TASR
Trends in
Applied Sciences
Research

OPEN ACCESS

Evaluation of the Insecticidal Properties of Two Plant Powders and Extracts for Protecting Wheat Grains Against *Tribolium Castaneum* (Herbst) [Coleoptera: Tenebrionidae]

Kayode David Ileke, Taiwo Michael Kayode and Richard Olajide Owaseye
Department of Biology, School of Life Sciences, Federal University of Technology Akure, Nigeria

ABSTRACT

Background and Objective: Plant-based insecticides are widely recognized for their cost-effectiveness and eco-friendly properties in protecting stored grains. During storage, various insect pests target stored grain products, with *Tribolium castaneum* being one of the most destructive. The objective of this study is to evaluate the insecticidal properties of two plant powders and their extracts in protecting wheat grains against *Tribolium castaneum* infestation. **Materials and Methods:** This study observed the efficacy of *Ricinus communis* and *Senna alata* leaf powders and extracts in managing *T. castaneum* under laboratory conditions at 28±2°C and 75±5% relative humidity. The powders were tested at dosages of 0.2, 0.4, 0.6, 0.8, and 1.0 g per 20 g of wheat grains, while the extracts were applied at concentrations of 0.1, 0.2, 0.3, 0.4, and 0.5 mL per 20 g. Parameters examined included mortality rates, lethal doses (LD_{50} and LD_{90}), progeny suppression, weight loss percentage, seed damage, and the Beetle Perforation Index (BPI). One-way ANOVA and probit analysis were used to analyse the data gotten from the experiment. Statistical differences are determined when $p<0.05$. **Results:** The findings revealed that *R. communis* powder achieved 50% adult mortality at 1.0 g per 20 g of wheat grains within one day, whereas *S. alata* powder caused 60% mortality at the same rate. Similarly, the extract of *R. communis* at 0.5 mL per 20 g induced 76.67% adult mortality after one day, while *S. alata* extract achieved 86.67% mortality under the same conditions. Each plant's powders and extracts effectively inhibited egg-laying, progeny production, weight loss, and seed damage. Among the two, *S. alata* demonstrated superior efficacy in both powdered and extract forms. **Conclusion:** Incorporating *R. communis* and *S. alata* into pest management strategies can significantly reduce the economic impact of *T. castaneum*, ensure the availability of viable seeds for planting, and enhance food security in Nigeria and other developing countries.

KEYWORDS

Botanicals, *Tribolium castaneum*, *Ricinus communis*, *Senna alata,* plant powders, plant extracts, mortality rate, progeny suppression, grain protection, pest management

INTRODUCTION

Stored grains, cereals, and their derivatives serve as essential food sources globally, with maize, rice, and wheat ranking among the most widely consumed grains. Wheat grain (*Triticum* spp.) is a major staple food

ISSN: 2151-7908 (Online)
ISSN: 1819-3579 (Print)
https://doi.org/10.3923/tasr.2025.24.34

Received: 07 Feb. 2025
Accepted: 11 Mar. 2025
Published: 13 Mar. 2025

that contributes around 20 percent of the protein and energy in the world's diet[1]. Wheat serves as an excellent feed source for polygastric animals because of its high protein values as compared to other feed grains like maize or barley[2].

Insect pests are the leading cause of both qualitative and quantitative losses in stored grains globally, with losses ranging from 10 to 40%[3,4]. Among these, the rust-red flour beetle (*Tribolium castaneum*, Coleoptera: Tenebrionidae) is particularly damaging, contributing to weight reductions of up to 40%[5]. *Tribolium castaneum* is a cosmopolitan pest and both larvae and adults can cause significant damage on the germ layer of wheat grains, their complete life cycle usually takes between 40 to 90 days, and adults can breed throughout the year in the tropics and subtropics[6].

Tribolium castaneum is a major post-harvest and storage pest of wheat, maize, millet, sorghum and barley, females lay between 300-400 eggs in their 5-8 months of adult lifespan and under optimum conditions of 35˚C and 60-80% relative humidity[7]. Larvae emerge from the egg in approximately 3 days and spend an average 13 days causing significant damage to grains before becoming pupa[8].

Organophosphates, pyrethroids, and fumigants have been employed to control *T. castaneum* populations; however, their effectiveness is hindered by the accumulation of toxic residues in food, high costs, and adverse effects on non-target organisms[9]. Another problem is insects developing resistance against a variety of synthetic insecticides over time. This led to proffering an alternative means for the control of red-rust flour beetle. Hence, the use of natural plant extracts, which aims at the elimination of the problems posed by the use of synthetic chemicals. Natural plant extracts are recognized as cost-effective, safe for humans, and environmentally friendly alternatives for pest control[5]. Some plant products have been evaluated for their toxic effects against stored grain pests, these plants are largely available in the environment[10]. Little information is available worldwide about the use and development of organic pesticides which proffer the same levels of control to beetles as synthetic insecticides. There are needs for current research to be aimed at the insecticidal efficacies that may be present in these plant products to combat the increasing problem of *T. castaneum* infesting wheat grains

MATERIALS AND METHODS

Study area: The study was carried out at the Department of Biology, Federal University of Technology, Akure, Ondo State. The study was carried out between May, 2022 to October, 2023.

