**BIORATIONAL INSECTICIDES AS SEED PROTECTANTS ON *TRIBOLIUM CASTANEUM* (HERBST) IN STORED SESAME**

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ABSTRACT

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| **Aim:** To evaluate the efficacy of essential oils (EOs) and insect growth regulators (IGRs) against *Tribolium castaneum* (H.) infesting stored sesame seeds.  **Study design:** Completely Randomised Design.  **Place and Duration of Study:** ICAR-Indian Institute of Oilseeds Research, Division of Crop Protection, Rajendranagar between January to June 2024.  **Methodology:** The study involved six treatments *viz.,* clove oil (5 ml kg⁻¹), peppermint oil (5 ml kg⁻¹), pyriproxyfen 10 EC (5 ppm kg⁻¹), azadirachtin 1500 ppm (5 ml kg⁻¹), deltamethrin 2.8 EC (1 ppm kg⁻1) and an untreated control. The repellent activity of treatments were studies using area preference method. One hundred grams of treated seeds were infested with ten pairs of freshly emerged *Tribolium castaneum* adults and incubated at 25°C and 55% RH. Adult mortality was assessed at 1, 3, 5, 7, and 14 days after treatment (DAT) using Abbott’s formula.  **Results:** Results revealed that all treatments were having strong repellent activity. Among all treatments, peppermint oil @ 5 ml kg⁻¹ recorded the highest per cent repellency (98.00%). The treatments caused significantly higher mortality than the control. Among all treatments, peppermint oil @ 5 ml kg⁻¹ recorded the highest adult mortality at 14 DAT (62.33%), which was on par with the standard chemical (deltamethrin) and botanical (azadirachtin) checks. Clove oil and pyriproxyfen showed moderate efficacy. The insecticidal activity of peppermint oil was attributed to its major bioactive compounds-menthol, menthone, limonene, carvone, and pulegone which disrupt insect nervous, respiratory and hormonal systems.  **Conclusion:** This study highlights the potential of EOs and IGRs as eco-friendly alternatives to synthetic insecticides in storage pest management. Their multiple modes of action also reduce the risk of resistance development, making them suitable alternatives for sustainable pest control strategies. however, further studies are required to increase their persistence and efficacy under long term storage conditions. |

*Keywords: Essential oils, Insect Growth Regulators, peppermint oil, sesame, bioactive compounds.*

1. INTRODUCTION

Sesame (*Sesamum indicum* L.), commonly known as til is the oldest indigenous oilseed crop. The sesamum contains 50% oil content and 18-20% protein content. Red flour beetle, *Tribolium castaneum* (Herbst) is a cosmopolitan and serious primary pest of sesame. The average loss estimated due to *T. castaneum* was 6.8 per cent in non-cereal crops (Ahir *et al.,* 2018). A study on storage pest management in sesame is relatively less when compared with cereals and pulses. Though chemical fumigants were used for storage pest control, they pose risks to the environment, human health, and seed quality. Due to various international agreements the usage of fumigant methyl bromide is reduced and thereby the dependence on phosphine is increasing noticeably in stored grain pest management in the recent past (Rajendran, 2001). The indiscriminate and continuous use of phosphine in poorly sealed warehouses at sub lethal doses resulted in the development of phosphine resistance in many of the stored grain pests especially in bulk storage and that was further worsened by the lack of suitable alternatives (Nayak et al., 2019). Indian food exports (sesame also) are sometimes rejected due to pesticide residues which are higher than Maximum Residue Limit (MRL) of importing nations (IOPEPC, 2020). A study on storage pest management in sesame is relatively less when compared with cereals and pulses. Therefore, this study assessed biorational insecticides *viz.*, two essential oils (EOs) (clove oil @ 5ml kg-1 and peppermint oil @ 5ml kg-1) and insect growth regulator (IGR) (Pyriproxyfen 10 EC @ 5 ppm) against *T. castaneum.*

2. material and methods

The experiment was carried out with six treatments and three replications in a Completely Randomised Design at ICAR- Indian Institute of Oilseeds Research, Division of crop protection, Rajendranagar from Jan-June 2024. The treatments include: Clove oil @ 5ml kg-1, peppermint oil @ 5ml kg-1, pyriproxyfen 10 EC @ 5ppm, azadirachtin 1500 ppm @ 5ml kg-1 and deltamethrin 2.8 EC @ 1ppm (deltamethrin 2.8 EC and azadirachtin 1500 ppm were used as standard chemical and botanical check respectively).

