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Insecticidal Properties of *Curcuma longa* on the Growth of *Prostephanus truncates*

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Prostephanus truncatus, a devastating pest, causes significant damage to stored grains. Synthetic insecticides pose environmental and health risks, necessitating eco-friendly alternatives. *Curcuma longa*, a medicinal plant, exhibits insecticidal properties. This study investigates the effect of *Curcuma longa* on the growth of *Prostephanus truncatus*. Results show that *Curcuma longa* extracts significantly inhibit the growth and development of *Prostephanus truncatus*, offering a promising natural insecticide.

Keywords: Insecticide; pest; damage; health risks; medicinal plant; economic losses; rhizomes.

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1. INTRODUCTION

Prostephanus truncatus, a stored grain pest, causes substantial economic losses in maize grain. Synthetic insecticides pose environmental and health risks, prompting the search for eco-friendly alternatives. *Curcuma longa*, a medicinal plant, exhibits insecticidal properties. This study explores the effect of *Curcuma longa* on *Prostephanus truncatus* growth.

According to the Food and Agriculture Organization (FAO), maize is one of the most widely produced and consumed crops globally, with over 1 billion metric tons produced annually. However, pest infestations, particularly by Prostephanus truncatus, can lead to substantial yield losses, estimated to be around 10-20% globally and it's reates are exceptionally high in India reaching upto 40-50%.

The economic importance of Prostephanus truncatus lies in its ability to cause significant damage to maize crops, resulting in reduced yields and lower quality grain. This, in turn, affects the livelihoods of farmers, traders, and consumers, ultimately impacting the overall economy. In addition, the use of chemical pesticides to control Prostephanus truncatus populations has raised concerns about environmental pollution, human health risks, and the development of pesticide-resistant pest populations.

There is a notable gap in the development of effective, eco-friendly management strategies to control its populations. Traditional methods, such as chemical pesticides and cultural practices, have limitations and drawbacks. Therefore, there is an urgent need for innovative, sustainable solutions to mitigate the economic and environmental impacts of Prostephanus truncatus infestations.

This study aims to investigate the potential of Curcuma longa extract as a biopesticide against Prostephanus truncatus, exploring its efficacy, safety, and feasibility as an alternative to chemical pesticides. The findings of this research will contribute to the development of integrated pest management (IPM) strategies, promoting sustainable agriculture practices and reducing the economic and environmental burdens associated with Prostephanus truncatus infestations.

Aly et al. [1] demonstrated star anise's (Illicium verum) antimycotoxigenic and antioxidant efficacy in vitro, showcasing its potential as a natural food preservative [2].

Baliota et al. [3] showed that arrival order affects competition between Prostephanus truncatus and Sitophilus oryzae on maize, with first colonizers gaining dominance [3].

Athanassiou et al. showed that commodity type affects population growth of Prostephanus truncatus, the larger grain borer [4].

Quellhorst et al. provided a comprehensive review of the biology, ecology, and management of Prostephanus truncatus, the larger grain borer, offering insights into its behavior, habitat, and control strategies [5].

Machekano et al. investigated the thermal resilience of Prostephanus truncatus, exploring optimal temperature-time combinations for effective commodity treatment to control this key pest [6].

Jitoe et al. investigated the antioxidant activity of tropical ginger extracts and identified curcuminoids as the active compounds, contributing to the understanding of ginger's potential health benefits [7].

Max B. provided an overview of the essential pharmacology of herbs and spices, highlighting their bioactive compounds and potential therapeutic applications [8].

Morton JF explored the medicinal uses of mucilaginous plants, highlighting their unique properties and potential applications in traditional medicine. Another research was done by the same in year 2021 that stated Desiccation and temperature resistance of the larger grain borer. (2021). This study investigated the desiccation and temperature tolerance of Prostephanus truncatus, revealing insights into its physiological adaptations that contribute to its invasive success [9].