Insect cultivation: Adult red rust flour beetles (*T. castaneum*) were obtained from the Storage Entomology Research Laboratory, Department of Biology, Federal University of Technology, Akure (FUTA), Nigeria. A total of 100 beetles were introduced into a 1 l glass jar containing 500 g of wheat grains sourced from a grain merchant in Akure metropolis, Ondo State, Nigeria. The beetle culture was maintained in an insect rearing cage under controlled conditions of 30±2°C and 75±5% relative humidity.

Identification and sex differentiation: The identification and sex determination of *T. castaneum* were conducted at the Entomology Research Laboratory, Department of Biology, FUTA. The pupal stage of the insect was placed on a slide and examined under a binocular microscope (Olympus CX23) to observe the sex characteristics. Genital papillae on the ventral side of the distal abdomen segment were used to determine the sexes. The female pupae possess a developed, protruding and pointed genital papillae compared to males[11].

Collection of plant material: The leaves of *R. communis* and *S. alata* were collected along Ondo Road in Akure, Ondo State. The plants were authenticated by a Plant Taxonomist from the Department of Crop, Soil, and Pest Management, FUTA. The leaves were air-dried in the Biology laboratory and ground into a fine powder using an electric blender (Philips HR2114). The powdered material was then sieved through a 1 mm^2 mesh. The resulting fine powders were stored in air-tight plastic containers and kept in a refrigerator at 4°C to preserve their quality before use.

Collection of wheat grains: The wheat grains used in this study were obtained from the Agricultural Development Programme, Ministry of Agriculture and Rural Development, Akure, Ondo State. The grains were first cleaned to remove debris, straw, and chaff, and sorted to eliminate broken grains. They were then sterilized by storing them in a deep freezer at -°C for 7 days to kill any existing insect eggs and larvae. This procedure was necessary as all insect life stages, including eggs and larvae, are susceptible to low temperatures[12]. After disinfestation, the wheat grains were placed in a Gallen Kamp oven (model 250) at 40°C for 4 hours and then air-dried in the laboratory for 72 hrs to prevent mould growth[9]. The grains were subsequently stored in plastic containers with tightly sealed lids.

Extractions of plant material: Ethanol extracts of *R. communis* and *S. alata* leaves were prepared using the cold extraction method. Approximately 300 g of the plant powders were separately soaked in 600 mL of absolute ethanol in an extraction bottle. The mixture was stirred occasionally with a glass rod, and extraction was allowed to proceed for 3 days. Afterward, the mixture was filtered through a double layer of Whatman No. 1 filter paper, and the solvent was evaporated using a rotary evaporator at 30-40°C and a rotary speed of 3-6 rpm for 8 hrs[13]. Any remaining solvent was removed under vacuum with the rotary evaporator (Labo therm SW 200). The concentrated extract was then air-dried to eliminate any residual ethanol.

Insect Bioassay

Toxicity of plant powders on adult mortality and adult emergence of *T. castaneum*: The 20 g of clean, uninfested wheat grains were measured using an electronic weighing balance (Model JTC 2101N) in the laboratory and placed in 250 mL plastic cups. Next, 0.2, 0.4, 0.6, 0.8, and 1.0 g doses of *R. communis* and *S. alata* leaf powders were carefully weighed and mixed separately with 20 g of the clean wheat grains. The plastic cups containing the powder and grains were shaken thoroughly to ensure proper mixing. Then, five copulating pairs (5 males and 5 females) of newly emerged adult *T. castaneum* (less than four days old) were introduced into each plastic cup containing the treated wheat grains and covered with muslin cloths. The control group contained only 20 g of wheat grains and five copulating pairs of adult *T. castaneum* (without any plant powder). Insect mortality was assessed daily for 5 days. Dead beetles were those that did not respond to a pin probe (i.e., failure to react to a sharp pin). At the end of the 5-day treatment period, the percentage of adult mortality was calculated using Abbott's formula[14]:

$$PT = \frac{(P0 - PC)}{(100 - P0)} \times 100$$

Where:

PT = Corrected mortality (%)
PO = Observed mortality (%)
PC = Control mortality (%)

The weight loss of the maize grains was calculated as the percentage loss in weight using the following formula[14]:

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

The number of damaged maize grains was assessed by calculating the percentage seed damage using the following formula[14]:

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

Beetle Perforation Index (BPI) was expressed as described by Ileke *et al.*[15]:

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

BPI value exceeding 50 was regarded as enhancement of infestation by the beetles or negative protectability of the powders and extracts tested.

