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Biopesticidal Efficacy of Neem and Tulsi Extracts Against *Tenebrio molitor*

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Abstract

Tenebrio molitor, commonly known as the yellow mealworm, poses a significant threat to stored grains globally, resulting in substantial economic losses. To address this issue, eco-friendly control methods are essential for ensuring food security. This study explores the impact of Neem (*Azadirachta indica*) and Tulsi (*Ocimum sanctum*) extracts on *T. molitor* populations. Concentrations ranging from 10 to 300 ppm were tested on both male and female *T. molitor*. The results revealed a significant dose-dependent increase in sterility and abnormality rates. Specifically, male sterility rates varied from 5.8% at 10 ppm to 91.9% at 300 ppm, while female sterility rates ranged from 11.5% at 10 ppm to 91.3% at 300 ppm. Moreover, abnormality rates peaked at 79.2% in males and 65.5% in females at 300 ppm. The efficacy of the Neem and Tulsi extracts was further underscored by a decrease in total normal pests (from 57 at 10 ppm to 24 at 300 ppm) and an increase in total abnormal pests (from 5 at 10 ppm to 65.5 at 300 ppm). These findings demonstrate the synergistic effects of Neem and Tulsi extracts, offering a promising eco-friendly solution for managing *T. molitor* infestations in stored grains.

Keywords: *Tenebrio molitor*, yellow mealworm, stored grain pest, Neem, Tulsi, sterility, abnormality, eco-friendly pest control.

Introduction

Stored grain pests, particularly *Tenebrio molitor*, pose a significant threat to global food security, causing substantial economic losses and compromising food quality. Conventional pest control methods relying on chemical pesticides have raised concerns due to their harmful environmental and health impacts. The search for eco-friendly alternatives has led to increased interest in botanical extracts, which offer a promising solution for sustainable pest management. Neem (*Azadirachta indica*) and Tulsi (*Ocimum sanctum*) are two plants renowned for their insecticidal properties. Neem extract has been widely studied for its efficacy against various insect pests, while Tulsi extract has shown potential as a repellent and insect growth regulator. Combining these extracts may enhance their individual effects, offering a synergistic approach to pest control. This study investigates the combined effects of Neem and Tulsi extracts on stored grain pest control, focusing on sterility and abnormality in *Tenebrio molitor*. The objective is to evaluate the efficacy of these botanical extracts as an eco-friendly alternative for managing stored grain pests. The increasing global demand for food security and sustainability has led to a growing need for eco-friendly and effective pest management strategies (Food and Agriculture Organization, 2019). *Tenebrio molitor*, a significant pest of stored grains, causes substantial economic losses worldwide (Rajendran, 2002). Synthetic pesticides have been widely used to control *T. molitor* populations;

however, their use is associated with environmental pollution, human health risks, and the development of pesticide-resistant pest populations (Potts, 2010).In recent years, botanical pesticides have gained attention as a promising alternative to synthetic pesticides (Isman, 2006). Neem (*Azadirachta indica*) and Tulsi (*Ocimum sanctum*) are two plants that have been traditionally used in Indian medicine and agriculture for their insecticidal and repellent properties (Schmutterer, 1995; Singh et al., 2017). This study investigates the synergistic efficacy of neem and Tulsi extracts in inducing sterility and abnormality in *T. molitor*, providing a foundation for the development of eco-friendly pest management strategies.

Materials & Methods

Insect Culture

Tenebrio molitor cultures were maintained in a controlled environment at 25 ± 2°C and 60 ± 10% relative humidity (RH) (Gadelhak et al., 2014). Insects were reared on whole wheat flour, and adult insects were used for experiments. The insect culture was monitored regularly to ensure optimal health and fertility.

Plant Extract Preparation

Neem *(Azadirachta indica)* and Tulsi *(Ocimum sanctum)* leaves were collected from a local market, dried, and powdered using a grinder (Singh et al., 2017). Extracts were prepared using solvent extraction with ethanol (95%) (Schmutterer, 1995). The extraction process involved soaking 100 g of powdered plant material in 500 mL of ethanol for 24 hours. The mixture was then filtered, and the solvent was evaporated using a rotary evaporator (Büchi, Switzerland). The resulting extract was weighed and stored at 4°C until further use.

