B. Patel (Eds.), Elsevier Inc., Netherlands, ISBN: 978-0-12-375688-6, pp: 333-343.
6. Pal, M.K., S. Tiwari, R. Regmi and F.M. Ali, 2021. Efficacy of plant-powders against rice weevil, *Sitophilus oryzae* (Linnaeus) (Curculionidae: Coleoptera) at laboratory condition. SAARC J. Agric., 19: 331-338.
7. Asawalam, E.F., U.E. Ebere and K.C. Emeasor, 2012. Effect of some plant products on the control of rice weevil *Sitophilus oryzae* (L.) Coleoptera: Curculionidae. J. Med. Plants Res., 6: 4811-4814.
8. Batiha, G.E.S., L.M. Alkazmi, L.G. Wasef, A.M. Beshbishy, E.H. Nadwa and E.K. Rashwan, 2020. *Syzygium aromaticum* L. (myrtaceae): Traditional uses, bioactive chemical constituents, pharmacological and toxicological activities. Biomolecules, Vol. 10. 10.3390/biom10020202.
9. Ileke, K.D., J.E. Idoko, D.O. Ojo and B.C. Adesina, 2020. Evaluation of botanical powders and extracts from Nigerian plants as protectants of maize grains against maize weevil, *Sitophilus zeamais* (Motschulsky) [Coleoptera: Curculionidae]. Biocatal. Agric. Biotechnol., Vol. 27. 10.1016/j.bcab.2020.101702.
10. Ileke, K.D., J.M. Adesina, L.C. Nwosu and A. Olagunju, 2020. Perforation index assessment of cowpea seeds against cowpea bruchid, *Callosobruchus maculatus* (Fabricius) [Coleoptera: Chrysomelidae], infestation using *Piper guineense*. J. Basic Appl. Zool., Vol. 81. 10.1186/s41936-020-00195-7.
11. Ashamo, M.O., K.D. Ileke and A.I. Onasile, 2022. Phytochemical compositions and insecticidal efficacy of four agro-waste used as biological control of cowpea beetle, *Callosobruchus maculatus* (Fab.) [Coleoptera: Bruchidae]. Bull. Natl. Res. Cent., Vol. 46. 10.1186/s42269-022-00795-z.
12. Ileke, K.D. and M.O. Oni, 2011. Toxicity of some plant powders to maize weevil, *Sitophilus zeamais* (Motschulsky) [Coleoptera: Curculiondae] on stored wheat grains (*Triticum aestivum*). Afr. J. Agric. Res., 6: 3043-3048.
13. Udo, I.O., M.S. Ekanem and E.U. Inyang, 2011. Laboratory evaluation of West African black pepper (*Piper guineense*) seed powder against maize weevil (*Sitophilus zeamais* Mots.). Munis Entomol. Zool. J., 6: 1003-1007.
14. Ezeonu, C.S. and C.M. Ejikeme, 2016. Qualitative and quantitative determination of phytochemical contents of indigenous Nigerian softwoods. New J. Sci., Vol. 2016. 10.1155/2016/5601327.
15. Ejikeme, C.M., C.S. Ezeonu and A.N. Eboatu, 2014. Determination of physical and phytochemical constituents of some tropical timbers indigenous to Niger Delta area of Nigeria. Eur. Sci. J., 10: 247-270.
16. Abbott, W.S., 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol., 18: 265-267.
17. Alabi, O.Y. and M.M. Adewole, 2017. Essential oil extract from *Moringa oleifera* roots as cowpea seed protectant against cowpea beetle. Afr. Crop Sci. J., 25: 71-81.

18. Ojo, D.O. and R.F. Ogunleye, 2013. Comparative effectiveness of the powders of some underutilized botanicals for the control of *Callosobruchus maculatus* (Coleoptera: Bruchidae). J. Plant Dis. Prot., 120: 227-232.
19. Adedire, C.O. and T.S. Ajayi, 1996. Assessment of the insecticidal properties of some plant extracts as grain protectants against maize weevil, *Sitophilus zeamais* Motschulsky. Niger. J. Entomol., 13: 93-101.
20. Nzelu, C.O., K.C. Emeasor and N.J. Okonkwo, 2020. Insecticidal activity of *piper guineense* (schumach and thonn) seed oil against *callosobruchus maculatus* (f.) (coleoptera: chrysomelidae) in stored cowpea seeds. Int. J. Res. Granthaalayah, 8: 262-270.
21. Ofuya, T.I. and E.O. Dawodu, 2002. Aspects of Insecticidal action of *Piper guineense* Schum and Thonn fruit powders against *Callosobruchus maculatus* (F.) Coleoptera: Bruchidae). Niger. J. Entomol., 19: 40-50.