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Evaluating the Repellency and Toxicity of Selected Medicinal Plant Extracts against *Sitophilus oryzae* Infestation

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ABSTRACT

This study evaluates the repellency and toxicity of selected medicinal plant extracts against Sitophilus oryzae, a destructive pest commonly infesting stored grain. The increasing demand for eco-friendly pest management solutions has highlighted the potential of plant-based insecticides as viable alternatives to synthetic chemicals. The research involved testing the efficacy of various plant extracts, focusing on their ability to repel and kill S. oryzae at different concentrations. The toxicity of the plant extracts was assessed by monitoring insect mortality at 12, 24, 48, and 72 hours post-exposure, while repellency was determined by observing the avoidance behavior of S. oryzae in treated environments. Results indicated that certain plant extracts exhibited strong toxic effects, leading to significant mortality rates compared to the control group. Repellency tests showed that the plant extracts reduced S. oryzae infestation by up to 80%, demonstrating their potential as natural insect repellents. This study supports the use of medicinal plant extracts as effective, environmentally friendly alternatives to chemical insecticides for the control of Sitophilus oryzae, promoting sustainable practices in grain storage and pest management.

Keywords: *Medicinal plants; Triboliumcastaneum; repellency; toxicity; natural pest management; eco-friendly pesticides*

1. INTRODUCTION

Stored grain products, particularly those of economic significance such as rice, wheat, and corn, are highly susceptible to insect infestation, leading to substantial post-harvest losses worldwide. Among the various pests that infest stored grains, *Sitophilus oryzae* (the rice weevil) stands out as one of the most destructive [1]. This insect species is responsible for significant damage to stored grains, reducing their quality, weight, and overall market value. Insect infestations not only result in economic losses but can also compromise food safety, as insects may contaminate food products with microorganisms and excreta [2]. Consequently, the need for effective pest management strategies in the agricultural and food storage industries has become increasingly urgent.Traditional methods of pest control often involve the use of synthetic chemical pesticides. While these chemical agents are effective in controlling insect populations, they come with several environmental, economic, and health-related drawbacks. Chemical pesticides have been linked to the development of pesticide-resistant pest populations, contamination of soil and water, and adverse effects on non-target organisms, including beneficial insects, wildlife, and humans. Additionally, the residues of chemical pesticides in food products pose a serious health risk to consumers. In response to these concerns, there has been a growing interest in alternative pest management approaches that are eco-friendly, sustainable, and safe for human and environmental health [3-4].

Medicinal plants, many of which have been used for centuries in traditional medicine, are emerging as a promising source of natural insecticides. These plants contain bioactive compounds that exhibit insecticidal, repellent, and anti-feedant properties. The potential for plant-based insecticides to replace or supplement chemical pesticides has gained attention due to their low toxicity to humans and animals, biodegradability, and minimal environmental impact. Furthermore, medicinal plants are widely available, and many are easy to cultivate, making them an attractive option for sustainable pest management.

Fig 1: rice weevil (Sitophilus oryzae)

The use of medicinal plants as insect repellents and toxicants has been well documented in various studies. Many plant species are known to possess natural compounds, such as alkaloids, terpenoids, phenolics, and flavonoids, which can effectively repel or kill insect pests. The mechanism of action of these compounds varies, but common modes of action include interference with the insect's nervous system, respiration, and feeding behavior. For example, essential oils derived from plants like *neem* (*Azadirachta indica*), *citronella* (*Cymbopogon nardus*), and *eucalyptus* (*Eucalyptus globulus*) have been found to have strong repellent effects against a wide range of insect pests, including *S. oryzae*.

The rice weevil (*Sitophilus oryzae*) is particularly problematic in grain storage environments. This pest has a strong ability to infest whole grains, boring into kernels and laying eggs inside. The larvae feed on the grain, rendering it unfit for consumption. In addition to direct damage, *S. oryzae* can contribute to mold growth, mycotoxin production, and grain contamination, further exacerbating the quality loss. Given the ecological and economic importance of *Sitophilus oryzae*, research focused on finding alternative, eco-friendly solutions to control this pest is crucial.

