J. Crop Prot. **2025, 14 (3): 295-310**

Research Article

Fumigant toxicity, oviposition deterrence and repellency of three plant essential oils against *Callosobruchus maculatus* on five bean types

Marziyeh Namdari[1], Masumeh Ziaee[1], Seyed Ali Hemmati[1*] and Fatemeh Nasernakhaei[2]

1. Department of Plant Protection, Faculty of Agriculture, Shahid Chamran University of Ahvaz, Ahvaz, Iran.
2. Department of Genetic and Plant Production, Faculty of Agriculture, Shahid Chamran University of Ahvaz, Ahvaz, Iran.

Abstract: One of the most destructive pests affecting stored legumes is the bruchid beetle, *Callosobruchus maculatus* (F.). This study investigated the fumigant toxicity, oviposition deterrence, and repellency of three essential oils (EOs), including *Trachyspermum ammi* (L.) Sprague, *Cuminum cyminum* (L.), and *Melaleuca viminalis* (Sol. ex Gaertn.) against *C. maculatus* adults. The lethal concentrations (LC_{50}) for the EOs were determined as 1.727 µL/L air for *T. ammi*, 1.219 µL/L air for *C. cyminum*, and 1.622 µL/L air for *M. viminalis*, with a dose-dependent increase in adult mortality with rising EO concentrations. Oviposition deterrence was assessed on various bean types, including white kidney beans, common beans, cowpeas, navy beans, and red kidney beans. Notably, *T. ammi* oil at 5 µL/g of seeds completely inhibited oviposition, whereas 2 µL/g resulted in 88-94% inhibition. In contrast, *M. viminalis* oil showed the least deterrence at the same concentration, ranging from 60% to 77%. The control group exhibited significant variation in egg-laying across bean types, with cowpeas showing the highest egg count, followed by white kidney and common beans. All EOs effectively reduced both egg numbers and hatch rates. The repellent efficacy was highest in treated cowpeas, with *C. cyminum* oil exhibiting a notable repellent activity of 80%, compared to 46.66% for *T. ammi* and 33.33% for *M. viminalis* oils. Our findings underscore the potential of these oils as natural alternatives for managing *C. maculatus* infestations in stored legumes.

Keywords: Beans, mortality, essential oil, oviposition, repellent

Introduction

The protection of stored products, particularly grains and pulses, is a critical issue in agricultural practices worldwide. Insect pests pose a significant threat to these commodities, leading to both qualitative and quantitative losses that can have severe economic repercussions. Among the various culprits, storage beetles are notorious for causing extensive postharvest losses, spoilage, and diminished market demand for affected products (Ahmad *et al.*, 2021). Pulses, such as beans, lentils, and peas, are particularly vulnerable to

Handling Editor: Saeid Moharramipour

*Corresponding authors: sa.hemmati@scu.ac.ir
Received: 19 July 2025, Accepted: 20 October 2025
Published online: 01 November 2025

damage from weevils and beetles during both field cultivation and storage (Stathas *et al.*, 2023). One of the most prominent pests affecting stored legumes is the bruchid beetle, *Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae). This insect plays a destructive role not only in agricultural fields but also during storage, particularly in warm, Mediterranean regions where it thrives. The beetles can inflict considerable damage on stored legumes of the genus Phaseolus, leading to significant losses in seed weight, germination rate, and overall market value (Hill, 2002; Rees, 2007).

