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Assessing the Impact of Essential Oil on the Mortality of *Tribolium castaneum* (Herbst.).

Pallavi Pawar*, Reshma Mahevi, and Hemant Dhamke.

Dr. D.Y. Patil Arts Commerce and Science Women's College, Pimpri, Pune, Maharashtra, India.

ABSTRACT

The red flour beetle, *Tribolium castaneum*, (Coleoptera: Tenebrionidae) is a significant pest in stored products worldwide. This study investigates the adulticidal and larvicidal effects of jojoba oil (*Simmondsia chinensis*) on *T. castaneum*. Larvicidal and adulticidal bioassay tests were conducted, revealing that jojoba oil concentrations of 3% and 5%, respectively, resulted in 50% mortality (LC50) of the fourth instar larvae and adults. The results demonstrated that jojoba oil exhibits notable efficacy against both the larval and adult stages of *T. castaneum*. These findings suggest that jojoba oil, along with other plant oils like *Azadirachta indica* (neem) and *Brassica juncea* (mustard), holds significant potential as a natural insecticide for managing *T. castaneum* infestations. Additionally, these plant oils offer promising, eco-friendly alternatives to synthetic pesticides.

Keywords: Adulticidal effects; Jojoba oil; Larvicidal effects; Natural insecticides; *Tribolium castaneum*

Corresponding author

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INTRODUCTION

Many agricultural products, particularly dried, stored, and durable commodities, are highly susceptible to infestation by various stored product insects. Additionally, numerous value-added food products and non-food derivatives are also vulnerable to damage caused by these insects. [20,8] The nutritious value of pest-ridden stored grains decreased [21]. Significant food loss during storage due to pest infestations is a major issue in both developed and developing countries, leading to substantial economic losses [7,1]. Various techniques have been developed through Integrated Pest Management (IPM) approaches to control grain infestations; however, synthetic insecticides, including malathion, phosphine, pyrethroids, and chlorpyrifos, are still commonly used worldwide for quality control [14]. Despite their effectiveness, repeated application of these chemicals often leads to undesirable consequences, such as the development of resistance in insect pests. [18, 16], the negative effects also extend to the environment and non-target animals [12].

Essential oils possess distinct properties that make them a promising and increasingly popular alternative to synthetic insecticides [10, 4]. Essential oils are less determined in the environment than conventional pesticides due to their high volatility and sensitivity to temperature and ultraviolet light degradation. Moreover, compared to traditional insecticides, many essential oils exhibit low toxicity to mammals and are considered more environmentally friendly [17].

The red flour beetle, *Tribolium castaneum* (Herbst, 1797), is a prevalent pest of stored grains and is considered one of the major secondary insect pests. It infests a broad range of products, including grains, flours, peas, beans, nuts, dried fruits, and spices, causing damage estimated at 15–20% to these commodities [5]. *T. castaneum* degrades the dietary quality of stored products and often releases its own metabolites into the stored foods, further compromising their quality. Several lines of evidence suggest that metabolites secreted by *T. castaneum*, such as benzoquinones, may pose potential health risks to consumers [24, 6]. Recently, jojoba oil, extracted from the jojoba plant *Simmondsia chinensis* (L.), a monotypic species native to North American deserts and cultivated globally, has gained attention for its potential benefits. Various studies have highlighted the significant medicinal properties of jojoba oil. Furthermore, it has been reported to exhibit toxicity to adult *Sitophilus oryzae* (L.), the rice weevil [13, 15, 2, and 25].

MATERIAL AND METHOD

Insect Collection

The adult *Tribolium castaneum* used in this study were collected from naturally infested wheat flour obtained from the market and subsequently reared in the laboratory to establish a homogeneous population.