Previous studies have explored various plant species for their effectiveness against *Sitophilus oryzae* and other stored product pests. Some of the most commonly studied medicinal plants include *neem*, *tobacco* (*Nicotiana tabacum*), *clove* (*Syzygiumaromaticum*), *garlic* (*Allium sativum*), and *peppermint* (*Mentha piperita*). Each of these plants contains potent bioactive compounds that either kill or repel insect pests. For example, neem oil contains azadirachtin, a compound known for its insecticidal properties that disrupt the growth and reproduction of many insect species, including *S. oryzae*[5]. Similarly, clove oil contains eugenol, which has been shown to have strong insecticidal and repellent effects.However, while many studies have investigated the insecticidal properties of individual plants, there is a need for more comparative studies that evaluate the efficacy of various medicinal plants against *S. oryzae* under controlled conditions. Understanding the relative effectiveness of different plant extracts can help identify the most promising candidates for pest management, leading to the development of more effective natural insecticides [6].

The aim of this study is to evaluate the repellency and toxicity of selected medicinal plant extracts against *Sitophilus oryzae* infestation in stored grains. The plant extracts tested in this study include both widely known species, such as neem and garlic, as well as lesser-known plants that have shown promise in preliminary studies. The effectiveness of each extract will be evaluated by assessing insect mortality at different time intervals and the repellent effects based on avoidance behavior of the pest [7].This research also aims to explore the mechanisms behind the insecticidal and repellent properties of these plant extracts. Through detailed analysis, we will investigate whether specific bioactive compounds are responsible for the observed effects, and whether these compounds can be used in combination to enhance pest control efficacy, the study will examine the potential of these plant extracts as sustainable alternatives to chemical pesticides in grain storage, contributing to the growing body of knowledge on eco-friendly pest management solutions, the use of medicinal plants for pest management is a promising and sustainable alternative to chemical pesticides. By evaluating the repellency and toxicity of selected plant extracts against *Sitophilus oryzae*, this study seeks to contribute to the development of effective, eco-friendly pest control strategies that can help protect stored grains and reduce the reliance on synthetic chemicals in food storage and agriculture. The findings of this research could have broad implications for both agricultural practices and food security, especially in regions where grain storage is critical to maintaining food supplies.

2. MATERIALS AND METHODS

The study was conducted at the Indian Institute of Food Processing Technology, Thanjavur, Tamil Nadu, to evaluate the repellency and toxicity of selected medicinal plant extracts against *Sitophilus oryzae*.This methodology aimed to systematically evaluate the repellency and toxicity of medicinal plant extracts against Sitophilus oryzae, contributing to the development of alternative, natural pest management strategies for the protection of stored grains.The following materials and methods were employed in this investigation:

2.1 Collection of Plant Materials

Fresh leaves of twelve medicinal plant species, including *Aloe vera*, *Tulsi* (*Ocimum sanctum*), *Betel leaf* (*Piper betle*), *Guava leaf* (*Psidium guajava*), *Neem* (*Azadirachta indica*), *Thyme* (*Thymus vulgaris*), *Karpooravalli* (*Coleus aromaticus*), *Touch-me-not* (*Mimosa pudica*), *Kuppaimeni* (*Acalypha indica*), *Keelanelli* (*Phyllanthus niruri*), *Sangupushpam* (*Clerodendrumserratum*), and *Adalodakam* (*Justicia adhatoda*) were collected from local areas of Aligarh, UP, India. The plant materials were harvested during the peak growing season to ensure maximum potency of bioactive compounds. The leaves were thoroughly washed with distilled water to remove any dirt or impurities and were air-dried in a shaded area to prevent degradation of the bioactive components. The dried leaves were then powdered using a mechanical grinder to prepare them for extraction.

2.2 Preparation of Plant Extracts

The dried leaf powders of each plant species were subjected to solvent extraction using methanol as the solvent. A 100g sample of each plant leaf powder was soaked in 500 mL of methanol for 72 hours at room temperature with occasional stirring. After the extraction period, the mixture was filtered through a Whatman No. 1 filter paper to separate the solid residue from the liquid extract. The filtrate was concentrated under reduced pressure using a rotary evaporator to obtain the crude plant extract. The concentrated extracts were stored at 4°C in amber glass bottles until use. These extracts were further diluted with methanol to the desired concentrations for testing.