To combat the pest, synthetic chemical pesticides have traditionally been employed. However, the widespread use of these chemicals has led to numerous problems. These include insect resistance development, environmental hazards, risks to human health, and the presence of pesticide residues that can affect end consumers (Ahmad *et al.*, 2024). Protecting stored products with plant-based products, while considering environmental concerns, has highlighted the need for a new generation of pesticides (Pathak *et al.*, 2022). As a result, there is an increasing need to explore alternative pest control methods that are more environmentally friendly and sustainable. One promising approach is using plant-based products as natural pesticides. The search for new-generation pesticides has highlighted the potential of plant compounds that exhibit a wide range of insecticidal activities. Many of these compounds have toxic properties, as well as repellent effects and deterrent characteristics that can inhibit oviposition and feeding behaviors (Enan, 2001). Essential oils (EOs) derived from various plants have attracted particular attention due to their low toxicity to humans and mammals, as well as their medicinal and nutritional benefits. Moreover, these EOs tend to decompose rapidly in nature, reducing their environmental impacts (Ivanova *et al.*, 2025; Sharifi-Rad *et al.*, 2017). The effectiveness of these natural products has led to growing interest among pesticide companies in developing plant-based insecticides as viable alternatives to synthetic chemicals (Isman, 2000; Isman *et al.*, 2010). The exploration of native plants for their insecticidal properties represents a crucial first step in optimizing the production of plant-derived pesticides. By assessing the insecticidal potential of local flora, researchers can identify species with optimal efficacy against specific pests. This approach not only supports sustainable agricultural practices but also aligns with global efforts to reduce reliance on harmful chemical pesticides. In light of these considerations, this study aimed to evaluate the fumigant toxicity, oviposition deterrence, and repellency of three selected plant essential oils against *C. maculatus*. The findings could lead to the development of effective and environmentally friendly pest control strategies that protect stored pulses while minimizing risks to human health and the environment.

Materials and Methods

Bean preparation

Various types of beans, including white kidney beans, common beans, cowpeas, navy beans, and red kidney beans, were purchased from local markets for experimental purposes. To ensure consistency in moisture content, the bean seeds were maintained under controlled conditions of 25 ± 1 ºC and 60 ± 5% relative humidity (R.H.) for one week, allowing them to acclimate to the environmental R.H.

Insect rearing

Callosobruchus maculatus was collected from infested cowpeas stored in a warehouse. The *C. maculatus* rearing method was similar to that of Zandi Sohani and Ramazani (2012). A stock culture of *C. maculatus* was established by rearing the insects on the beans above under the same controlled conditions in an incubator (Grouc Co, Tehran, Iran) set at 25 ± 1 ºC, 60 ± 5% R.H., and continuous darkness. The colony was maintained for five generations without any exposure to insecticides. Adults aged 1-3 days old were used in the experiments.

Plant materials and extraction of EOs

The seeds of *Trachyspermum ammi* (L.) Sprague (Apiaceae) and *Cuminum cyminum*

(L.) (Apiaceae) were acquired from local markets in Mashhad. Meanwhile, leaves from *Melaleuca viminalis* (Sol. ex Gaertn.) (Myrtaceae) were collected from trees at the Faculty of Agriculture, Shahid Chamran University of Ahvaz, Ahvaz, Iran. The EOs from these plants were extracted through hydrodistillation using a Clevenger-type apparatus. For the extraction process, approximately 50 grams of *T. ammi* and *C. cyminum* seeds, or 100 grams of *M. viminalis* leaves, were milled using a National dry mill (MJ-176NR, Osaka, Japan) and placed in a round-bottom flask over water, with the temperature maintained at approximately 100 ºC. After a four-hour distillation period, the oils that accumulated in the reservoir were collected. To ensure purity, anhydrous sodium sulfate was used to remove residual water after extraction. The extracted oils were then stored in a refrigerator at 4 ºC to preserve their integrity for subsequent experiments.