Insect Rearing

This study was conducted in the Laboratory of the Department of Zoology at Dr. D.Y. Patil Arts, Commerce, and Science College during 2024. The red flour beetles (*Tribolium castaneum*) were reared on sterilized wheat flour in plastic jars. Adult beetles were introduced into the flour to lay eggs, and after 5 days, the beetles were removed using sieving. The eggs were left to hatch and develop under controlled conditions in an incubator maintained at a constant temperature of 27 ± 3°C and 65-70 ± 5% relative humidity. The plastic jars were covered with muslin cloth and secured with rubber bands to prevent *T. castaneum* escape. A homogeneous population (F1 generation) was achieved after 30–35 days, as described by [11].

Plant essential oil

Jojoba (*Simmondsia chinensis*) plant oil was used in the experiments. Plant oils were purchased from local market, and tested against the red flour beetle.

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Mortality Bioassay

Larvicidal Bioassay

An experiment was conducted to assess the lethal concentration at which 50% of the fourth instar larvae (Lc50) of a specific species are affected by jojoba oil. The larvae were exposed to a series of jojoba oil concentrations, including 1%, 2%, 3%, 4%, and 5%, with the oil dissolved in acetone as the solvent. A control group of larvae was maintained under identical conditions, but treated only with acetone without the addition of essential oils. Each treatment group, including the control, was replicated five times to ensure statistical reliability. The larvae were observed for a 24-hour period, and the mortality rate was recorded for each concentration. The Lc50 value, representing the concentration at which 50% mortality occurred, was determined through log-probit analysis of the mortality data.

Adulticidal Bioassay

An adulticidal bioassay was conducted to determine the lethal concentration (LC_{50}) of jojoba oil on adult *Tribolium castaneum*. Ten adult beetles were placed in a jar containing 20 grams of wheat grains, which were treated with various concentrations of jojoba oil (1%, 3%, 5%, 7%, and 9%). After exposure, the mortality rate of the beetles was recorded. The data obtained from the experiment were analyzed using log-probit analysis to determine the lethal concentration (LC_{50}) value at which a specified percentage of beetles were affected.

RESULT AND DISCUSSION

To evaluate the toxic effects of jojoba oil on the fourth instar larvae and adult of *Tribolium castaneum*, toxicity assays were conducted. The results demonstrated a dose-dependent increase in mortality, indicating that jojoba oil had a significant toxic effect on both larvae and adults of *T. castaneum*. Data in Table (1) show the LC_{50} their confidence limit values of jojoba plant oil applied against red flour beetle larvae and adults.

Table 1. LC_{50} their confidence limit values for jojoba oil tested against *T. castaneum* after 24 hours.

Jojoba Oil	LC_{50} (%)	95% Confidential limits		Regression equation
		LCL	UCL	
4th Instar Larva	3	2.80963	3.5897	Y=3.5774X+3.4489
Adult	5	4.40981	6.1555	Y=2.5482X+3.4202

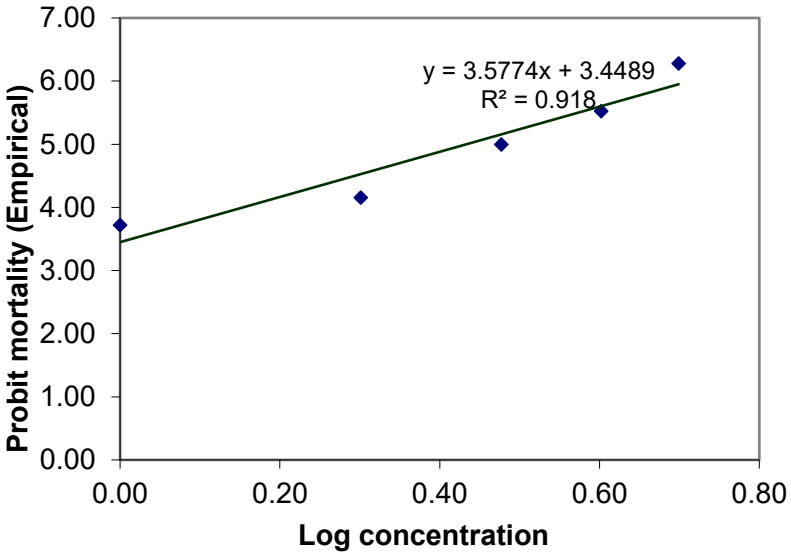

Figure-1: Regression line of probit mortality of 4th instar larva of *T. castaneum* against jojoba oil