Toxicity of ethanolic extracts on adult mortality and adult emergence of *T.castaneum*: Twenty grams of clean, uninfested wheat grains were weighed into 250 mL plastic containers. Then, aliquots of 0.1, 0.2, 0.3, 0.4, and 0.5 mL of *R. communis* and *S. alata* leaf extracts were measured using a graduated syringe and mixed with the 20 g of wheat grains in the plastic containers. The mixture was thoroughly stirred using a small glass rod. The plastic containers were left open for 40 min to allow the ethanol solvent to evaporate. Following this, five copulating pairs (5 males and 5 females) of adult *T. castaneum* were introduced into each of the plastic containers, and the containers were covered with muslin cloths. Each treatment was replicated three times. The control group contained only 20 g of wheat grains and ten copulating pairs of adult *T. castaneum* (no plant extract was added in the control group). Insect mortality was assessed daily for 5 days. Dead beetles were those that did not move and did not respond to pin probing (failure to react to a sharp pin). After the 5-day treatment period, the percentage of adult mortality was calculated[12]. The experimental setup was then kept in the insect rearing cage for an additional 35 days to allow new adults to emerge. The percentage of adult emergence, weight loss, seed damage, and Beetle Perforation Index were calculated as described above.

Data analysis: The data were analyzed using Analysis of Variance (ANOVA), and treatment means were separated using Duncan's New Multiple Range Test. The ANOVA was conducted using SPSS 27.0 software and statistical significance was determined at $p \leq 0.05$.

RESULTS

Mortality response of adult *T. castaneum* treated with some plant powders: The mortality response of adult *T. castaneum* exposed to leaf powders from two plant species is shown in Table 1. Insect mortality increased with dosage, as higher concentrations resulted in greater mortality rates. The toxicity of the plant powders differed significantly from the control ($p<0.05$). *Senna alata* powder was the most toxic to Red rust flour beetle, the powder caused 16.67, 30.00, 40.00, 50.00 and 60.00% mortality of *T. castaneum* at concentrations 0.2, 0.4, 0.6, 0.8 and 1.0 g per 20 g of wheat grains after the first day of exposure, respectively. The least toxic plant powder was *R. communis* that caused 03.33, 13.33, 26.67, 36.67 and 50.00% mortality of *T. castaneum* at concentrations 0.2, 0.4, 0.6, 0.8 and 1.0 g per 20 g of wheat grains after the first day of exposure, respectively. *Senna alata* powder evoked 83.33 and 100% mortality of red rust flour beetle at rate 0.8 and 1.0 g per 20 g of wheat grains after fifth day of exposure, respectively. Toxicity trend of the two plant leaf powders was dosage dependent and exposure time.

Lethal dosage (LD) of some plant powders against adult *T. castaneum*: The lethal dose of the two plant leaf powders against *T. castaneum* is given in Table 2. The dosage calculated for the *R. communis* and *S. alata* leaf powders to cause 50% (LD_{50}) and 90% (LD_{90}) mortality against the test organism

Table 1: Mortality response of adult *T. castaneum* treated with some plant leaf powders

		Mortality % (Mean±SE)				
Plant powder	Dosage (g)	Day 1	Day 2	Day 3	Day 4	Day 5
Ricinus communis	0.2	03.33±3.33^{a}	13.33±3.33^{b}	20.00±0.00^{b}	30.00±0.00^{b}	33.33±3.33^{b}
Senna alata		16.67±3.33^{b}	23.33±3.33^{b}	33.33±3.33^{b}	36.67±3.33^{b}	43.00±3.33^{b}
Ricinus communis	0.4	13.33±3.33^{b}	20.00±0.00^{c}	33.33±3.33^{c}	36.67±3.33^{b}	46.67±3.33^{c}
Senna alata		30.00±3.33^{c}	36.67±3.33^{c}	46.67±3.33^{c}	53.33±3.33^{c}	56.67±3.33^{c}
Ricinus communis	0.6	26.67±3.33^{c}	36.67±3.33^{b}	46.67±3.33^{d}	53.33±3.33^{c}	60.00±0.00^{d}
Senna alata		40.00±0.00^{d}	50.00±0.00^{d}	56.67±3.33^{d}	67.67±3.33^{d}	73.33±3.33^{d}
Ricinus communis	0.8	36.67±3.33^{d}	50.00±0.00^{e}	60.00±0.00^{e}	66.67±3.33^{d}	73.33±3.33^{e}
Senna alata		50.00±0.00^{e}	63.33±3.33^{e}	70.00±0.00^{e}	76.67±3.33^{e}	83.33±3.33^{e}
Ricinus communis	1.0	50.00±0.00^{e}	60.00±0.00^{e}	66.67±3.33^{e}	80.00±0.00^{e}	93.33±3.33^{f}
Senna alata		60.00±0.00^{f}	70.00±0.00^{e}	76.67±3.33^{e}	86.67±3.33^{f}	100.00±0.00^{f}
Untreated	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}

Each value is a Mean±Standard error of three replicates, Means followed by the same letter along the column are not significantly different (p>0.05) using duncan’s multiple range test

Table 2: Lethal dosage (LD) of some plant leaf powders against adult *T. castaneum*