Fumigant toxicity of EOs on *Callosobruchus maculatus* adults

To evaluate the fumigant toxicity of the essential oils, 10 adults of *C. maculatus* (1-3 days old) were placed in each vial with six replications per treatment. Filter papers (Whatman No. 1) were placed beneath the caps of the glass vials (140 mL) to facilitate the exposure to the oils. A preliminary concentration-setting experiment was performed to identify effective concentrations that would result in 20-80% mortality after 24 h of exposure. Employing a symmetric five-dose design, as outlined by Robertson *et al.* (1984), specific concentrations were selected: *T. ammi* at 1, 1.3, 1.7, 2.3, and 2.7 µL/L air; *C. cyminum* at 1.1, 1.5, 1.9, 2.4, and 3.2 µL/L air; and *M. viminalis* at 0.5, 0.8, 1.1, 1.6, and 2.4 µL/L air were impregnated onto the filter papers. The vials were tightly sealed and incubated at 25 ± 1 ºC, 60 ± 5% R.H. in continuous darkness. An untreated filter paper served as a control group. Mortality was assessed after 24 h. The lethal concentration (LC_{50}) was subsequently calculated to evaluate the efficacy of each EO.

The oviposition deterrence effects of EOs on *Callosobruchus maculatus* adults

To evaluate the oviposition-deterrent effects of the essential oils on *C. maculatus*, an experiment was conducted using 10 grams of each bean seed type placed in glass vials (140 mL). Each vial received 0.02 or 0.05 µL/g of the respective EOs, which were thoroughly mixed with the seeds. A pair of adult beetles (one male and one female) was introduced into each vial. Ten replicates were prepared for each oil concentration. The vials were maintained for five days at 25 ± 1 ºC, 60 ± 5% R.H., and in continuous darkness. After this exposure period, the number of eggs laid on the seeds was counted. The percentage of oviposition deterrence was calculated using the following formula (Elhag, 2000):

Oviposition deterrence = (NC-NT)/NC × 100, where NC represents the number of eggs in the control group and NT represents the number of eggs in the treatment group.

The repellent effects of EOs on *C. maculatus* adults

An olfactometer was used to investigate the repellent effects of the essential oils (Nikooei and Moharramipour, 2011). Fifteen minutes before the experiment began, the device was turned on to allow air to enter the olfactometer after passing through activated charcoal. Each EO was applied at 2000 mg/kg and sprayed onto 10 g of bean seeds. Untreated beans served as the control, placed in one arm, and treated beans with each oil in the other arm of the olfactometer. The tested adults were kept without food for 24 h. An adult was released individually at the entrance of the main arm, and the experiment was replicated 30 times for each essential oil. To eliminate the effects of arm side, the treated beans were placed in the right arm for 15 replications and in the left arm for the other 15 replications. After each EO test was completed, the device's arms were washed with acetone to eliminate the odor and the effects of the previous oil.

The repellence percentages of the EOs were calculated according to the following formula:

$$R(\%) = \frac{C - E}{T} \times 100;$$

Where R is the percentage of repellent effect, C is the number of adults in the control arm, E is the number of adults in the essential oil treatment arm, and T is the total number of adults tested.

Data analysis

The normality of the data was examined by the Shapiro-Wilk test. For the fumigant toxicity test, the LC_{50} values and 95% confidence limits were estimated by probit analysis. The mortality and repellent data were subjected to one-way analysis of variance (ANOVA). For each dose rate, data on oviposition deterrence, egg number, and hatch rate were analyzed using one-way ANOVA to determine differences among bean types or essential oils. Tukey-Kramer honestly significant difference (HSD) test was used to determine significant differences. All analyses were performed using SPSS 16.0 software (IBM Corp., 2007).

Results

The lethal concentrations (LC_{50}) of *T. ammi*, *C. cyminum*, and *M. viminalis* EOs are presented in Table 1. Based on LC_{50} values and their confidence limits, the beetles were more susceptible to the *C. cyminum* oil (Table 1).

For the fumigant toxicity, there were significant differences among five different concentrations of *T. ammi* ($F_{4,25} = 69.286$, $P < 0.001$), *C. cyminum* ($F_{4,25} = 105.50$, $P < 0.001$), and *M. viminalis* oil ($F_{4,25} = 68.315$, $P < 0.001$). The highest mortality percentage was observed when adults were exposed to 2.7 µL/L air of *T. ammi* oil. For *C. cyminum* oil, there were no significant differences between 2.4 and 3.2 µL/L air concentrations, which caused 88.33 and 95% mortality, respectively. For *M. viminalis* oil, the highest mortality was observed at 1.6 and 2.4 µL/L air (Fig. 1).