The treatments were tested for their repellent activity. The repellent activity of EOs, IGRs and standard checks were tested using area preference methodas described by Jilani and Su (1983). The filter paper was made into two equal halves. One half of the filter paper was used as control which is applied with acetone alone and the test chemical is applied to the other half of the filter paper. Both the control and treated filter paper were allowed to dry until all the solvent gets evaporated, Later the two halves were joined by attaching with adhesive tape. The filter paper disc is then placed tightly on to a petri plate. Ten pairs of 24 hrs starved adults were released at the centre of the petri plate, later covered with perforated aluminium foil and placed in BOD incubator at 25±2°C. Three replicates were maintained and observations were recorded at 24h of exposure.

Later, 100 grams of sesame seeds were treated with each treatment and were transferred to plastic containers. Ten pairs of freshly emerged *T. castaneum* adults were released into each plastic container and covered with aluminium foil having pores on it. Later plastic containers were placed in incubator (25°C and 55% RH). Beetle mortality (%) was calculated 1, 3, 5, 7 and 14 days of exposure by using Abbot's formula (Abbott, 1925).

3. results and discussion

The per cent repellency data observed at 24 hrs after release were in the range of 75.00-98.00 per cent. All the treatments resulted strong repellent activity against *T. castaneum (*Figure 1*)*. The highest per cent repellency was recorded in peppermint oil @ 5m kg-1. While, the lowest repellency was recorded in pyriproxyfen 10 EC @ 5 ppm.

**Figure 1: Repellent activity of essential oils and insect growth regulators on *Tribolium castaneum***

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At 1 DAT, there was significant difference observed on the adult mortality compared to untreated control (Table. 1). Deltamethrin 2.8 EC @ 1ppm recorded highest adult mortality (25.00%) followed by peppermint oil @ 5ml kg-1 (23.33%) but both the treatments found on par with each other. While, azadirachtin 1500 ppm @ 5ml kg-1 recorded 20.00% adult mortality followed by clove oil @ 5ml kg-1 (18.33%). Pyriproxyfen 10 EC @ 5 ppm recorded only 13.33% adult mortality. However, untreated control resulted no adult mortality. Gradually, the adult mortality increased in all treatments. At 3, 5 and 7 DAT, the highest adult mortality was recorded in peppermint oil @ 5ml kg-1 with 35.67, 44.66 and 56.00% mortality, respectively. However, deltamethrin 2.8 EC @ 1ppm found on par with the peppermint oil @ 5ml kg-1 at 3, 5 and 7 DAT. Therefore, peppermint oil @ 5ml kg-1was showing same efficacy as that of standard checks.

At 14 days after treatment also, peppermint oil @ 5ml kg-1 was found as best treatment with 62.33% adult mortality. The standard checks, azadirachtin 1500 ppm @ 5ml kg-1 and deltamethrin 2.8 EC @ 1ppm were also found effective and found on par with peppermint oil @ 5ml kg-1.

It is concluded that EOs and IGRs are showing similar results to that of standard checks. The use of EOs and IGRs proved as best alternate insecticides against storage pests. EOs and IGRs present a promising alternative to conventional insecticides for storage pest management as these have multiple level of mode of actions, thus the possibility of resistance development is also less probable. The findings of this study contribute to the development of new EO and IGR based formulations for improved efficacy and pest control even under change in optimal conditions.

Elnabawy et al. (2022)reported that clove oilhad a high repellency (100%) effect against *T. castaneum.* Aryal et al*.* (2023) also concluded that 10% sweet flag oil concentration showed highest repellent activity (98.75 %). The results of clove oil @ 5ml kg-1 are also in agreement with Alsudani et al. (2021) where pure clove oil resulted complete repellency of *T. castaneum* after 36 h of exposure.