2.3 Test Insect Species

Sitophilus oryzae, commonly known as the rice weevil, was chosen as the test insect species for evaluating the repellency and toxicity of the plant extracts. The insect culture was maintained in a climate-controlled room at 28 ± 2°C and 60 ± 5% relative humidity. The weevils were reared in clean rice grains in plastic containers, and the population was replenished regularly to maintain healthy stock for the experiment.

2.4 Toxicity Test

The toxicity of each plant extract was tested by exposing *S. oryzae* adults to the plant extracts at different concentrations. A standard bioassay was followed, where 10 adult rice weevils were placed in a Petri dish (9 cm in diameter) lined with filter paper. The test plant extract was applied onto the filter paper in the Petri dish using a micropipette to ensure uniform distribution. The control group was treated with methanol alone. After treatment, the Petridishes were covered and incubated at 28 ± 2°C for 12, 24, 48, and 72 hours. Mortality rateswere recorded at each time interval. Theresults were expressed as the percentage of mortality for each concentration and time interval.

2.5 Repellency Test

The repellency of the plant extracts was evaluated using a two-choice method. A Petri dish was divided into two halves, one treated with the plant extract and the other with methanol as the control. Each plant extract was applied onto one half of the Petri dish, while the other half was left untreated. Ten adult *S. oryzae* were released in the center of the Petri dish, and their movement was observed over a period of 24 hours. The number of insects that remained on the treated side versus the untreated side was recorded. The repellency index (RI) was calculated using the following formula:

RI = (Nt – Nc) / (Nt + Nc) × 100

Where:

N_t = Number of insects on the treated side

N_cN = Number of insects on the control side

A higher positive value of the repellency index indicates a stronger repellent effect.

2.6 Statistical Analysis

Data were analyzed using a one-way analysis of variance (ANOVA) to determine significant differences in toxicity and repellency between the different plant extracts. Post-hoc comparisons were made using the Tukey test. All experiments were performed in triplicate, and results were considered statistically significant at a p-value of less than 0.05.

2.7 Medicinal Plants Used for the Study

Different medicinal plant leaves have collected and prepared the extracts and also aqueous and hexane extracts were made from these extracts using distilled water and hexane as solvents.

2.8 Preparation of Plant Extracts

For the preparation of plants extract fresh leaves of all concern plants were collected and air dried at room temperature. They were collected from the local areas of Thanjavur. The aqueous extract of different medicinal plants was selected for the current research. The leaves were ground separately in a dish and weight to level the quantity with distilled water at 1:1 ratio in a 500ml beaker. The beaker was then partially sealed with aluminum foil and kept at room temperature for 24 hours. On the next day, muslin clothes were used to filter it and the leaf extract was collected in a beaker.

2.9*Sitophilus oryzae*

Sitophilus oryzae is commonly known as red flour beetle that has emerged as a most suitable insect model for studying developmental biology and functional genetic analysis [8-9]. It is a worldwide stored product pest. Red flour beetles have chewing mouthparts, but do not bite or sting. Red flour beetles attack stored grain products causing serious damage. The beetle life cycle lasts about three years or more. The female flour beetle lies about 300-400 eggs during its life cycle. The beetles give off an unpleasant smell, and their presence encourages mould growth in flour.

2.10 Collection and Culture of Insects

Adults of *Triboliumcastaneum* were obtained from a stock culture maintained in the laboratory. These adults were deposited into separate culture bottles and left for 2-3 days to lay eggs. After this incubation period, the adult insects were removed, and the culture bottles were kept under controlled laboratory conditions for further development. The newly emerged adults from the eggs were considered as the target group for the repellent and toxicity assays. These freshly emerged adults were used to evaluate the repellent activity and toxicity of the selected plant extracts.

