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Effect on the Egg Laying Capacity of Dysdercus Koenigii When Fed With Different Concentrations of Zingerone

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ABSTRACT

The red cotton bug, Dysdercus koenigii (Fabricius), is a serious pest of cotton that feeds on developing seeds and bolls, causing staining and yield loss. Zingerone (4-(4-hydroxy-3-methoxyphenyl)-2-butanone), a natural compound derived from ginger (Zingiber officinale), exhibits insecticidal and growth-regulating properties. The present study was undertaken to evaluate the effect of different concentrations of zingerone on the egg-laying capacity (fecundity) of D. koenigii under laboratory conditions. Adult pairs were fed with cotton seeds treated with zingerone at concentrations of 0.1%, 0.25%, 0.5%, 1.0%, and 2.0%, with untreated seeds as control. Results revealed a concentration-dependent decline in egg-laying activity. The highest inhibition in oviposition (78%) was recorded at 2.0% concentration, while the 0.1% treatment caused a 22% reduction compared to control. Zingerone treatment also prolonged the pre-oviposition period and reduced egg viability. The findings suggest that zingerone interferes with the reproductive physiology of D. koenigii, likely by disrupting hormonal regulation or nutrient assimilation, and could serve as a potential botanical pesticide for pest management in cotton ecosystems.

Keywords: Dysdercus koenigii, zingerone, fecundity, oviposition, natural insecticide, reproduction inhibition, cotton pest.

INTRODUCTION

The red cotton bug, Dysdercus koenigii (Fabricius) (Hemiptera: Pyrrhocoridae), is recognized as one of the most destructive pests affecting cotton (Gossypium spp.), okra (Abelmoschus esculentus), and various malvaceous plants that thrive in tropical and subtropical regions. This pest poses a significant economic threat to cotton farmers due to its piercing and sucking feeding habit. Both nymphs and adults feed on developing bolls, seeds, and flowers, resulting in discoloration, shriveling, seed deformation, and lint staining, which ultimately reduce the quality and market value of cotton fiber. Moreover, their feeding often facilitates secondary infections by fungal pathogens, further intensifying yield losses. Traditionally, farmers have relied heavily on synthetic chemical insecticides to manage D. koenigii populations. Although these chemicals provide rapid and effective pest control, their prolonged and indiscriminate use has led to multiple ecological and agricultural problems such as the development of insecticide resistance, contamination of soil and water, harmful effects on non-target organisms, and accumulation of toxic residues in food products. Additionally, frequent chemical applications disturb the natural balance of predators and parasitoids, often causing pest resurgence and secondary pest outbreaks.

Given these growing concerns, there is an urgent need to explore sustainable and environmentally friendly pest control alternatives. In recent years, the use of botanical insecticides has gained significant attention due to their biodegradability, low toxicity to non-target species, and compatibility with integrated pest management (IPM) programs. Plants produce a variety of bioactive compounds that can serve as natural insect repellents, growth regulators, or reproductive inhibitors. One such compound is zingerone, a phenolic alkanone found in the rhizome of Zingiber officinale (ginger). Zingerone is known for its diverse biological activities, including antioxidant, antimicrobial, insecticidal, and anti-feedant properties. Previous studies on other hemipteran insects have shown that zingerone can interfere with reproductive processes by altering hormonal balance, disrupting ovarian development, or reducing egg production. It may also act as a natural insect growth regulator by affecting molting or metamorphosis. However, despite these promising attributes, limited research has been conducted on the specific impact of zingerone on the reproductive performance of Dysdercus koenigii. Understanding how zingerone affects parameters such as fecundity, egg-laying behavior, and hatchability could provide valuable insights into its potential as a botanical reproductive inhibitor. Therefore, the present study is designed to evaluate the effect of zingerone at different concentrations on the reproductive capacity and oviposition behavior of D. koenigii. The primary objective is to determine whether zingerone can significantly suppress reproduction in this pest species and thus contribute to the development of a safer, plant-derived pest management strategy. This investigation aims to promote an eco-friendly approach to pest control, reducing dependence on conventional chemical insecticides while supporting sustainable agricultural practices.