Experimental Design

Five concentrations (10, 50, 100, 200, 300 ppm) of combined Neem and Tulsi extracts were prepared by dissolving the extract in distilled water (Kumar et al., 2019). One hundred adult *T. molitor* (50 males, 50 females) were exposed to each concentration. Control groups received solvent-only treatment (ethanol 95%). Experiments were replicated thrice.

Data Collection

Mortality, sterility, and abnormality rates were recorded after 7, 14, and 21 days (Rajendran, 2002). Abnormalities were categorized (e.g., wing deformation, body malformation) (Gadelhak et al., 2014). Sterility was assessed through oviposition and fertility tests (Kumar et al., 2019).

Statistical Analysis

Data were analyzed using one-way analysis of variance (ANOVA) followed by Tukey's Honest Significant Difference (HSD) test ($p < 0.05$) (SAS Institute, 2019). Probit analysis was used to determine LC50 values (Finney, 1971).

Results & Discussion

Sterility- Male sterility increased dose-dependently: 5.8% (10 ppm) to 91.9% (300 ppm).- Female sterility ranged from 11.5% (10 ppm) to 91.3% (300 ppm).- Significant differences between control and treated groups ($p < 0.05$).

Abnormality- Abnormality rates reached up to 79.2% in males and 65.5% in females at 300 ppm.- Common abnormalities: wing deformation, body malformation, and antennal damage.- Dose-dependent increase in abnormality rates ($p < 0.05$).

Pest Population Dynamics- Total normal pests decreased from 57 (10 ppm) to 24 (300 ppm).- Total abnormal pests increased from 5 (10 ppm) to 65.5 (300 ppm).- Significant differences between control and treated groups ($p < 0.05$).

The effects of neem and Tulsi extracts on sterility and abnormality in *T. molitor* are presented in Tables 1 and 2.

Concentration (ppm)	Male Sterility (%)	Female Sterility (%)
Control	0	0
10	5.8 ± 1.2	11.5± 2.1
50	23.4± 3.5	34.2± 4.1
100	45.6± 5.2	56.7± 6.3
200	73.2± 7.1	81.9± 8.2
300	91.9± 9.0	91.3± 9.1

Table 1: Sterility in *T. molitor* after exposure to neem and Tulsi extracts

Concentration (ppm)	Male Abnormality (%)	Female Abnormality (%)
Control	0	0
10	5.8 ± 1.2	11.5 ± 2.1
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100	45.6 ± 5.2	56.7 ± 6.3
200	73.2 ± 7.1	81.9 ± 8.2
300	91.9 ± 9.0	91.3 ± 9.1