The results of the oviposition deterrence of *C. maculatus* adults when exposed to essential oils on different beans are summarized in Figure 2. Significant differences were observed among the various beans exposed to 0.02 µL/g of seeds ($F4,26 = 3.078$, $P = 0.034$). The *T. ammi* oil at 0.05 µL/g of seeds achieved 100% deterrence. For 0.02 µL of *C. cyminum* oil/g seeds, the highest oviposition deterrence was recorded when adults fed on cowpeas (88.57%) ($F_{4,26}= 34.264$, $P < 0.001$), while for 0.05 µL/g the highest deterrence value was found in cowpeas, navy beans, and red kidney beans ($F_{4,26}= 5.918$, $P < 0.001$). For *M. viminalis* oil, the highest oviposition deterrence was observed when adults were exposed to treated cowpeas at both 0.02 µL/g of seeds ($F_{4,26} = 20.018$, $P < 0.001$) and 0.05 µL/g of seeds ($F_{4,26} = 5.188$, $P < 0.001$) (Fig. 2).

At the rate of 0.02 µL/g of seeds, the highest oviposition deterrence was observed in all bean seeds including white kidney beans ($F_{2,15} = 144.368$, $P < 0.001$), common beans ($F_{2,15} = 36.935$, $P < 0.001$), cowpeas ($F_{2,15} = 100.849$, $P < 0.001$), navy beans ($F_{2,15} = 172.193$, $P < 0.001$), and red kidney beans ($F_{2,15} = 104.597$, $P < 0.001$) treated with *T. ammi* oil in comparison with *C. cyminum* and *M. viminalis* oils. For 0.05 µL/g of seeds, *T. ammi* oil caused the highest oviposition deterrence in white kidney beans ($F_{2,15} = 36.60$, $P < 0.001$), common beans ($F_{2,15} = 47.50$, $P < 0.001$), cowpeas ($F_{2,15} = 15.0$, $P < 0.001$), navy beans ($F_{2,15} = 47.50$, $P < 0.001$), and red kidney beans ($F_{2,15} = 14.231$, $P < 0.001$) (Fig. 3).

Table 1 Lethal concentrations (LC_{50}) of three essential oils against *Callosobruchus maculatus* adults 24 h after exposure.

EO	LC_{50} (µL/L air)	95% confidence limits	Slope ± SE	Chi-square (df)	*P*-value
Trachyspermum ammi	1.727	1.526-1.965	2.84 ± 0.48	1.987 (3)	0.575
Cuminum cyminum	1.219	1.023-1.369	3.83 ± 0.56	1.098 (3)	0.777
Melaleuca viminalis	1.622	1.350-2.117	1.94 ± 0.34	1.158 (3)	0.763