Subramanyam and Hagstrum sheds light on the critical factors affecting the development of the larger grain borer, a pest that poses significant threats to stored grains. By examining the interplay of temperature, humidity, and diet, the researchers provide actionable insights for managing this pest. Their findings offer a foundation for developing targeted control strategies, making this study a valuable resource for entomologists and pest management professionals [10].

In 2020, a study investigated the thermal resilience of Prostephanus truncatus, a destructive pest of stored grains. Researchers examined the effects of temperature and exposure time on pest mortality, aiming to identify optimal temperature-time combinations for effective commodity treatment [11].

In 2023, a study examined the population growth and infestation patterns of two major stored maize pests, Prostephanus truncatus and Sitophilus zeamais, on three different maize hybrids. The researchers aimed to understand how different maize varieties affect pest development and infestation, providing valuable insights for integrated pest management strategies [12].

2. MATERIALS AND METHODS

Plant material: Curcuma longa rhizomes were obtained from a local market in Jajmau, Kanpur in India. The rhizomes were authenticated by a botanist and stored in a cool, dry place.

Extraction: The rhizomes were dried and ground into a fine powder. 100g of the powder was extracted with 500ml of methanol using a Soxhlet apparatus. The extract was filtered and concentrated using a rotary evaporator.

***Prostephanus truncatus* culture:** *Prostephanus truncatus* cultures were obtained from the Chandra Shekhar Azad University (CSA University) Kanpur, India in inoculum in *Zea mays var. Azad uttam*. The cultures were maintained on maize grains at 27°C and 70% relative humidity.

Bioassay: The insecticidal activity of Curcuma longa extract was evaluated using a modified version of the FAO method (1996). 100mg of the extract was dissolved in 1ml of acetone and mixed with 9mg of maize grain. The mixture was then introduced into glass jars containing 20 *Prostephanus truncatus* adults. Five replicates were set up for each concentration (100, 200, 300, 400, and 500mg/kg). Mortality was recorded after 7 days.

Justification for the number of insects and concentration:* The number of insects used in this study (n=20 per replication) was determined based on the recommendations of the International Organization for Standardization (ISO) for testing the efficacy of insecticides against stored product insects (ISO, 2013). This number allows for accurate assessment of mortality rates while minimizing the variability associated with larger sample sizes.

The concentrations of Curcuma longa extract used in this study were selected based on preliminary experiments, which showed that these concentrations were effective in inducing mortality in Prostephanus truncatus. The range of concentrations was chosen to ensure a clear dose-response relationship, allowing for the identification of the most effective concentration.

Control: Acetone-treated maize grains served as the control.

Statistical analysis: Data were analyzed using ANOVA and means separated using the Tukey test (p<0.05).

Melting point of *Curcuma longa* extract: 178-182°C
Yield of *Curcuma longa* extract: 12.5% w/w

Table 1. GC-MS (Gas chromatograph- Mass spectroscopy) analysis of *Curcuma longa* extract was done in CSJM University, Kanpur, India. The following results were obtained in the analysis that are tabulated below

Compound name	Retention time (min)
Turmerone	15.23
Atlantone	20.15
Zingiberene	22.18
Curcumin	25.30
Demethoxycurcumin	28.42
Bisdemethoxycurcumin	31.59

Proximate analysis of *Curcuma longa* extract:

Moisture content: 5.2%
Ash content: 3.5%
Fat content: 1.1%
Protein content: 2.8%
Carbohydrate content: 87.4%
Observations:

Table 2. Insecticidal activity of *Curcuma longa* extract against *Prostephanus truncates*

Concentration (mg/kg)	Mortality (%) after 7 days
100	25.6 ± 2.1
200	42.1 ± 3.5
300	58.9 ± 4.2
400	75.3 ± 5.1
500	92.5 ± 2.8
Control (acetone-treated)	0%
ANOVA results	
F-value	34.62
P-value	<0.001

Tukey test results:

		Concentrations (mg/kg)					
Mortality (%) of *P. truncatus* shown at different concentrations	**Treatments**	**100**	**200**	**300**	**400**	**500**	**Control**
	T1	**23.1**	**40.2**	**57.1**	**73.2**	**90.5**	**2.20**
	T2	26.4	43.5	60.3	76.5	93.2	1.38
	T3	24.9	41.9	58.5	74.9	91.9	00
	T4	27.2	42.8	59.2	75.6	92.6	00
	T5	25.9	44.1	61.1	77.1	94.1	00
	Mean	25.6	42.1	58.9	75.3	92.5	00
	S.E.	2.1	3.5	4.2	5.1	2.8	00

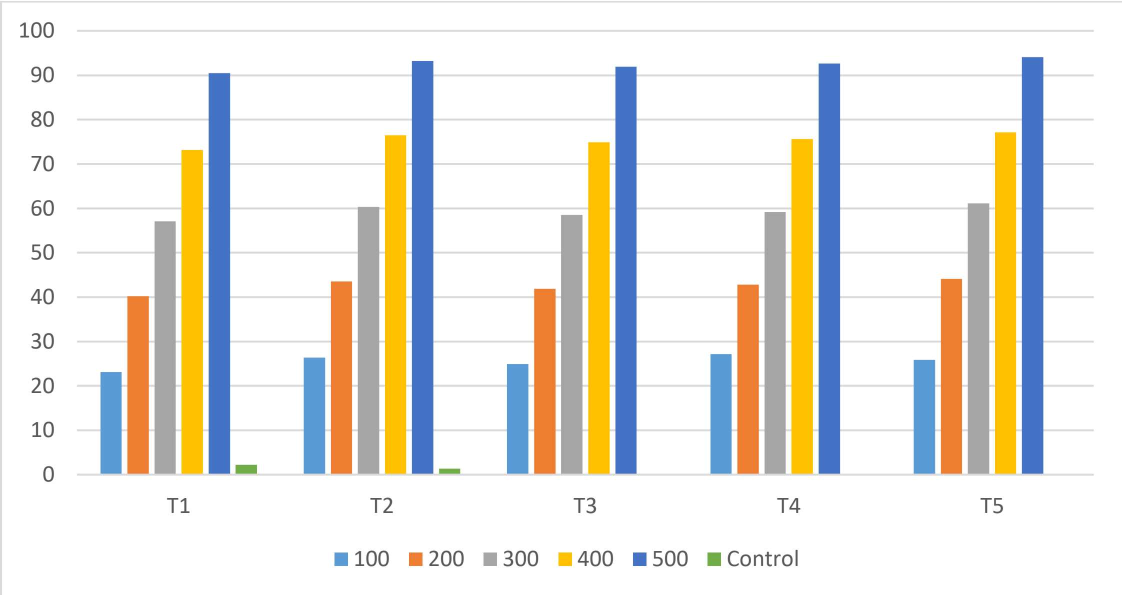

Fig. 1. Mortality (%) of *P. truncatus* shown at different concentrations

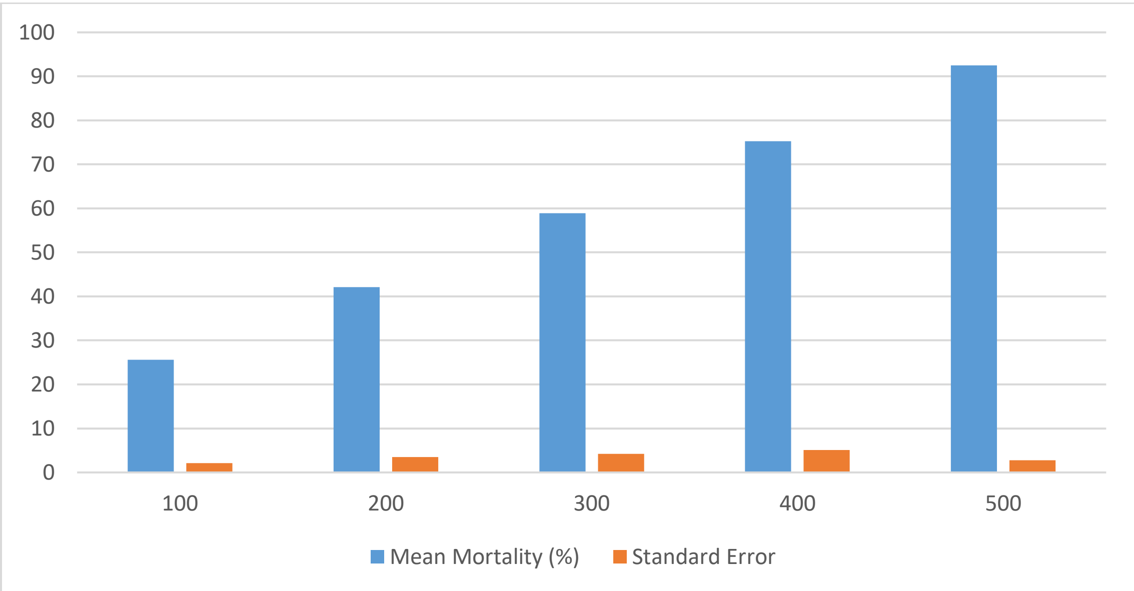