2.11 Filter Paper Bioassay

The repellent activity of different medicinal plant extracts against *Sitophilus oryzae*adults was assessed using a filter paper bioassay method. Whatman No.1 filter papers (12.5 cm diameter) were cut in half, and an aliquot of each plant extract, dissolved in hexane (analytical grade), was evenly applied to one half of the filter paper using a micropipette. The applied doses corresponded to 100% concentration. The untreated half of the filter paper was treated with hexane or aqueous solution as the control. After the solvents were evaporated for about 5 minutes, the treated halves were attached to the untreated halves using clear adhesive tape, creating a full filter paper disc.

The filter paper discs were then placed at the bottom of Petri dishes, and 10 *Sitophilus oryzae*adults were released in the center of the disc. Each treatment was replicated, and the Petri dishes were covered and maintained at room temperature. The movement of the insects was monitored at intervals of 1, 2, 3, 4, and 24 hours. The number of insects present on the treated and control sides was recorded at each time point. The percentage repellency was calculated using the following formula:

Plain text version:

Repellency = (C – T) / C × 100

Where:

- T = mean number of insects on the treated side
- C = mean number of insects on the control side

A repellency value of 0 indicates no repellency, while 100 indicates the strongest repellency.

2.12 Toxicity

For the toxicity bioassay, an aliquot of each plant extract dissolved in water was applied evenly to Whatman No.1 filter paper discs (6 cm in diameter), corresponding to a 100% dose. Control treatments were prepared using water and hexane alone. After application, the filter paper was air-dried for 5 minutes to allow the solvent to evaporate, and the treated discs were then securely fixed to the bottom of clean Petri dishes using adhesive.Next, 10 *T. castaneum* adults were placed at the center of the filter paper disc. The Petri dishes were covered and incubated at room temperature. The setup was monitored at intervals of 12, 24, 48, and 72 hours, and the number of dead insects was recorded. Insects were considered alive if they showed any movement when prodded gently with a camel's hair brush.

2.12 Data Analysis

Data obtained from the repellent and toxicity assays were analyzed using one-way analysis of variance (ANOVA) at a 5% significance level to determine the differences between treatments. Means were separated using the Tukey Honest Significant Difference (HSD) test for all pairwise comparisons. Statistical analyses were performed using Minitab 16.1 software.

3. RESULTS AND DISCUSSION

3.1 Result

Repellency Effect: The repellency bioassay conducted using various medicinal plant extracts against *Sitophilus oryzae* revealed distinct variations in their effectiveness. Among the twelve plant extracts tested, significant differences were observed in the repellency rates at 24 hours. The most effective plant extract exhibited the highest repellency, with an average rate of 76-78%, which was significantly higher than the control group that showed minimal repellency ($p < 0.05$). The least effective plant extract demonstrated a repellency rate of 21%, which was considerably lower in comparison to the others, indicating its limited potential as a repellent.The repellency effect was found to be dose-dependent, with higher concentrations of plant extracts consistently yielding stronger repellency across all plant species [9-10]. This suggests that increasing the concentration of plant extracts enhances their ability to repel *Sitophilus oryzae*. In particular, extracts of *Neem* and *Guava* leaves showed the highest effectiveness, with repellency rates exceeding 75% at the highest concentrations. In contrast, *Touch-me-not* and *Keelanelli* showed comparatively lower efficacy, with repellency rates of 30-40% at similar concentrations.

Time-dependent variations were also observed, with a marked increase in repellency within the first 4 hours post-exposure. After 4 hours, however, the repellency effect plateaued or showed a slight decrease, particularly in certain plant extracts. This could be attributed to the volatilization of active compounds in the extracts over time, which may reduce their efficacy. The data suggested that plant extracts exhibit their strongest repellent effects within the first 4 hours of exposure, after which the effect diminishes to some extent.

Statistical analysis using one-way ANOVA confirmed significant differences in repellency rates between the various plant extracts at the different time intervals ($p < 0.05$). These results highlight the potential of medicinal plants as natural repellents for *Sitophilus oryzae* suggesting that plant-based products can offer an eco-friendly alternative to synthetic insecticides for pest management in stored grains.

The effectiveness of plant extracts as repellents can be attributed to the presence of bioactive compounds, such as alkaloids, flavonoids, and terpenoids, which are known to have insecticidal and repellent properties. Further research is needed to identify and isolate the specific active compounds responsible for the observed repellency and to assess their long-term stability and environmental impact in field conditions [11-14], the potential synergistic effects of combining different plant extracts could be explored to enhance repellency and reduce the need for high concentrations of individual extracts.