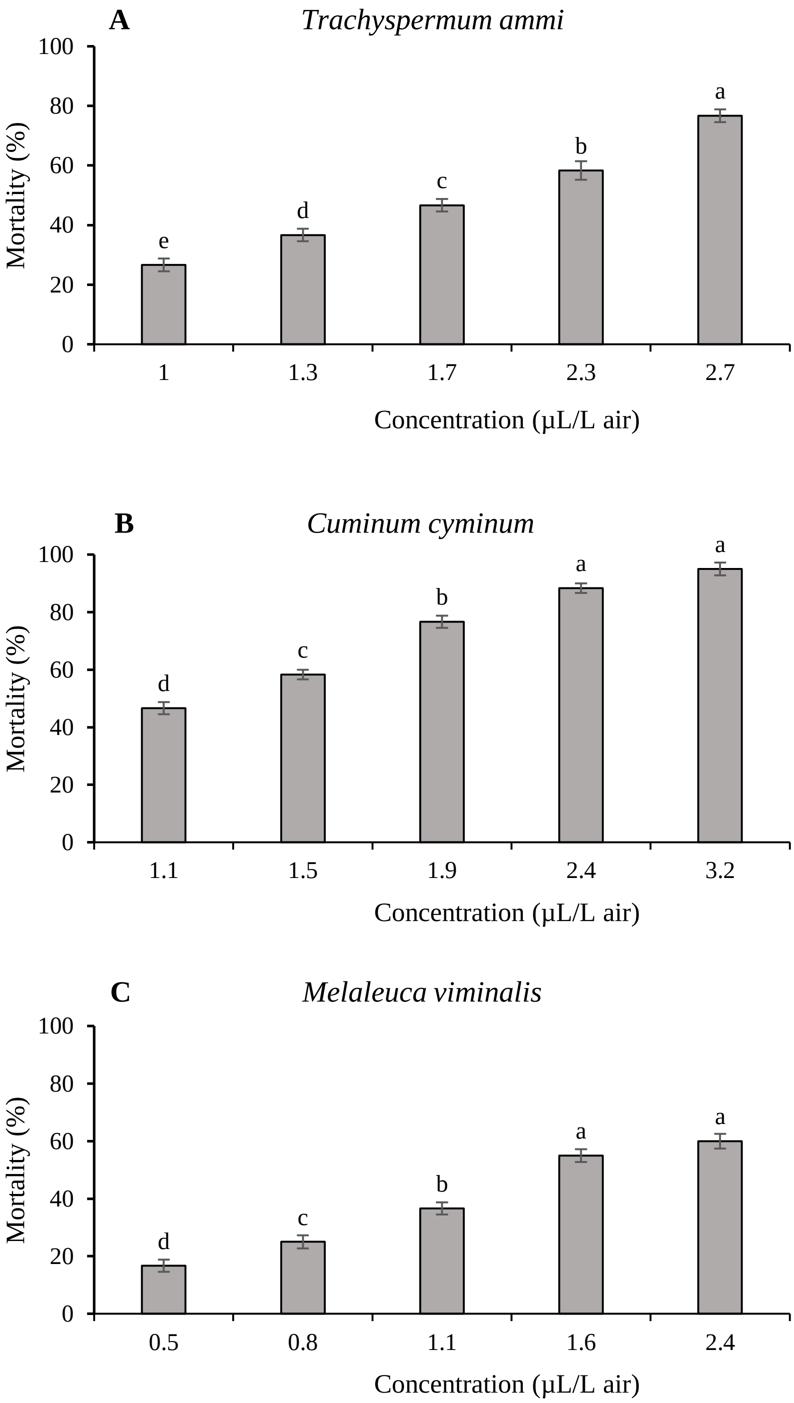

Figure 1 Mean (± SE) mortality of Callosobruchus maculatus adults due to fumigant toxicity of Trachyspermum ammi (A), Cuminum cyminum (B), and Melaleuca viminalis (C) essential oils 24 h after exposure. Means followed by the same letter are not significantly different using Tukey-Kramer (HSD) test at P < 0. 5.