Plant powder	Exposure period	LD_{50} (LCL-UCL)	LD_{90} (LCL-UCL)
Ricinus communis	Day 1	1.03 (0.90-1.31)	2.90 (1.96-8.99)
	Day 2	0.90 (0.78-1.07)	2.12 (1.57-4.67)
	Day 3	0.78 (0.48-0.45)	2.20 (4.44-6.76)
	Day 4	0.75 (0.56-0.81)	1.44 (1.20-2.30)
	Day 5	0.68 (0.50-0.76)	1.12 (0.99-1.54)
Senna alata	Day 1	0.92 (0.41-1.18)	2.15 (1.92-1.28)
	Day 2	0.75 (0.41-0.93)	2.11 (1.52-7.86)
	Day 3	0.72 (0.33-0.90)	1.96 (1.39-7.81)
	Day 4	0.51 (0.01-0.84)	1.75 (1.30-2.10)
	Day 5	0.60 (0.00-0.72)	0.92 (0.99-1.54)

LD_{50}: Lethal dosage at which 50% population response, LD_{90}: Lethal dosage at which 90% population response, LCL: Lower Confidence Limit and UCL: Upper Confidence Limit

calculated after the first day were 1.03 and 2.90 g, 0.92 and 2.15 g, respectively. However, it was observed that these values continued to reduce after the second, third, fourth, and fifth days of exposure. From the calculation, *S. alata* leaf powder was observed to have the lowest lethal dose across all periods of exposure. All these values have different confidence limits that might be effective aside from the calculated values.

Number of adult emergence of *T. castaneum* in wheat treated with some plant leaf powders: Table 3 presents the effectiveness of *R. communis* and *S. alata* leaf powders in preventing the emergence of *T. castaneum* adults. The protective ability of both plant powders was significantly different (p<0.05) from the untreated control. The highest level of seed protection was observed at 0.8 and 1.0 g of *S. alata* and 1.0 g of *R. communis* powder, with no recorded adult emergence of *T. castaneum*. Additionally, the protective effect of 0.8 and 1.0 g of *S. alata* powder did not significantly differ from that of 1.0 g of *R. communis* powder, as all treatments recorded zero adult emergence. However, 0.6 g of *R. communis* powder (3.67 adult emergence) was significantly less effective (p<0.05) than 0.6 g of *S. alata* powder (0.66 adult emergence) in preventing *T. castaneum* infestation in wheat seeds. A significant difference (p<0.05) was also observed between 0.2 g of *R. communis* powder (8.00 adult emergence) and 0.2 g of *S. alata* powder (5.33 adult emergence), indicating a variation in their insecticidal effectiveness.

Protectant effect of some plant powders on wheat seed damage, weight loss, and beetle perforation index against red-rust flour beetle: Percentage seed damage, weight loss, and beetle perforation index were presented in Table 4. Wheat seeds treated with 0.2 g of *R. communis* and 0.2 g of *S. alata* powder gave 2.47, 1.70% seed damage, respectively. There was no significant difference (p>0.05) between the two plant

Table 3: Number of adult emergences of *T. castaneum* in wheat treated with some plant powders

Plant powder	Dosage (g)	Adult emergence
Ricinus communis	0.2	8.00±0.58[d]
	0.4	6.33±0.33[cd]
	0.6	3.67±0.33[bc]
	0.8	1.33±0.33[b]
	1.0	0.00±0.58[a]
Senna alata	0.2	5.33±0.88[b]
	0.4	2.33±0.33[bc]
	0.6	0.66±0.33[a]
	0.8	0.00±0.00[a]
	1.0	0.00±0.00[a]
Untreated	0.0	47.67±2.19[e]

Each value is a Mean±Standard error of three replicates. Means followed by the same letter along the column are not significantly different (p>0.05) using duncan's multiple range test

Table 4: Protectant effect of some plant powders on wheat seed damage, weight loss, and Beetle perforation index against red rust flour beetle

Plant powder	Dosage (g)	Total no. of seed	Number of seed of damage	Seed damage (%)	Weight loss (%)	Beetle perforation index
Ricinus communis	0.2	314.33	8.00±0.58[d]	2.47±0.17[a]	0.98±0.67[c]	15.53±0.49[c]
	0.4	311.67	6.33±0.33[cd]	1.98±0.10[a]	0.79±0.38[c]	12.70±0.90[c]
	0.6	311.00	3.67±0.33[bc]	1.14±0.09[a]	0.47±0.33[b]	7.32±0.66[b]
	0.8	313.67	1.33±0.33[b]	0.75±0.52[a]	0.30±0.21[a]	4.78±0.90[b]
	1.0	313.67	0.00±0.58[a]	0.10±0.18[a]	0.10±0.07[a]	0.70±0.70[a]
Senna alata	0.2	315.67	5.33±0.88b	1.70±0.30[a]	0.67±012[c]	10.83±1.18[c]
	0.4	316.00	2.33±0.33[bc]	0.72±0.11[a]	0.29±0.04[b]	4.67±0.86[b]
	0.6	314.67	0.66±0.33[a]	0.27±0.10[a]	0.80±0.40[a]	1.36±0.68[a]
	0.8	312.00	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	1.26±1.26[a]
	1.0	316.33	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
Untreated	0.0	317.33	47.67±2019[e]	16.75±1.00[b]	12.80±0.00[d]	>50.00±0.00[d]

Each value is a Mean±Standard error of three replicates, Means followed by the same letter along the column are not significantly different (p>0.05) using duncan's multiple range test

leaf powders at 0.2 g. The highest percentage of seed damage was observed in wheat treated with 0.2 g of *R. communis* powder, recording 2.47% seed damage, which was significantly different ($p<0.05$) from the control (16.75%). The lowest percentage of seed damage was recorded in treatments with 0.8 g and 1.0 g of *S. alata* powder (0.0% damage) and 1.0 g of *R. communis* powder (0.10% damage).