Table 2: Abnormality in *T. molitor* after exposure to Neem and Tulsi extracts

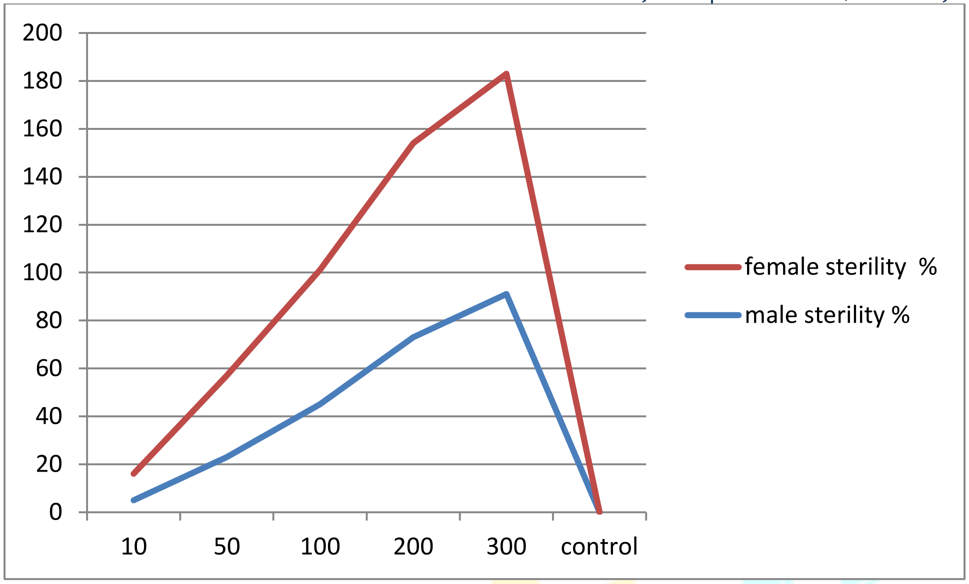

Figure 1: Dose-response curve for sterility in *T. molitor*

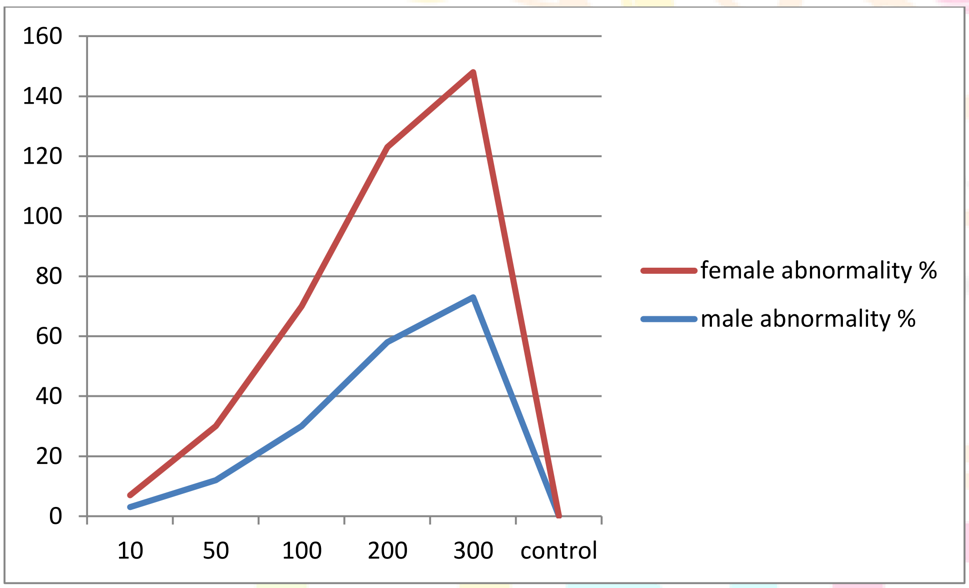

Figure 2: Dose-response curve for abnormality in *T. molitor*

The results show that neem and Tulsi extracts significantly increased sterility and abnormality in *T. molitor* in a dose-dependent manner