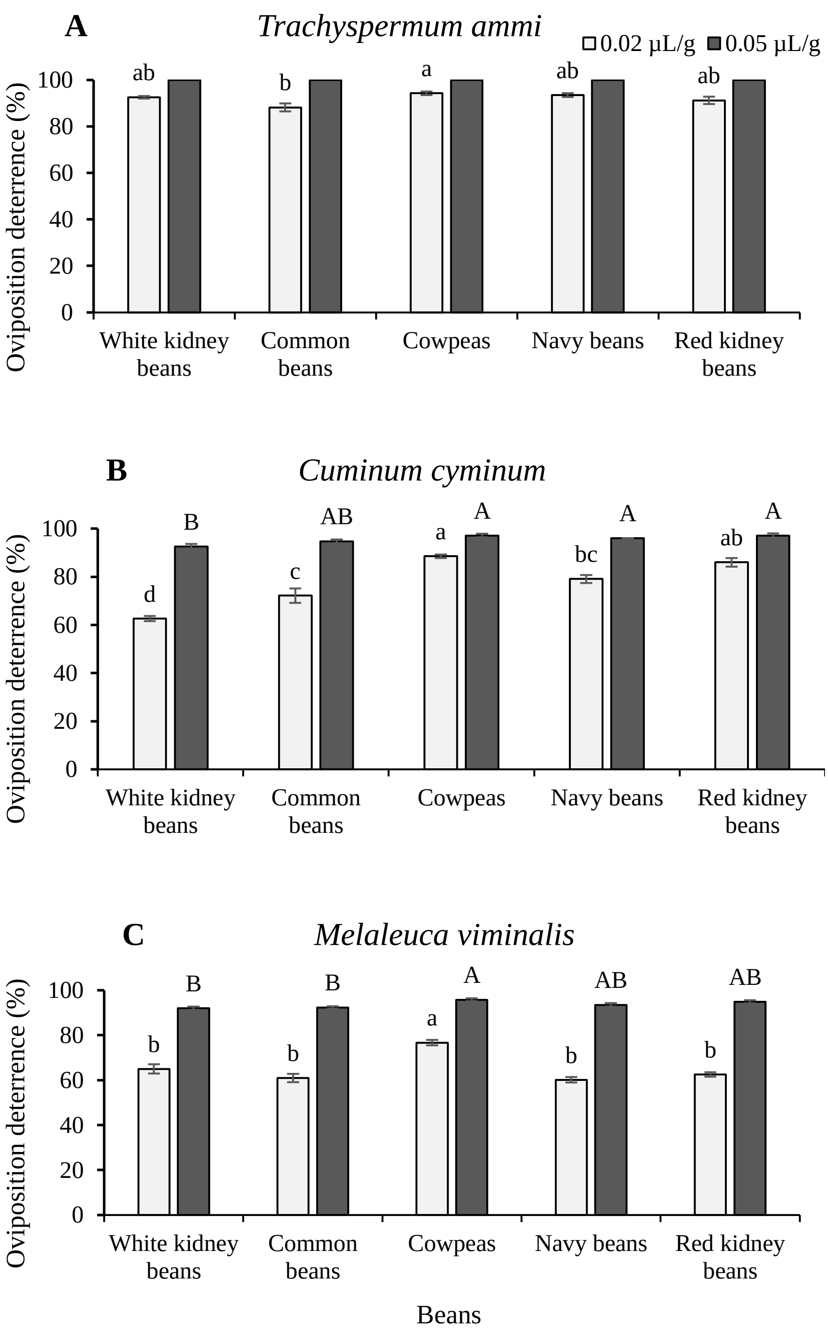

Figure 2 Mean (± SE) oviposition deterrence of *Callosobruchus maculatus* when exposed to *Trachyspermum ammi* (A), *Cuminum cyminum* (B), and *Melaleuca viminalis* (C) essential oils on five different beans. Means followed by the same lowercase letter for 0.02 µL/g and same uppercase letter for 0.05 µL/g of seeds are not significantly different using Tukey-Kramer (HSD) test at $P < 0.05$.