Peppermint oil contains several bioactive components *viz*., menthol, menthone, limonene, carvone and pulegone which exhibit insecticidal properties (Khani *et al.,* 2012). Each bioactive component has varied mode of actions like, menthol, menthone, and pulegone disrupt the nervous system of insects, leading to paralysis and mortality. Limonene affects insect respiratory systems and has strong repellent properties. Carvone and Pulegone interfere with hormonal regulation in insects, reducing larval development. All these bioactive compounds are monoterpenes. Monoterpenes, which are often volatile and relatively lipophilic substances that can quickly enter insects via cuticle (contact), the respiratory system (fumigation) and the digestive system (ingestion) (Prates *et al.,* 1998). and impede their physiological processes, are primarily responsible for the insecticidal properties of many essential oils. The management of storage insects through essential oils is due to their diverse range of effects, including their insecticidal, antifeeding, repellent and ovicidal properties (Weaver and Subramanayam, 2000).

The results of peppermint oil @ 5ml kg-1 are in line with Alshaibani *et al*. (2024) who reported that 10% mint oil caused 70 per cent adult mortality of *T. castaneum* after 7 days after treatment. The results are also in accordance with Panezai *et al*. 2019 who found that peppermint oil caused 70% adult mortality of *Trogoderma granarium*. Kaviya *et al*. (2021) reported that 6% peppermint oil resulted in 76.00% adult mortality of *T. castaneum* in stored sesame. The essential oil of *Mentha piperita* (peppermint) has the potential to control two important stored product pests, *T. castaneum* and *Sitophilus granaries* (Atay *et al.,* 2024). The results of clove oil @ 5ml kg-1 are in line with Arora *et al.* (2018) who found that clove oil @ 25% recorded 100% mortality after 48 h of exposure against *T. castaneum*. Elnabawy *et al.* (2022) reported that clove oil @ 5% recorded 86.66 % against *T. castaneum* at 180 minutes of exposure.

**Table 1. Effect of essential oils and insect growth regulators on *Tribolium castaneum* in sesame**

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| --- | --- | --- | --- | --- | --- | --- |
| **S. No.** | **Treatments** | **1 DAT** | **3 DAT** | **5 DAT** | **7 DAT** | **14 DAT** |
| 1 | Clove oil @ 5ml kg-1 | 18.33±1.67bc | 28.00±0.00b | 39.66±1.67c | 45.33±1.67c | 53.66±1.67b |
| 2 | Peppermint oil 5ml kg-1 | 23.33±1.67ab | 35.67±1.67a | 44.66±1.67a | 56.00±0.00a | 63.33±1.67a |
| 3 | Pyriproxyfen 10 EC @ 5 ppm | 13.33±1.67cd | 20.00±2.89c | 27.33±1.67d | 32.33±3.33d | 37.00±2.89c |
| 4 | Azadirachtin 1500 ppm (Standard botanical check) @ 5ml kg-1 | 20.00±2.89b | 33.33±1.67ab | 41.00±2.89ab | 54.33±3.33ab | 62.33±4.41a |
| 5 | Deltamethrin 2.8 EC (Standard chemical check) @1 ppm | 25.00±2.89a | 34.33±3.33a | 42.33±3.33a | 52.66±1.67bc | 62.00±2.89a |
| 6 | Untreated control | 0.00±0.00e | 0.00±0.00e | 0.00±0.00e | 0.00±0.00e | 0.00±0.00d |
|  | F value | 18.40 | 13.95 | 13.90 | 33.60 | 21.47 |

*\*Mean±SE mortality of three replicates, means followed by same small letters are not significantly different according to DMRT.*

4. Conclusion

In the study, we used 100% pure essential oils and insect growth regulators on sesame seeds. They showed promising results based on their respective insecticidal properties. Although peppermint oil results were found to be on par with the results of neem oil and deltamethrin. In case of IGRs, pyriproxyfen provided adequate control, however, it can be further evaluated in combination with other biorational insecticides for complete control of stored grain pest. The results suggest that peppermint oil can be used as an alternative to synthetic insecticides for the management of *T. castaneum* in the storage of sesame seeds. Maintaining optimal conditions is necessary for improving the insecticidal performance to obtain better results. However, further research is needed to enhance their toxicity for long term storage through slow-release, carrier-based technologies, to ensure complete control, residue-free products for safe storage and export.

**ACKNOWLEDGMENT**

The authors would like to express gratitude for the support of PJTAU and ICAR-IIOR.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declares 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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