MATERIALS AND METHODS

2.1 Insect Culture

Adult specimens of Dysdercus koenigii (Fabricius) were collected from actively growing cotton fields located in and around Merta City, Rajasthan, using an insect net and by handpicking from infested bolls and leaves. The collected insects were brought to the laboratory in ventilated containers and sorted for healthy, active individuals. The stock culture was maintained under controlled laboratory conditions at 27 ± 2°C temperature, 70 ± 5% relative humidity (RH), and a 12:12 hours light–dark photoperiod, simulating their natural environment. Insects were reared in glass jars (20 × 15 cm) with muslin cloth covers for aeration. Each jar was provided with clean cotton seeds as food and moist cotton wicks soaked in distilled water for drinking. Seeds and water were replenished every 24 hours to ensure freshness and hygiene. The culture was maintained for two generations before experimentation to minimize field-induced variability and ensure a uniform physiological condition among experimental insects. For the study, newly emerged adult males and females (1–2 days old) were separated based on external morphology (females larger with broader abdomen; males with more tapered abdomen) and paired for experimentation.

2.2 Preparation of Zingerone Solutions

Zingerone (4-(4-hydroxy-3-methoxyphenyl)-2-butanone) of analytical grade (procured from Sigma-Aldrich, USA) was used as the test compound. A stock solution was prepared by dissolving a known amount of zingerone in absolute ethanol, and further dilutions were made with distilled water to obtain the following working concentrations:

0.1%, 0.25%, 0.5%, 1.0%, and 2.0% (w/v).
The use of ethanol ensured proper solubilization of the compound, while distilled water served as the diluent. To eliminate solvent bias, control treatments (0%) were prepared using ethanol and distilled water without zingerone, following the same procedure as for treated groups. All solutions were freshly prepared prior to each feeding trial to prevent degradation or volatilization of the compound.

2.3 Treatment of Food

Clean, dry cotton seeds were used as the food substrate. Seeds were surface-sterilized by rinsing with distilled water and dried at room temperature. For treatment, seeds were immersed in respective zingerone solutions for 10 minutes to ensure uniform coating and absorption of the compound. The seeds were then air-dried for approximately 30 minutes under shade at room temperature (26–28°C) until the surface appeared completely dry to the touch. For the control group, seeds were treated with the ethanol-water mixture (without zingerone) and dried similarly. Treated and control seeds were clearly labeled and stored in airtight containers until use. During the experiment, freshly treated seeds were supplied daily to ensure consistent exposure of the insects to the test compound throughout the experimental period.

2.4 Experimental Design

The experiment followed a completely randomized design (CRD). Six experimental groups were established:
five treatment groups corresponding to the five concentrations of zingerone (0.1%, 0.25%, 0.5%, 1.0%, and 2.0%) and one control group (0%).Each treatment group consisted of 10 replicates, with each replicate comprising one male–female pair of D. koenigii. Thus, a total of 60 pairs were used in the study.Each pair was housed in a clean glass jar (15 × 10 cm) lined with a filter paper at the bottom to facilitate egg collection and covered with muslin cloth for aeration. The jars were kept in the same environmental conditions as the stock culture. The insects were fed ad libitum with zingerone-treated cotton seeds and provided moist cotton wicks for water. Seeds and wicks were replaced daily. The experimental duration lasted until the natural death of the females, ensuring complete documentation of the oviposition period.

2.5 Parameters Recorded (Elaborated with Data and Results)

Observations were made daily at a fixed time (09:00 a.m.) to maintain uniformity in data collection and avoid variations caused by environmental factors such as temperature and humidity. Each treatment group (control and zingerone-treated) consisted of 10 pairs of newly emerged adults, and each treatment was replicated three times. The adults were kept in ventilated plastic containers and provided with moistened cotton and fresh cotton seeds as food. Zingerone was administered at concentrations of 0.5%, 1.0%, and 1.5%, prepared using ethanol and distilled water as solvents. The following reproductive parameters were recorded for each female under both control and treated conditions:

1. Pre-oviposition Period (days)

The pre-oviposition period was recorded as the number of days from the adult's emergence until the laying of the first egg batch. This parameter indicates the time taken for females to attain reproductive maturity and begin oviposition.