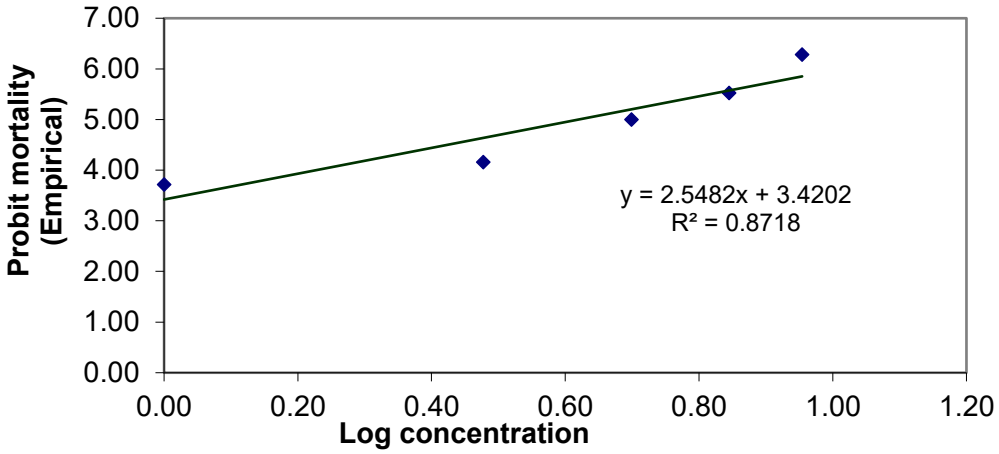

Figure 2: Regression line of probit mortality of adult of *T. castaneum* against jojoba oil

The toxicity of jojoba oil on the fourth instar larvae was evaluated across various concentrations, resulting in an LC_{50} value of 3%. In contrast, the adulticidal activity of jojoba oil against adult *Tribolium castaneum* exhibited an LC_{50} value at a concentration of 5%. Figures 1 and 2 display the 95% confidence intervals and regression coefficients, specifically depicting the larvicidal and adulticidal activities of jojoba oil against *Tribolium castaneum*.

There is increasing interest among researchers in exploring the bioactivity of plant essential oils and extracts against stored-grain insect pests [3,19]. In that study, oil from *Simmondsia chinensis* demonstrated significant insecticidal potential against *Tribolium castaneum* [3,19]. The insecticidal activity varied with different oil concentrations and exposure durations. A clear dose-response relationship was observed, where larval and adult mortality increased, while larval survival and adult emergence decreased as the concentration of the essential oils increased, as reported by [23]. The insecticidal activity of jojoba oil was significantly greater than that of Cyperus oil, with LC50 values of 485.0 mg/g and 1700.73 mg/g for jojoba and Cyperus oils, respectively, against *Sitophilus oryzae* in terms of antifeedant activity [9]. Nanoemulsion of jojoba oil exhibited a concentration- and time-dependent mortality effect on *Sitophilus oryzae* adults, suggesting it may serve as an effective alternative to conventional pesticides for controlling the rice weevil [23].

CONCLUSION

The results of this study demonstrate that jojoba oil (*Simmondsia chinensis*) exhibits significant adulticidal and larvicidal effects against *Tribolium castaneum*, with LC50 values of 3% and 5% for the fourth instar larvae and adults, respectively. The findings highlight jojoba oil's potential as an effective natural insecticide for managing *T. castaneum* infestations. Jojoba oil emerges as a promising alternative to synthetic pesticides, offering an environmentally friendly and sustainable solution for pest control.

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