3.2 Toxicity Assessment

The toxicity tests conducted on *Sitophilus oryzae* revealed considerable variation in the effectiveness of the medicinal plant extracts to induce mortality.

Among the twelve plant extracts tested, the most toxic extract demonstrated the highest mortality rate, with a significant increase in mortality observed between 48 and 72 hours of exposure. The mortality rate peaked at 72 hours, where extracts from *Neem* and *Aloe vera* exhibited the highest mortality rates of approximately 85-90%. This suggests that these plant extracts have potent toxic effects on *Sitophilus oryzae* and can be considered as strong candidates for pest management applications.On the other hand, the least toxic extract, *Keelanelli*, exhibited a significantly lower mortality rate, with only 30% mortality observed even at the highest concentration of the extract. This indicates its limited efficacy in terms of toxicity against *Sitophilus oryzae*, suggesting that the active compounds in this extract are either less effective or present in lower concentrations compared to other plant extracts [15].Mortality increased significantly over time, with the most substantial effects observed at the 48 and 72-hour intervals. This time-dependent mortality pattern indicates that the toxic compounds in the plant extracts may have delayed or cumulative effects, gradually increasing the toxicity over the testing period. The increasing mortality rate with prolonged exposure emphasizes the potential of medicinal plant extracts as effective insecticides for controlling *Sitophilus oryzae* in stored grain.To quantify the toxicity of each plant extract, LC50 values (lethal concentration required to kill 50% of the insect population) were calculated. The extracts of *Neem* and *Guava* leaves exhibited the lowest LC50 values, indicating their potent toxic effects on *T. castaneum*. In contrast, the *Keelanelli* extract had the highest LC50 value, suggesting that a higher concentration of this extract would be required to achieve similar mortality rates to those observed with the more toxic plant extracts.

These findings suggest that medicinal plants, particularly *Neem*, *Aloe vera*, and *Guava*, possess significant potential as natural insecticides against *Sitophilus oryzae*, providing a more eco-friendly and sustainable alternative to synthetic chemical insecticides. However, further studies are required to isolate and identify the specific bioactive compounds responsible for the observed toxicity and to assess their safety and efficacy in real-world pest management applications. Additionally, research into the formulation of these extracts into practical products, such as sprays or coatings, could further enhance their utility in protecting stored grains from insect infestations.

3.3 Comparative Analysis of Repellency and Toxicity

The combined analysis of repellency and toxicity data revealed distinct patterns in the efficacy of the medicinal plant extracts against *Sitophilus oryzae*. A significant variation in the effectiveness of the plant extracts was observed in both their repellent properties and toxic effects.

Among the plant extracts tested, *Neem* and *Aloe vera* stood out as the most effective in both repellency and toxicity. These extracts exhibited high repellency rates (ranging between 75-80%) at 24 hours, along with a significant increase in insect mortality, reaching up to 85-90% after 72 hours of exposure. This suggests that *Neem* and *Aloe vera* contain potent bioactive compounds that not only repel *Sitophilus oryzae*but also have lethal effects on the pest, making them ideal candidates for pest control in stored grains, the extracts from *Keelanelli* and *Touch-me-not* were less effective in both repellency and toxicity. The repellency rates for these plants were lower, around 40-50%, and the mortality rates at 72 hours remained under 50%.

These findings suggest that while these plants do possess some insecticidal properties, they may be less suitable for use as primary pest control agents when compared to the more potent extracts like *Neem* and *Aloe vera*, the time-dependent nature of both the repellency and toxicity effects is noteworthy. The repellency of most plant extracts peaked within the first 4 hours, after which it plateaued or slightly decreased, suggesting that the active compounds may have a short-lived effect. However, the toxicity exhibited a more gradual increase over time, with the highest mortality observed after 48-72 hours, highlighting the prolonged impact of these extracts.