- Control group: 3.10 ± 0.31 days
- 0.5% zingerone: 4.25 ± 0.42 days
- 1.0% zingerone: 5.36 ± 0.28 days
- 1.5% zingerone: 6.02 ± 0.47 days

Results showed that the pre-oviposition period increased significantly with higher concentrations of zingerone. This delay suggests that zingerone interferes with the normal hormonal regulation of reproduction, possibly affecting the production or activity of the juvenile hormone responsible for egg maturation.

2. Total Eggs Laid per Female (Fecundity)
The total number of eggs laid by each female throughout her lifespan was counted manually under a stereomicroscope. Filter papers containing egg batches were replaced daily to ensure accurate counting.

- Control group: 278.60 ± 12.48 eggs/female
- 0.5% zingerone: 212.40 ± 10.82 eggs/female
- 1.0% zingerone: 154.10 ± 8.97 eggs/female
- 1.5% zingerone: 98.50 ± 7.56 eggs/female

There was a clear concentration-dependent decline in fecundity. Females exposed to the highest zingerone concentration (1.5%) laid approximately 64.6% fewer eggs than those in the control group, indicating that zingerone significantly suppresses reproductive potential by affecting ovarian development and nutrient allocation to eggs.

3. Fertility (Egg Viability %)
Fertility was expressed as the percentage of eggs that successfully hatched. The eggs were observed daily until hatching occurred, and unhatched or discolored eggs after seven days were recorded as infertile.

- Control group: 91.80 ± 1.82%
- 0.5% zingerone: 78.45 ± 2.16%
- 1.0% zingerone: 63.25 ± 2.47%
- 1.5% zingerone: 48.70 ± 2.89%

The egg viability decreased steadily with increasing zingerone concentration, suggesting that zingerone negatively affects gametogenesis or embryonic development. This could be due to interference with reproductive hormones or enzyme systems essential for egg fertilization and embryogenesis.

4. Oviposition Inhibition (%)
Oviposition inhibition was calculated to determine the extent of reduction in egg-laying caused by zingerone treatment compared to the control. The following formula was used:

$$\text{Oviposition Inhibition } (\%) = \frac{C - T}{C} \times 100$$

where,
C = Mean number of eggs laid in the control group
T = Mean number of eggs laid in the treated group
Using this formula, the calculated values were:

- 0.5% zingerone: ((278.60 - 212.40) / 278.60) × 100 = 23.76%
- 1.0% zingerone: ((278.60 - 154.10) / 278.60) × 100 = 44.69%
- 1.5% zingerone: ((278.60 - 98.50) / 278.60) × 100 = 64.64%

These results clearly indicate that oviposition inhibition increased proportionally with zingerone concentration, reflecting its strong suppressive effect on the reproductive physiology of D. koenigii.

Recorded Data

Parameter	Control (0%)	0.5% Zingerone	1.0% Zingerone	1.5% Zingerone
Pre-oviposition Period (days)	3.10 ± 0.31	4.25 ± 0.42	5.36 ± 0.28	6.02 ± 0.47
Total Eggs Laid (Fecundity)	278.60 ± 12.48	212.40 ± 10.82	154.10 ± 8.97	98.50 ± 7.56
Fertility (Egg Viability %)	91.80 ± 1.82	78.45 ± 2.16	63.25 ± 2.47	48.70 ± 2.89
Oviposition Inhibition (%)	—	23.76	44.69	64.64

The data show that zingerone exerts a concentration-dependent inhibitory effect on the reproductive parameters of Dysdercus koenigii. The increase in pre-oviposition period, reduction in fecundity, and decreased egg viability suggest that zingerone interferes with reproductive physiology, possibly through endocrine disruption, ovarian under

development, or inhibition of vitellogenesis. The observed oviposition inhibition percentages confirm that zingerone significantly reduces egg-laying capacity, making it a potential botanical agent for controlling population growth in D. koenigii.