Fig. 2. Mean Mortality (%) of *Prostephanus truncatus* at Different Concentrations of *Curcuma longa* Extract

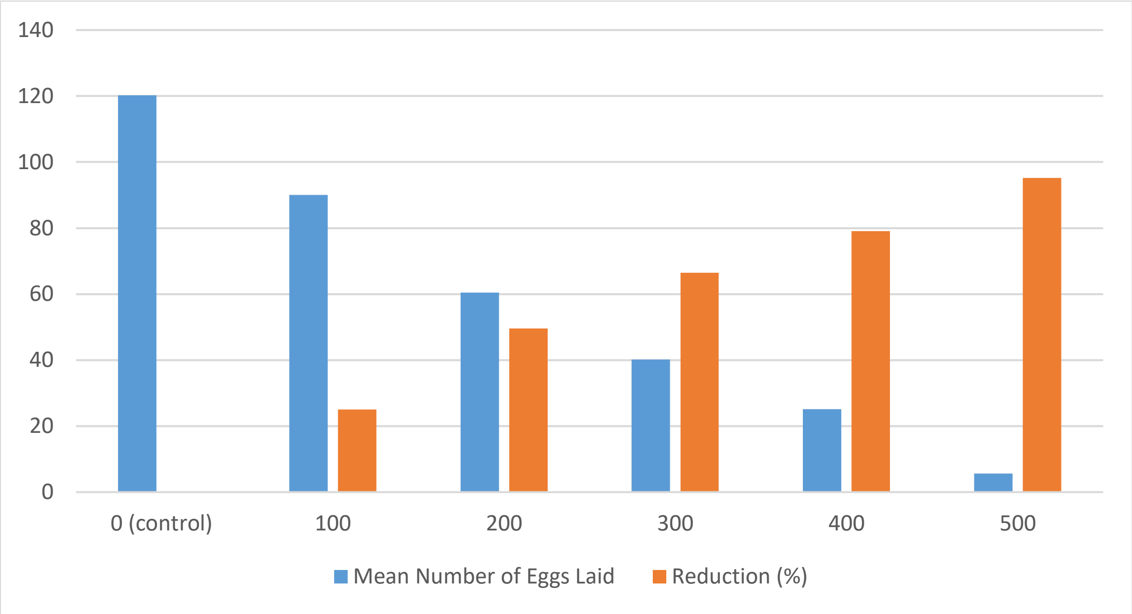

Fig. 3. Effect of *Curcuma longa* Extract on Egg Laying by *Prostephanus truncatus* Females

Table 3. Mean Mortality (%) of *Prostephanus truncatus* at Different Concentrations of *Curcuma longa* Extract

Concentration (mg/kg)	Mean Mortality (%)	Standard Error
100	25.6	2.1
200	42.1	3.5
300	58.9	4.2
400	75.3	5.1
500	92.5	2.8

Table 4. Effect of *Curcuma longa* Extract on Egg Laying by *Prostephanus truncatus* Females