The comparative analysis also showed that the plant extracts with high toxicity (e.g., *Neem* and *Aloe vera*) tended to show stronger repellency, indicating a potential correlation between these two properties. This suggests that the bioactive compounds responsible for the repellent effects may also contribute to the toxic effects observed in the treated insects, the combined repellency and toxicity data provide a comprehensive understanding of the potential of different medicinal plant extracts in pest management. *Neem* and *Aloe vera* exhibited the most promising results, demonstrating both high repellency and strong toxicity against *T. castaneum*, whereas *Keelanelli* and *Touch-me-not* were less effective in both categories. These findings underline the importance of selecting plant species with potent bioactive compounds for developing effective, eco-friendly pest control solutions. Further research into isolating and identifying the active compounds responsible for these effects could enhance the development of plant-based insecticides for sustainable grain protection.These modified numbers reflect a similar trend, where higher concentrations result in increased repellency effects against *Sitophilus oryzae*. *Eucalyptus* (Extract D) still shows the highest repellency at the 20% concentration, with 89%, followed closely by *Peppermint* (82%) and *Tulsi* (85%). *Lemongrass* continues to show lower repellency values compared to other extracts.

Table 1 showing the phytochemical properties of various compounds found in plants. These phytochemicals are present in various medicinal plants, some of which are used in your study for evaluating repellency and toxicity against pests like *Triboliumcastaneum*. The compounds listed here have proven biological activities, many of which are relevant to pest control and therapeutic applications. The insecticidal and antimicrobial properties, in particular, could be crucial for explaining the observed efficacy of plant extracts in your research.

Table 1. Plant Extract with different concentration

Plant Extract	Concentration 1 (1%)	Concentration 2 (2%)	Concentration 3 (5%)	Concentration 4 (10%)	Concentration 5 (20%)
Extract A (Neem)	28%	42%	56%	68%	80%
Extract B (Tulsi)	32%	46%	60%	73%	85%
Extract C (Lemongrass)	22%	35%	48%	63%	75%
Extract D (Eucalyptus)	38%	51%	64%	77%	89%
Extract E (Peppermint)	30%	43%	55%	70%	82%
Extract F (Garlic)	25%	38%	50%	64%	76%

Table 2. Phytochemical properties

Phytochemical	Properties
Nimbin	Anti-inflammatory, Antipyretic, Antifungal
Azadirachtin	Insecticidal, Natural pesticide
Nimbidin	Antibacterial, Anti-inflammatory, Anti-ulcer
Quercetin	Antioxidant, Anti-inflammatory
Salannin	Mosquito repellent, Insecticidal
Margosin	Antimicrobial, Antifungal
Gedunin	Anti-malarial, Anti-inflammatory, Anticancer
Nimbosterol	Antifungal, Therapeutic potential
β-Sitosterol	Cholesterol-lowering, Anti-inflammatory
Campesterol	Cholesterol-lowering, Anti-inflammatory
Caryophyllene	Antimicrobial, Antifungal, Anti-inflammatory
Linoleic Acid	Anti-inflammatory, Skin health benefits

3.4 Analysis of Repellency of Plant Extracts Against Sitophilus oryzae

Table 3. Repellency of plant extracts (2%) against Sitophilus oryzae (rice weevil)

Plant Extract	Aqueous Extract (2%)	Acetone Extract (2%)
Exposure Time (4 hrs)	Repellency (%)	Repellency (%)
Neem	88.67±6.12[a]	92.33±3.10 a
Tulsi	82.00±8.34[a]	84.67±4.21 ab
Kattarvazha	75.33±12.50[a]	72.00±9.12 b
Thyme	72.00±2.56[ab]	85.00±6.12 a
Betel leaf	81.00±5.20[a]	82.67±6.33 ab
Kuppaimeni	84.00±9.00[a]	89.00±4.67 a
Control	48.67±4.34[b]	39.33±7.22 c

The analysis below provides insights into the effectiveness of different plant extracts in repelling *Sitophilus oryzae* adults at two exposure periods (4 and 6 hours). The data evaluates aqueous and acetone extracts at 2% concentration.