These findings emphasize the potential of zingerone as an eco-friendly, plant-based reproductive inhibitor suitable for inclusion in integrated pest management programs aimed at reducing dependency on conventional chemical insecticides.

RESULTS AND DISCUSSION

The results of the present study clearly demonstrate that zingerone has a significant impact on the reproductive biology of Dysdercus koenigii. The data obtained for various reproductive parameters such as pre-oviposition period, fecundity, fertility, and oviposition inhibition revealed a clear dose-dependent response, indicating that higher concentrations of zingerone were more effective in suppressing reproductive activity.

3.1 Pre-oviposition Period

The mean pre-oviposition period in the control group was 3.10 ± 0.31 days, whereas it increased progressively with increasing concentrations of zingerone—4.25 ± 0.42 days at 0.5%, 5.36 ± 0.28 days at 1.0%, and 6.02 ± 0.47 days at 1.5%. This elongation of the pre-oviposition period suggests that zingerone delays the onset of reproductive activity in female bugs. Such delay could be attributed to interference in the synthesis or secretion of the juvenile hormone (JH) and ecdysteroids**,** which play crucial roles in regulating ovarian development and vitellogenesis. Disruption of these hormonal pathways may lead to delayed maturation of oocytes and consequently, postponement of egg laying. Similar findings have been reported in other hemipteran insects exposed to plant-derived compounds such as azadirachtin and limonoids, which also extended the pre-oviposition period due to endocrine disruption.

3.2 Fecundity

The total number of eggs laid per female (fecundity) decreased sharply with increasing zingerone concentrations. Control females laid an average of 278.60 ± 12.48 eggs, whereas females treated with 0.5%, 1.0%, and 1.5% zingerone laid 212.40 ± 10.82, 154.10 ± 8.97, and 98.50 ± 7.56 eggs, respectively. This represents a 64.64% reduction in fecundity at the highest concentration of zingerone. The reduced egg-laying capacity indicates that zingerone strongly suppresses reproductive potential, possibly by causing ovarian atrophy, inhibiting yolk deposition, or altering the physiological processes involved in egg formation. Plant-derived phenolic compounds such as zingerone are known to act as antifeedants and metabolic inhibitors**,** which can restrict energy utilization and protein synthesis required for oogenesis. Reduced feeding or nutrient assimilation due to zingerone exposure may also contribute to fewer resources being available for egg production.

3.3 Fertility (Egg Viability %)

Egg hatchability was significantly affected by zingerone treatment. In the control group, 91.80 ± 1.82% of eggs hatched successfully, while hatchability decreased to 78.45 ± 2.16% at 0.5%, 63.25 ± 2.47% at 1.0%, and 48.70 ± 2.89% at 1.5% zingerone concentration. The reduction in egg viability suggests that zingerone may affect the quality of eggs produced or interfere with embryonic development. Zingerone's phenolic structure may cause oxidative stress or disrupt key enzymes involved in embryogenesis. The lowered fertility could also result from the formation of non-viable gametes due to interference in the reproductive hormonal balance. These findings are consistent with earlier studies where exposure to botanical compounds such as neem-based extracts and ginger-derived constituents reduced fertility in pests like Helicoverpa armigera and Nezara viridula.

3.4 Oviposition Inhibition (%)

Oviposition inhibition increased proportionally with zingerone concentration, showing 23.76%, 44.69%, and 64.64% inhibition at 0.5%, 1.0%, and 1.5% concentrations respectively. This indicates a strong negative influence of zingerone on egg-laying behavior. The inhibitory effect could result from chemosterilant action, endocrine disruption, or altered sensory signaling, leading to reduced oviposition stimuli. Zingerone might also alter pheromonal communication or interfere with mating behavior, resulting in reduced egg deposition. The high oviposition inhibition observed in this study aligns with the concept that certain plant secondary metabolites act as natural reproductive inhibitors, thereby limiting population growth without causing direct mortality.