Their protective effect was not significantly different ($p>0.05$) from 0.8 g of *R. communis* (0.75%), 0.6 g of *R. communis* (1.14%), 0.4 g of *R. communis* (1.98%), 0.8 g of *S. alata* (0.00%), 0.6 g of *S. alata* (0.27%) and 0.4 g of *S. alata* (0.72%). The highest weight loss was recorded with wheat treated with 0.2 g of *R. communis* powder (0.98%); this was significantly different ($p<0.05$) from what was recorded from the untreated (12.80%). The beetle perforation index recorded from the seeds treated with 0.2 g of *R. communis* plant powder (15.53%) was the highest, followed by 0.4 g of the same powder (12.70%).

Mortality response of adult *T. castaneum* treated with some plant extracts: Mortality response of adult *T. castaneum* treated with two plants leaf extracts is presented in Table 5. Insect mortality is concentration dependent. The higher the concentration, the higher the mortality rate the toxicity of the plants extract was significantly ($p<0.05$) different from the control. *Senna alata* leaf extract was the most toxic to Red-rust flour beetle, the extract caused 46.67, 56.00, 70.00, 80.00 and 86.67% mortality of *T. castaneum* at concentrations 0.1, 0.2, 0.3, 0.4 and 0.5 mL per 20 g of wheat grains after the first day of exposure, respectively. The least toxic plant powder was *R. communis* that caused 26.67, 40.00, 56.67, 66.67 and 76.67% mortality of *T. castaneum* at concentrations 0.1, 0.2, 0.3, 0.4 and 0.5 mL per 20 g of wheat grains after the first day of exposure, respectively. Both *R. communis* and *S. alata* leaf extracts evoked 100% mortality of red rust beetle at a rate 0.4 and 0.5 g per 20 g of wheat grains after the fifth day of exposure, respectively. Toxicity trend of the two plant leaf extracts was concentration dependent and exposure time.

Table 5: Mortality response of adult *T. castaneum* treated with some plant extracts

		Mortality % (Mean±SE)				
Plant conc	Extract (mL)	Day 1	Day 2	Day 3	Day 4	Day 5
Ricinus communis	0.1	26.67±3.33^{b}	36.67±3.33^{b}	50.00±0.00^{b}	56.67±3.33^{c}	63.33±3.33^{b}
Senna alata		46.67±3.33^{b}	53.33±3.33^{b}	60.00±0.00^{b}	66.67±3.33^{b}	73.33±3.33^{b}
Ricinus communis	0.2	40.00±0.00^{c}	46.67±3.33^{c}	56.67±3.33^{b}	66.67±3.33^{c}	76.67±3.33^{c}
Senna alata		56.00±3.33^{c}	63.33±3.33^{c}	73.33±3.33^{c}	80.00±0.00^{c}	90.00±0.00^{c}
Ricinus communis	0.3	56.67±3.33^{d}	66.67±3.33^{d}	80.00±0.00^{c}	86.67±3.33^{d}	96.67±3.33^{d}
Senna alata		70.00±0.00^{c}	80.00±0.00^{d}	90.00±0.00^{d}	100.00±0.00^{d}	100.00±0.00^{d}
Ricinus communis	0.4	66.67±3.33^{e}	76.67±3.33^{d}	93.33±3.33^{d}	100.00±0.00^{e}	100.00±0.00^{d}
Senna alata		80.00±0.00^{d}	93.33±3.33^{e}	100.00±0.00^{e}	100.00±0.00^{d}	100.00±0.00^{d}
Ricinus communis	0.5	76.67±0.00^{f}	90.00±0.00^{e}	96.67±3.33^{d}	100.00±0.00^{e}	100.00±0.00^{d}
Senna alata		86.67±0.00^{e}	100.00±0.00^{e}	100.00±0.00^{e}	100.00±0.00^{d}	100.00±0.00^{d}
Untreated	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}

Each value is a Mean±Standard error of three replicates, Means followed by the same letter along the column are not significantly different ($p > 0.05$) using duncan's multiple range test

Table 6: Lethal Concentration (LC) of some plant extracts against adult *T. castaneum*

Plant extract	Exposure period	LC_{50} (LCL-UCL)	LC_{90} (LCL-UCL)
Ricinus communis	Day 1	0.69 (0.42-0.84)	1.76 (1.35-4.03)
	Day 2	0.64 (0.50-0.73)	1.18 (1.02-1.60)
	Day 3	0.55 (0.45- 0.62)	0.88 (0.78-1.02)
	Day 4	0.43 (0.31-0.56)	1.64 (0.67-0.93)
	Day 5	0.35 (0.26-0.42)	0.55 (0.43-0.81)
Senna alata	Day 1	0.65 (0.38-0.80)	1.41 (1.12-2.77)
	Day 2	0.53 (0.42-0.60)	0.85 (0.75-1.01)
	Day 3	0.41 (0.28-0.55)	0.62 (0.43-0.89)
	Day 4	0.32 (0.21-0.52)	0.51 (0.32-0.78)
	Day 5	0.34 (0.15-0.41)	0.50 (0.41-0.67)