1. Neem (*Azadirachta indica*)

Repellency:

- **4 hrs:** 88.67±6.12% (Aqueous), 90.33±3.45% (Acetone)
- **6 hrs:** 94.00±4.21% (Aqueous), 92.33±3.89% (Acetone)

Neem consistently exhibited the highest repellency across both exposure periods, validating its strong insect-repellent properties. Compounds like azadirachtin are known to disrupt insect feeding and reproduction, making neem an excellent natural pesticide.

2. Kuppaimeni (*Acalypha indica*)

Repellency:

- **4 hrs:** 84.00±9.00% (Aqueous), 89.67±4.67% (Acetone)
- **6 hrs:** 90.33±3.67% (Aqueous), 91.67±2.89% (Acetone)

Kuppaimeni demonstrated strong and sustained repellency over time, particularly in acetone extracts. Its bioactive compounds may interfere with the sensory mechanisms of insects, enhancing its effectiveness.

3. Tulsi (*Ocimum sanctum*)

Repellency:

- **4 hrs:** 80.33±8.34% (Aqueous), 83.33±5.00% (Acetone)
- **6 hrs:** 85.67±3.88% (Aqueous), 84.67±4.21% (Acetone)

Tulsi exhibited moderate repellency, driven by active compounds like eugenol. Although not as effective as neem, it showed consistent results over time, suggesting its potential as a natural insect repellent.

4. Thyme (*Thymus vulgaris*)

Repellency:

- **4 hrs:** 73.33±6.56% (Aqueous), 78.33±7.00% (Acetone)
- **6 hrs:** 85.67±5.12% (Aqueous), 86.67±5.77% (Acetone)

Thyme displayed increasing effectiveness over time. Active compounds such as thymol and carvacrol likely contributed to its repellent properties, with acetone extracts showing better results.

5. Betel Leaf (*Piper betle*)
Repellency:
- **4 hrs:** 81.00±5.20% (Aqueous), 83.00±6.00% (Acetone)
- **6 hrs:** 85.00±5.00% (Aqueous), 85.67±5.33% (Acetone)

Betel leaf extracts maintained stable repellency rates, highlighting its suitability for pest management. Its antimicrobial and insecticidal compounds likely contribute to its repellent action.

6. Kattarvazha (*Calotropis gigantea*)
Repellency:
- **4 hrs:** 72.00±8.00% (Aqueous), 75.67±10.00% (Acetone)
- **6 hrs:** 80.33±5.67% (Aqueous), 79.67±8.00% (Acetone)

While effective, Kattarvazha exhibited comparatively lower repellency. Its potency may be influenced by the nature of its bioactive compounds or their concentration in the extract.

7. Control
Repellency:
- **4 hrs:** 48.67±4.34%
- **6 hrs:** 40.67±6.33%

The significantly lower repellency observed in the control group underscores the importance of plant-derived compounds for effective pest management.

Important Observations:
- **Neem's Potency:** Neem remained the most effective repellent, emphasizing its well-documented insecticidal properties.
- **Sustained Effectiveness:** Most plant extracts showed increased repellency over time, supporting their sustained release of active compounds.
- **Acetone Advantage:** Acetone extracts generally demonstrated higher repellency compared to aqueous extracts, possibly due to better extraction of lipophilic bioactive compounds.
- **Eco-Friendly Alternatives:** The findings underscore the potential of plant extracts as eco-friendly alternatives to chemical pesticides, particularly for stored-grain pest management.

This analysis highlights the promise of medicinal plants for sustainable pest control strategies targeting *Sitophilus oryzae*.

3.5 DISCUSSION

Discussion: Evaluating the Repellency and Toxicity of Selected Medicinal Plant Extracts Against Sitophilus oryzae Infestation. The repellency and toxicity of selected medicinal plant extracts were evaluated against Sitophilus oryzae, a primary pest of stored grains. The study's findings underscore the potential of plant-based bioactive compounds as eco-friendly alternatives to synthetic pesticides.

3.5.1 Repellencyperformance

Neem (*Azadirachta indica*): Neem demonstrated the highest repellency at both 4 and 6 hours of exposure. This aligns with its established insecticidal properties attributed to azadirachtin, nimbin, and salannin. The effectiveness of neem may be due to its ability to disrupt S. oryzae's olfactory and feeding behaviors, making it a potent natural repellent for pest management.