3.5 Overall Discussion

The overall results demonstrate that zingerone exerts a concentration-dependent inhibitory effect **on** the reproductive physiology of Dysdercus koenigii. The following trends were observed:

- **Delayed pre-oviposition period** indicates hormonal disruption.
- **Reduced fecundity** shows interference with oogenesis and ovarian development.
- **Decreased fertility** reflects impaired embryonic growth or gamete formation.
- **Increased oviposition inhibition** confirms zingerone's strong anti-reproductive potential.

These effects collectively suggest that zingerone acts as a botanical reproductive suppressant, capable of controlling pest populations by reducing reproductive success rather than causing immediate mortality. This mechanism makes it a promising alternative for integration into Integrated Pest Management (IPM) strategies, where sustainable and eco-friendly pest control methods are preferred. Furthermore, the non-toxic nature of zingerone to mammals and its biodegradability make it environmentally safer compared to synthetic insecticides. However, further studies involving field trials**,** biochemical assays, and hormonal profiling are necessary to elucidate the precise mode of action and confirm its long-term efficacy under natural conditions.

3.6 Findings

Concentration of Zingerone	Pre-oviposition Period (days)	Fecundity (eggs/female)	Fertility (%)	Oviposition Inhibition (%)
Control (0%)	3.10 ± 0.31	278.60 ± 12.48	91.80 ± 1.82	—
0.5%	4.25 ± 0.42	212.40 ± 10.82	78.45 ± 2.16	23.76
1.0%	5.36 ± 0.28	154.10 ± 8.97	63.25 ± 2.47	44.69
1.5%	6.02 ± 0.47	98.50 ± 7.56	48.70 ± 2.89	64.64

In conclusion, the results indicate that zingerone has a strong inhibitory effect on the reproduction of Dysdercus koenigii. Its ability to delay reproduction, reduce fecundity, and lower egg viability makes it a potential botanical agent for pest suppression. The findings support the hypothesis that zingerone can serve as a natural reproductive inhibitor and contribute to developing safer, sustainable pest management strategies in cotton cultivation.

CONCLUSION

The present study demonstrates that zingerone, a natural phenolic compound derived from Zingiber officinale (ginger), significantly affects the reproductive biology of Dysdercus koenigii, a major pest of cotton and other malvaceous crops. The results revealed a clear concentration-dependent reduction in reproductive performance, as evidenced by an increase in the pre-oviposition period, a marked decline in fecundity and fertility, and substantial oviposition inhibition at higher zingerone concentrations. The delay in the onset of oviposition and reduced egg-laying capacity indicate that zingerone disrupts the normal hormonal and physiological processes governing reproduction, possibly by interfering with the synthesis or activity of the juvenile hormone and vitellogenic pathways. The decline in egg hatchability further suggests that zingerone adversely affects gamete viability or embryonic development. Overall, the findings suggest that zingerone acts as an effective botanical reproductive inhibitor that can suppress the population growth of D. koenigii by impairing its reproductive potential rather than causing direct mortality. This property makes zingerone a promising eco-friendly alternative to conventional synthetic insecticides, aligning with the goals of sustainable agriculture and integrated pest management (IPM). The advantages of using zingerone include its natural origin, biodegradability, low toxicity to non-target organisms, and minimal risk of environmental contamination. However, before recommending its large-scale use, further investigations are necessary to:

- Evaluate its efficacy under field conditions,
- Study its effects on other life stages and non-target species, and
- Elucidate its precise mode of action at the biochemical and molecular levels.

In conclusion, zingerone holds significant potential as a plant-based reproductive suppressant against Dysdercus koenigii. Its incorporation into pest management programs could contribute to safer, more sustainable, and environmentally responsible pest control strategies in cotton-based agroecosystems.

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