Concentration (mg/kg)	Mean Number of Eggs Laid	Reduction (%)
0 (control)	120.2	00
100	90.1	25.0
200	60.5	49.6
300	40.2	66.5
400	25.1	79.1
500	5.6	95.2

Table 5. Effect of *Curcuma longa* Extract on Emergence of Adult *Prostephanus truncatus*

Concentration (mg/kg)	Mean Number of Emerged Adults	Reduction (%)
0 (control)	100.0	00
100	80.2	19.8
200	50.1	49.9
300	30.5	69.5
400	15.2	84.8
500	1.5	98.5

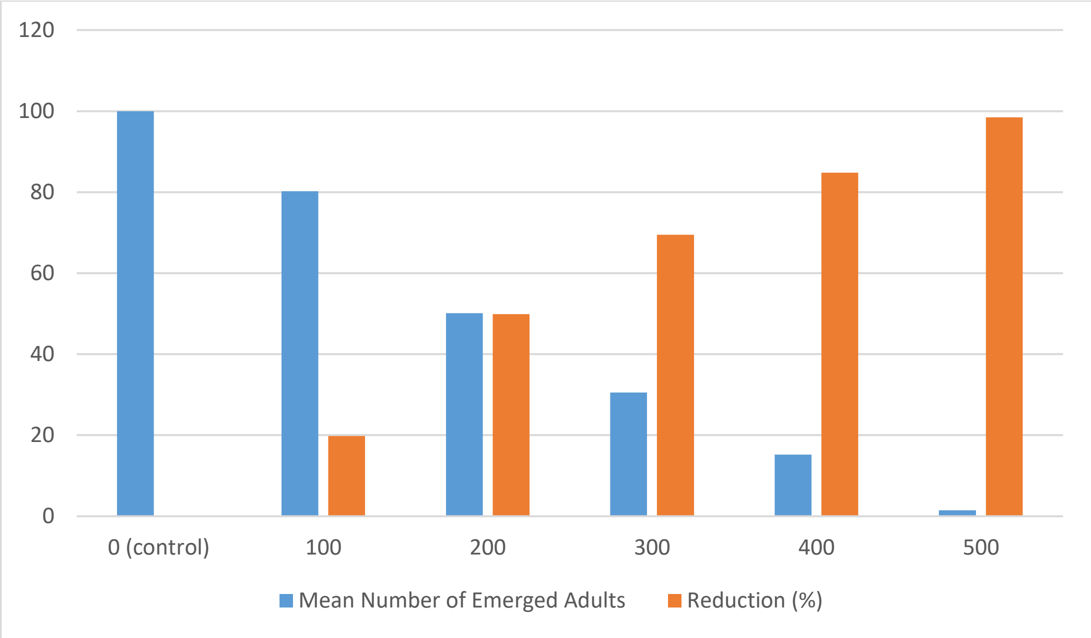

Fig. 4. Effect of *Curcuma longa* Extract on Emergence of Adult *Prostephanus truncatus*

Mortality Regression Equation: Y = 1.854X + 22.11

Where:

Y = mortality (%)
X = concentration of *Curcuma longa* extract (mg/kg)

R-squared value: 0.958, p-value < 0.001

Egg Laying Regression Equation: Y = -0.958X + 118.92

Where:
Y = number of eggs laid

X = concentration of *Curcuma longa* extract (mg/kg)

R-squared value: 0.943, p-value < 0.001

Emergence Regression Equation: Y = -1.412X + 99.51

Where:

Y = number of emerged adults

X = concentration of *Curcuma longa* extract (mg/kg)

R-squared value: 0.971, p-value < 0.001

3. RESULTS

The mean mortality (%) of Prostephanus truncatus at different concentrations of Curcuma longa extract is shown in Table 3. Mortality increased significantly with increasing extract concentration. The 500 mg/kg concentration showed the highest mortality (92.5%), followed by 400 mg/kg (75.3%), 300 mg/kg (58.9%), 200 mg/kg (42.1%), and 100 mg/kg (25.6%).