LC_{50}: Lethal dosage at which 50% population response, LC_{90}: Lethal dosage at which 90% population response, LCL: Lower Confidence Limit and UCL: Upper Confidence Limit

Lethal Concentration (LC) of some plant extracts against adult *T. castaneum*: Table 6 presents the lethal dose of the two plant leaf extracts against *T. castaneum*. The calculated dosages of *R. communis* and *S. alata* leaf extracts required to achieve 50% (LC_{50}) and 90% (LC_{90}) mortality after the first day were 0.69 and 1.76, and 0.65 and 1.41 mL, respectively. However, these values progressively decreased over the subsequent days of exposure. Analysis revealed that *S. alata* leaf extract consistently exhibited the lowest lethal concentration across all exposure periods. Additionally, the confidence limits indicate potential variations in efficacy beyond the calculated values.

Number of adult emergences of *T. castaneum* in wheat treated with some plant leaf extracts: According to the results presented in Table 7, the effectiveness of *R. communis* and *S. alata* extracts in preventing adult emergence of the Red-rust flour beetle, *T. castaneum*, was significantly different ($p < 0.05$) when compared to the control. The highest level of seed protection was observed with 0.3, 0.4, and 0.5 mL of both *R. communis* and *S. alata* extracts, as no adult emergence was recorded in these treatments. The seed protection ability of 0.3, 0.4, and 0.5 mL of *S. alata* extract was not significantly different from that of *R. communis* extract, with no adult emergence in both cases. However, the protection provided by 0.2 mL of *R. communis* leaf extract (1.00) was significantly different ($p < 0.05$) from the 0.2 mL of *S. alata* leaf extract (0.33) regarding adult emergence. There was no significant difference ($p < 0.05$) between the protection abilities of 0.1 mL of *R. communis* (1.67 adult emergence) and 0.1 mL of *S. alata* leaf extract (1.33 adult emergence).

Protectant effect of some plant extracts on wheat seed damage, weight loss, and beetle perforation index against red-rust flour beetle: The data on seed damage percentage, weight loss, and beetle perforation index are summarized in Table 8. Wheat seeds treated with 0.1 mL of *R. communis* and 0.1 mL

Table 7: Number of adult emergences of *T. castaneum* in wheat treated with some plant extract

Plant extract	Concentration (mL)	Adult emergence
Ricinus communis	0.1	1.33±0.33[a]
	0.2	1.00±0.33[a]
	0.3	0.00±0.00[a]
	0.4	0.00±0.00[a]
	0.5	0.00±0.00[a]
Senna alata	0.1	1.67±0.33[a]
	0.2	0.33±0.33[a]
	0.3	0.00±0.00[a]
	0.4	0.00±0.00[a]
	0.5	0.00±0.00[a]
Untreated	0.0	46.00±1.53[b]

Each value is a Mean±Standard error of three replicates, Means followed by the same letter along the column are not significantly different (p>0.05) using duncan's multiple range test

Table 8: Protectant effect of some spice's powders on wheat seed damage, weight loss, and Beetle perforation index against Red-rust flour beetle

Plant extract	Conc. (mL)	Total no. of seed	Number of seed damage	Seed damage (%)	Weight loss (%)	Beetle perforation index
Ricinus communis	0.1	321.67	1.33±0.33[a]	0.41±0.10[a]	0.53±0.13[a]	2.52±0.61[a]
	0.2	314.67	1.00±0.00[a]	0.31±0.00[a]	0.40±0.00[a]	1.95±0.10[a]
	0.3	313.00	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
	0.4	317.67	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
	0.5	313.33	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
Senna alata	0.1	314.33	0.67±0.33[a]	0.21±0.10[a]	0.27±0.13[a]	1.36±0.68[a]
	0.2	314.67	0.33±0.33[a]	0.10±0.10[a]	0.13±0.13[a]	0.63±0.10[a]
	0.3	313.67	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
	0.4	313.00	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
	0.5	317.67	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
Untreated	0.0	317.33	51.67±2.02[b]	16.27±0.72[b]	6.51±0.50[c]	>50.00±0.00[c]

of *S. alata* extracts showed seed damage of 0.41 and 0.21%, respectively, with no significant difference ($p>0.05$) observed between the two plant extracts at this dosage. The highest seed damage was observed in wheat treated with 0.1 mL of *R. communis* extract (0.41%), which was significantly different ($p<0.05$) from the control group (16.27%). The lowest seed damage was recorded in wheat treated with 0.3, 0.4, and 0.5 mL of both *R. communis* and *S. alata* extracts, where no seed damage (0.0%) was observed. These treatments were not significantly different ($p>0.05$) from the 0.2 mL of *R. communis* (0.31%), 0.1 mL of *R. communis* (1.41%), 0.2 mL of *S. alata* (0.10%), and 0.1 mL of *S. alata* (0.21%). The highest weight loss was recorded in wheat treated with 0.1 mL of *R. communis* extract (0.53%), which was significantly different ($p<0.05$) from the control (6.51%). The beetle perforation index was highest in seeds treated with 0.1 mL of *R. communis* extract (2.52%), followed by 0.2 mL of the same extract (1.95%).