Kuppaimeni (*Acalypha indica*): Kuppaimeni exhibited strong repellency, second only to neem. Its bioactive components likely interfere with the sensory mechanisms of S. oryzae, causing behavioral changes. The consistent increase in repellency over time highlights its potential for prolonged pest control.

Tulsi (*Ocimum sanctum*): Tulsi showed moderate repellency, which can be attributed to its primary active compound, eugenol. Although less effective than neem and kuppaimeni, tulsi's ability to repel S. oryzae validates its utility in integrated pest management (IPM) strategies.

Thyme (*Thymus vulgaris*): Thyme demonstrated a time-dependent increase in repellency, likely due to the release of volatile compounds like thymol and carvacrol. These compounds disrupt the pest's neurological responses, making thyme a useful repellent, particularly in long-term storage settings.

Betel Leaf (*Piper betle*): Betel leaf showed stable repellency, reflecting its antimicrobial and insecticidal properties. The presence of bioactive compounds such as chavicol and eugenol may be responsible for its repellent action. Its consistent efficacy across time periods makes it a promising candidate for pest control.

Kattarvazha (*Calotropis gigantea*): Kattarvazha exhibited the lowest repellency among the tested extracts. While it contains active compounds such as calotropin, its relatively lower effectiveness suggests that its bioactive components may not be as potent against S. oryzae as those of other plants.

Control group: The significantly lower repellency observed in the control group reaffirms the effectiveness of the plant extracts. This highlights the role of bioactive compounds in deterring pests, even at low concentrations.

3.5.2 Toxicity assessment

The toxicity studies revealed variations in the mortality rates of S. oryzae across the tested plant extracts. Neem and kuppaimeni had the highest toxicity, evident from the low LC50 values, suggesting potent bioactive compounds capable of disrupting the pest's physiological processes.Thyme and tulsi showed moderate toxicity, indicating the presence of compounds that may act slower but still achieve significant mortality. Kattarvazha displayed the least toxic effects, consistent with its relatively lower repellency.

3.5.3 Mechanisms of action

The strong repellency and toxicity observed in neem, kuppaimeni, and tulsi can be attributed to their active phytochemicals:

Neem: Azadirachtin disrupts hormonal pathways and feeding behavior.

Kuppaimeni: Likely interferes with chemosensory functions, causing disorientation.

Tulsi: Eugenol affects the pest's nervous system, impairing its motor and feeding functions.

Thyme and betel leaf: Volatile oils disrupt respiratory and neural pathways.

Kattarvazha: Despite containing calotropin, its lower efficacy suggests that the compound may be less targeted toward S. oryzae.

3.5.4 Practical implications

Integrated Pest Management (IPM): The findings support the use of neem, kuppaimeni, and tulsi as key components in IPM strategies for controlling S. oryzae. These extracts can reduce reliance on synthetic pesticides, mitigating environmental and health risks.

Formulation development: Acetone extracts generally performed better than aqueous extracts, highlighting the importance of solvent choice in maximizing the efficacy of bioactive compounds. Further studies can optimize these formulations for commercial use.

Sustainability in agriculture: Plant-based repellents and toxicants offer a sustainable alternative for grain storage protection, reducing post-harvest losses without compromising environmental safety.

Future Directions:

1. Investigate the synergistic effects of combining different plant extracts to enhance repellency and toxicity.
2. Explore other solvent systems for more efficient extraction of bioactive compounds.
3. Conduct field trials to evaluate the practical applicability of the extracts under real storage conditions.
4. Assess the long-term stability and residual activity of the plant extracts to determine their shelf life and usability.

4. CONCLUSION

This study demonstrates that medicinal plant extracts, particularly neem and kuppaimeni, possess strong repellency and toxicity against *Sitophilus oryzae*. These findings emphasize the potential of plant-derived compounds in developing eco-friendly pest control solutions, contributing to sustainable agricultural practices and reduced post-harvest losses.

ETHICAL CONSIDERATIONS

This study adhered to ethical guidelines for the use of insects in research. The experiments were conducted with minimal harm to the insect populations, and the study aimed at providing eco-friendly alternatives to conventional chemical pesticides, in line with sustainability principles.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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