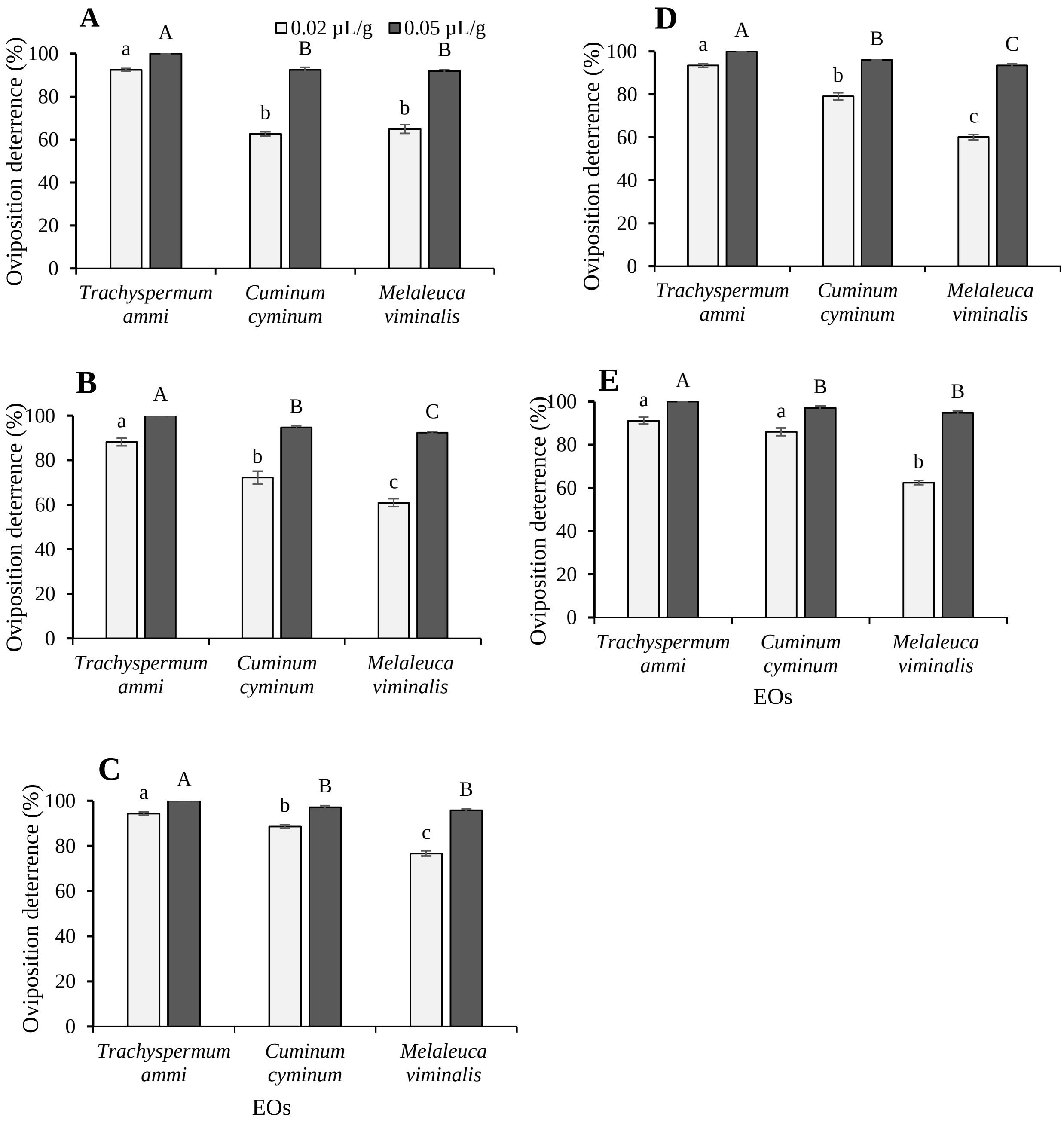

Figure 3 Mean (± SE) oviposition deterrence of *Callosobruchus maculatus* when exposed to three essential oils on white kidney beans (A), common beans (B), cowpeas (C), navy beans (D), and red kidney beans (E). Means followed by the same lowercase letter for 0.02 µL/g and same uppercase letter for 0.05 µL/g of seeds are not significantly different using Tukey-Kramer (HSD) test at $P < 0.05$.