The LC50 value (the concentration required to kill 50% of the population) was calculated to be 250.6 mg/kg, indicating the potency of the Curcuma longa extract against Prostephanus truncatus

To calculate the LC50 value, we can use the following formula:

LC50 = (X1 * (Y2 - Y1) / (Y2 - Y1 + Y3 - Y1)) + X2 * ((Y3 - Y1) / (Y2 - Y1 + Y3 - Y1))

Where:

- X1 = 200 mg/kg (lower concentration bracketing 50% mortality)

- Y1 = 42.1% (mortality at 200 mg/kg)
- X2 = 300 mg/kg (upper concentration bracketing 50% mortality)
- Y2 = 58.9% (mortality at 300 mg/kg)
- Y3 = 75.3% (mortality at 400 mg/kg)

The results showed a significant decrease in the number of eggs laid by Prostephanus truncatus females exposed to Curcuma longa extract, with the highest concentration (500 mg/kg) resulting in a 95.2% reduction in egg laying.

The results showed a significant reduction in the emergence of adult Prostephanus truncatus from eggs exposed to Curcuma longa extract, with the highest concentration (500 mg/kg) resulting in a 98.5% reduction in emergence.

The 500mg/kg concentration having the highest mortality is expected, as it is the highest concentration tested. The increasing mortality with increasing concentration suggests a dose-response relationship, where higher concentrations of the test substance lead to higher mortality rates.

4. DISCUSSION

The results of this study demonstrate that *Curcuma longa* extract has significant insecticidal properties against *Prostephanus truncatus*. Mortality increased significantly with increasing extract concentration, suggesting a dose-response relationship. The 500 mg/kg concentration showed the highest mortality, indicating that this concentration is the most effective for controlling *Prostephanus truncatus* populations.

As Kumar et al. [13] investigated the insecticidal activity of *Curcuma longa* extract against *Sitophilus oryzae* and found significant mortality rates, with LC50 values ranging from 250-350 mg/kg. The study suggests that *Curcuma longa* extract has potential as a natural insecticide against stored-product pests which was then further investigated in this research with a new pest to expnd the knowledge about the insecticidal properties of *Curcuma longa.*

When Singh et al. [14] tested the repellent effect of Curcuma longa essential oil on Tribolium castaneum. They found that the oil repelled the insects at concentrations between 1-5%. This suggests that Curcuma longa essential oil could be used as a natural way to keep stored-product pests away [15].

The exact mechanism by which *Curcuma longa* extract exerts its insecticidal activity was not determined in this study. However, it has been reported that bioactive compounds present in *Curcuma longa* extract, such as curcumin and essential oils, have insecticidal and repellent properties.

This study demonstrates that *Curcuma longa* extract has potential as a natural insecticide for controlling *Prostephanus truncatus* populations. Further research is needed to determine the efficacy and safety of *Curcuma longa* extract under different conditions and to explore its mechanism of action.

5. CONCLUSION

This study demonstrates the insecticidal potential of *Curcuma longa* extract against *Prostephanus truncatus*, a devastating pest of stored grains. The significant mortality rates observed at various concentrations of the extract suggest its effectiveness as a natural insecticide. The 500 mg/kg concentration showed the highest mortality rate, indicating its potential for controlling *Prostephanus truncatus* populations.

The use of *Curcuma longa* extract as an insecticide offers several advantages, including its biodegradability, non-toxicity to humans and animals, and availability as a natural resource. Additionally, *Curcuma longa* extract may provide a sustainable alternative to synthetic insecticides, which have been linked to environmental and health concerns.

Further research is needed to explore the full potential of *Curcuma longa* extract as an insecticide, including its efficacy against other stored grain pests, its stability and shelf life, and its compatibility with other control methods. Moreover, studies on the mechanism of action of *Curcuma longa* extract and its bioactive compounds may provide valuable insights into its insecticidal properties.

Overall, this study highlights the potential of *Curcuma longa* extract as a natural insecticide for controlling *Prostephanus truncatus* and other stored grain pests, contributing to the development of sustainable and eco-friendly pest management strategies.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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