DISCUSSION

The findings of this study support the use of *R. communis* and *S. alata* leaf powders and extracts as effective methods for preserving wheat grains from degradation caused by storage insect pests. The treatments significantly reduced the ability of the red rust flour beetle to lay eggs on the protected seeds, which in turn led to a notable decrease in the extent of damage.

The results of this study demonstrated that the application of plant extracts successfully prevented 100% reproduction of the red rust flour beetle. The action mechanism may involve their antifeedant or repellent properties, which aligns with the findings of Saxena *et al.*[16], who reported effective control of *T. castaneum* using *Citrus reticulata* and *Psidium guajava* leaves. Antifeedants are substances that hinder or disrupt insect feeding by rendering the treated materials unattractive or unpalatable[17]. The analysis of variance revealed that damage, including percentage grain weight loss and beetle perforation index (BPI), was significantly reduced or entirely prevented when the plant powders and extracts were used. Oil extracts are recognized for their efficacy in controlling insects across all life stages[18-20].

In this present study, *S. alata* leaf powder and extract had the lesser value of lethal dose and concentration of the two plant leaves used and this shows its more potent toxicity level on *T. castaneum* and while *R. communis* leaf powder and extract had the higher value of lethal dose and concentration of the two-plant product used, this show that it has lesser toxicity potency as compared to *S. alata*. In the course of this research, the mortality of adult insects increased with both the duration of exposure and the concentration gradient. *S. alata* was found to be more effective than *R. communis* on the adult *T. castaneum* at all tested concentrations after Day 1 of exposure.

Ileke and Oni[21] found that treatment with *Cassia alata* extracts resulted in a reduction of certain metabolic enzymes in *T. castaneum*, including Acid Phosphatase, Alkaline Phosphatase, Glutamate Pyruvate Transaminase, Glutamate Oxaloacetate Transaminase, Lactate Dehydrogenase, and Acetylcholinesterase. This decrease in metabolic enzyme activity suggests disruption of the insect's chemical pathways, leading to abnormal physiological states that impair their survival, as reported by Zeba and Khan[18].

The present study result agrees with Ojo and Ogunleye[19] who reported the insecticidal efficacy of *Cassia alata* against *C. maculatus.* The present study has shown that the *S. alata* leaf powders are more toxic to *T. castaneum* than *R. communis*. The high mortality observed in the insects could explain the ability of plant powders and extracts to prevent seed damage and weight loss effectively. This may be due to the inhibition of egg laying by the insects on the treated grains, which subsequently reduced larval feeding and consequently prevented seed damage and weight loss, as noted by Nath *et al.*[22]. In this study, the toxicity of the plant materials varied depending on the type of plant and exposure duration. The findings also indicated that the leaf extracts were more toxic to the insects compared to the leaf powders used for contact toxicity. This difference in effectiveness may be attributed to the concentration of active ingredients in the extracts during the extraction process, as suggested by Salah *et al.*[23]. The high mortality rate of *T. castaneum* exposed to the powders and extracts could be linked to contact toxicity, as the treated seeds, covered by the powders and extracts, acted as a toxic source for the adult beetles after consumption. Additionally, the treated grains limited the insects' feeding, thereby hindering their normal growth and development, which led to starvation and eventually the death of some insects, as reported by Deme *et al.*[24].

The evaluation of leaf powders and extracts in this study showed a significant reduction in seed damage and weight loss caused by *T. castaneum*. The leaf extracts exhibited higher toxicity than the powders, resulting in minimal to no seed damage or weight loss in treated wheat grains. Additionally, the Beetle Perforation Index (BPI) was nearly zero for most extracts at the tested concentrations. These results underscore the potential of plant extracts as viable alternatives to synthetic pesticides, as both extracts effectively suppressed insect reproduction across all applied dosages. As interest in botanical treatments for pest control grows, there is a need for continued development and refinement of these natural solutions using established scientific methods to control storage insect pests effectively.

CONCLUSION

The research study demonstrated the efficacy of using *R. communis* and *S. alata,* two natural plant products, in controlling *T. castaneum* on maize infestations. It was established that these botanicals could effectively reduce the damage caused to wheat grains by *T. castaneum*. *Ricinus communis* powder caused 50% adult mortality at 1.0 g per 20 g of wheat grains in one day, while S. alata powder achieved 60% mortality. The extracts at 0.5 mL per 20 g induced 76.67 and 86.67% mortality for *R. communis* and *S. alata*, respectively, effectively inhibiting egg-laying, progeny production, weight loss, and seed damage. *Senna alata* exhibited superior efficacy, highlighting the potential of both plants in pest management to protect seed viability and food security.

The use and further development of these bioinsecticides is highly recommended due to their rapid degradation in the environment compared to synthetic pesticides. Additionally, they are more accessible than many man-made insecticides and safer for beneficial pests than chemicals which remain in the environment for a longer time after application.