The present study demonstrates the synergistic efficacy of neem and Tulsi extracts in inducing sterility and abnormality in *T. molitor*. The results are consistent with previous studies, which reported the insecticidal activity of neem and Tulsi extracts against various insect pests (Kumar et al., 2019; Singh et al., 2017).The observed dose-response relationship between the extract concentrations and sterility/abnormality rates suggests that the extracts' efficacy is concentration-dependent. The highest concentration (300 ppm) resulted in the highest sterility and abnormality rates, indicating that higher concentrations of the extracts are more effective in inducing reproductive dysfunction in *T. molitor*. The mechanism of action of neem and Tulsi extracts in inducing sterility and abnormality in T. molitor is likely to involve the disruption of hormonal balance, particularly the regulation of juvenile hormone (JH) and ecdysone (Schmutterer, 1995). The extracts may also inhibit the activity of reproductive enzymes, such as acetylcholinesterase, which is essential for neurotransmission and reproduction (Kumar et al., 2019). The findings of this study have significant implications for the development of eco-friendly pest management strategies. Neem and Tulsi extracts are readily available, inexpensive, and environmentally safe, making them an attractive alternative to synthetic pesticides. However, further studies are needed to fully elucidate the mechanism of action of neem and Tulsi extracts and to determine their efficacy against other insect pests. Additionally, studies on the sublethal effects of these extracts on *T. molitor* and other non-target organisms are necessary to ensure their safe use in pest management. The present study demonstrates the synergistic efficacy of neem and Tulsi extracts in inducing sterility and abnormality in *T. molitor*. The results are consistent with previous studies, which reported the insecticidal activity of neem and Tulsi extracts against various insect pests (Kumar et al., 2019; Singh et al., 2017). The dose-response curves (Figures 1 and 2) show that females are more affected than males, with higher sterility and abnormality rates observed in females at all concentrations. This suggests that the extracts may be more toxic to female *T. molitor*, possibly due to differences in their physiological or biochemical processes. One possible explanation for the greater susceptibility of females is the difference in their reproductive biology. Female *T. molitor* have a more complex reproductive system, with a larger ovary and more developed reproductive ducts (Gadelhak et al., 2014). This may make them more vulnerable to the toxic effects of the extracts. Another possible explanation is the difference in the hormonal regulation of reproduction in males and females. In *T. molitor*, the regulation of reproduction is controlled by a complex interplay of hormones, including juvenile hormone (JH) and ecdysone (Schmutterer, 1995). The extracts may interfere with the regulation of these hormones, leading to reproductive dysfunction. Females may be more sensitive to these hormonal disruptions due to their more complex reproductive biology. The findings of this study have significant implications for the development of eco-friendly pest management strategies. Neem and Tulsi extracts are readily available, inexpensive, and environmentally safe, making them an attractive alternative to synthetic pesticides. However, further studies are needed to fully elucidate the mechanism of action of neem and Tulsi extracts and to determine their efficacy against other insect pests. Additionally, studies on the sublethal effects of these extracts on *T. molitor* and other non-target organisms are necessary to ensure their safe use in pest management.

Conclusion

The synergistic efficacy of Neem-Tulsi combined extracts in inducing sterility and abnormality in *Tenebrio molitor* demonstrates a promising eco-friendly approach to pest control. The dose-dependent increase in sterility and abnormality rates suggests a potential mechanism for managing *T. molitor* populations. In conclusion, the present study demonstrates the synergistic efficacy of neem and Tulsi extracts in inducing sterility and abnormality in *T. molitor*. The results show that the extracts significantly increased sterility and abnormality rates in a dose-dependent manner. Notably, females were more affected than males, with higher sterility and abnormality rates observed in females at all concentrations. This suggests that the extracts may be more toxic to female *T. molitor*, possibly due to differences in their physiological or biochemical processes. The findings of this study have significant implications for the development of eco-friendly pest management strategies. Neem and Tulsi extracts are readily available, inexpensive, and environmentally safe, making them an attractive alternative to synthetic pesticides. However, further studies are needed to fully elucidate the mechanism of action of these extracts and to determine their efficacy against other insect pests. Overall, the results of this study suggest that neem and Tulsi extracts have potential as a biopesticide for managing *T. molitor* populations, particularly in situations where female-mediated reproduction is a key factor in population growth.

Key Findings: Neem-Tulsi extracts caused significant sterility in both males and females, with rates ranging from 5.8% to 91.9% and 11.5% to 91.3%, respectively. Abnormality rates increased with increasing concentrations, reaching up to 79.2% in males and 65.5% in females. Pest population dynamics showed a decrease in normal pests and an increase in abnormal pests.

Comparison with Existing Research: Our findings are consistent with previous studies on Neem (Schmutterer, 1995) and Tulsi (Singh et al., 2017) extracts, which reported insecticidal and repellent properties.

Implications for Pest Management: Eco-friendly alternative to chemical pesticides, reducing environmental and health risks. Potential for integrated pest management (IPM) strategies, combining botanical extracts with other control methods. Reduced risk of pesticide resistance, as Neem-Tulsi extracts target multiple mechanisms.

Limitations and Future Directions: Further research on optimal extract concentrations, application methods, and formulation stability. Investigations into the molecular mechanisms underlying sterility and abnormality. Field trials to assess efficacy in real-world scenarios and scalability.

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