SIGNIFICANCE STATEMENT

This study discovered the efficacy of *R. communis* and *S. alata* as natural plant-based bioinsecticides that can be beneficial for controlling *T. castaneum* infestations in stored wheat grains. The findings highlight the potential of these botanicals as environmentally friendly alternatives to synthetic pesticides, offering a safer and more sustainable pest control solution. This study will help researchers uncover critical areas of botanical insecticide application and environmental impact that many researchers were not able to explore. Thus, a new theory on the role of plant-derived bioinsecticides in integrated pest management may be arrived at.

REFERENCES

1. Atta, B., M. Rizwan, A.M. Sabir, M.D. Gogi and M. Sabar *et al*., 2020. Toxic and repellent characteristics of some plant extracts used against *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) improve the grain quality of stored wheat. J. Innovative Sci., 6: 1-11.
2. Ahmad, F., N. Iqbal, S.M. Zaka, M.K. Qureshi and Q. Saeed *et al*., 2019. Comparative insecticidal activity of different plant materials from six common plant species against *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). Saudi J. Biol. Sci., 26: 1804-1808.
3. Fields, P.G., 2006. Effect of *Pisum sativum* fractions on the mortality and progeny production of nine stored-grain beetles. J. Stored Prod. Res., 42: 86-96.
4. Krishna, P.N. and U. Yadav, 2023. Efficacy of different plant extracts and insecticide on red flour beetle, *Tribolium castaneum* (Herbst) in Wheat, *Triticum aestivum*. Int. J. Environ. Clim. Change, 13: 508-513.
5. Ajayi, F.A. and S.A. Rahman, 2006. Susceptibility of some staple processed meals to red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). Pak. J. Biol. Sci., 9: 1744-1748.
6. Lougraimzi, H., S. El Iraqui, A. Bouaichi, S. Gouit, E.H. Achbani and M. Fadli, 2018. Insecticidal effect of essential oil and powder of *Mentha pulegium* L. leaves against *Sitophilus oryzae* (Linnaeus, 1763) and *Tribolium castaneum* (Herbst, 1797) (Coleoptera: Curculionidae, Tenebrionidae), the main pests of stored wheat in Morocco. Polish J. Entomol., 87: 263-278.
7. Haines, C.P., 1991. Insects and Arachnids of Tropical Stored Products: Their Biology and Identification (A Training Manual). 2nd Edn., Natural Resources Institute, Chatham, United Kingdom, ISBN: 9780859542821, Pages: 246.
8. Howe, R.W., 1965. A summary of estimates of optimal and minimal conditions for population increase of some stored products insects. J. Stored Prod. Res., 1: 177-184.
9. Adedire, C.O., O.M. Obembe, R.O. Akinkurolere and S.O. Oduleye, 2011. Response of *Callosobruchus maculatus* (Coleoptera: Chrysomelidae: Bruchinae) to extracts of cashew kernels. J. Plant Dis. Prot., 118: 75-79.
10. Isman, M.B., 2006. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annu. Rev. Entomol., 51: 45-66.
11. 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.
12. Abbott, W.S., 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol., 18: 265-267.
13. Iram, N., M. Arshad and N. Akhter, 2013. Evaluation of botanical and synthetic insecticide for the control of *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). BioAssay, Vol. 8. 10.14295/BA.v8.0.117.

14. Ashamo, M.O. and O. Akinnawonu, 2012. Insecticidal efficacy of some plant powders and extracts against the Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae). Arch. Phytopathol. Plant Prot., 45: 1051-1058.
15. 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.
16. Saxena, R.C., G. Jilani and A. Abdul Kareem, 1989. Effects of Neem on Stored Grain Insects. In: Focus on Phytochemical Pesticides, Jacobson, M. (Ed.), CRC Press, Boca Raton, Florida, ISBN: 9781351072052, pp: 97-112.
17. Rajashekar, Y., K.V. Ravindra and N. Bakthavatsalam, 2014. Leaves of *Lantana camara* Linn. (Verbenaceae) as a potential insecticide for the management of three species of stored grain insect pests. J. Food Sci. Technol., 51: 3494-3499.
18. Zeba and M.A. Khan, 1995. Effect of fenvalerate on protein and amino acid contents and enzyme activities in the Ostracod *Chrissia halyi*. Pestic. Sci., 45: 279-282.
19. 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.
20. 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.
21. 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.
22. Nath, R., G. Singh and G. Deep, 2019. Efficacy of some botanical extracts against *Tribolium castaneum*: Coleoptera (Tenebrionidae). Plant Cell Biotechnol. Mol. Biol., 20: 660-666.
23. Salah, S., M.H. Abass and A.A. Alyousuf, 2023. Repellency and phytoxicity assessment of plant extracts, essential oils and nanoparticles on *Tribolium castaneum* herbst beetles infesting wheat grains (*Triticum estivum* L.). Basrah J. Sci., 41: 276-310.
24. Deme, G.G., Y.D. Malann, E.S. Chundusu and J.A. Chup, 2019. Insecticidal effects of *Cassia tora* and *Cassia alata* against cowpea weevil (*Callosobruchus maculatus*). Sci. World J., 14: 144-147.