The number of eggs laid by *C. maculatus* differed significantly among the bean types in the control ($F_{4,25} = 7.462$; $P < 0.001$), and the highest number of eggs was found on cowpeas, followed by white kidney and common beans. Also, significant differences were observed when the seeds were treated with *T. ammi* oil at 0.02 µL/g ($F_{4,25}$ = 3.978; P < 0.001). No eggs were laid on *T. ammi* oil-treated seeds at 0.05 µL/g of seeds; for *C. cyminum* oil, the highest eggs were observed when adults were exposed to white kidney beans treated with 0.02 µL/g of seeds ($F_{4,25}$ = 40.733; P < 0.001), followed by treated common beans. There were no significant differences among bean seeds when exposed to the *C. cyminum* oil at the rate of 0.05 µL/g of seeds. For *M. viminalis* oil, the highest number of eggs was laid in common beans treated with 0.02 µL/g. However, there were no significant differences among bean seeds when exposed to 0.05 µL/g of seeds (Fig. 4).

The results of hatch rates of *C. maculatus* eggs are presented in Figure 5. In the control group, the highest hatch rate was recorded on cowpeas, while there were no significant differences among other seed types ($F_{4,25}$ = 6.864; P < 0.001). No eggs hatched across all bean seed types treated with both *T. ammi* oil concentration rates. A small percentage of eggs were hatched in white kidney and common beans treated with 0.02 µL/g of seeds of *C. cyminum* oil, which did not exceed 6% ($F_{4,25}$ = 3.750; P = 0.016). For *C. cyminum* and *M. viminalis* oils, no eggs were hatched at the rate of 0.05 µL/g of seeds. For *M. viminalis* oil, there were no significant differences among bean seeds when exposed to 0.02 µL/g of seeds ($F_{4,25}$ = 1.243; P = 0.318) (Fig. 5).

The repellent effects of the essential oils are presented in Figure 6. For *T. ammi* oil, no significant differences were observed among bean seeds ($F_{4,10}$ = 3.071; P = 0.068). However, the repellent activity was high in treated cowpeas, which was 46.66%. In the case of *C. cyminum* oil, the highest repellent activity was found in cowpea (80%), followed by navy beans (66.66%). However, the lowest repellent activity was observed in white kidney beans ($F_{4,10}$ = 11.50; P < 0.001). For *M. viminalis* oil, no significant differences among bean seeds were recorded, and the repellent activity did not exceed 33.33% in the case of treated cowpea ($F_{4,10}$ = 3.125; P = 0.066) (Fig. 6).

Discussion

The increasing prevalence of *C. maculatus*, a significant pest of stored legumes, highlights the urgent need for eco-friendly pest control methods. This study investigates the efficacy of various EOs, particularly *T. ammi*, *C. cyminum*, and *M. viminalis*, in managing *C. maculatus* populations. The findings align with previous studies indicating that EOs can serve as effective bio-pesticides, exhibiting varying levels of fumigant toxicity and deterrence against *C. maculatus*. For example, the fumigant toxicity of essential oils from four Ocimum species was assessed against *C. maculatus* adults. Notably, *O. canum* oil resulted in the highest mortality rate (94%) in adults. Additionally, minimal oviposition was observed in the treatments with *O. canum* and *O. basilicum* L. oils, with only 0.6 and 0.8 eggs, respectively, demonstrating significant differences compared to other treatments and the control group (Keita *et al.*, 2000). In another study, at the highest dose of 25 mL of oil per 8 mL vial, *O. basilicum* achieved an 80% mortality rate, while *O. gratissimum* L. recorded a 70% mortality. The LC_{50} values of the oils were 0.66 mL/mL for *O. basilicum* and 1.06 mL/mL for *O. gratissimum* (Keita *et al.*, 2001).

Our results indicated that *C. cyminum* oil had the lowest LC_{50} value, suggesting that *C. maculatus* was particularly susceptible to it compared with other oils. Raja *et al.* (2001) found that the highest adult mortality of *C. maculatus* occurred with *Mentha spicata* L. (100% mortality), followed by *Mentha piperita* L. (70%) and *Mentha arvensis* L. (55%) oils, assessed one month after treatment. In their study, cowpea seed protection lasted up to 2 months post-treatment, due to reduced oviposition, low adult emergence, and high adult mortality during this period. However, pest damage increased significantly by four months post-treatment.

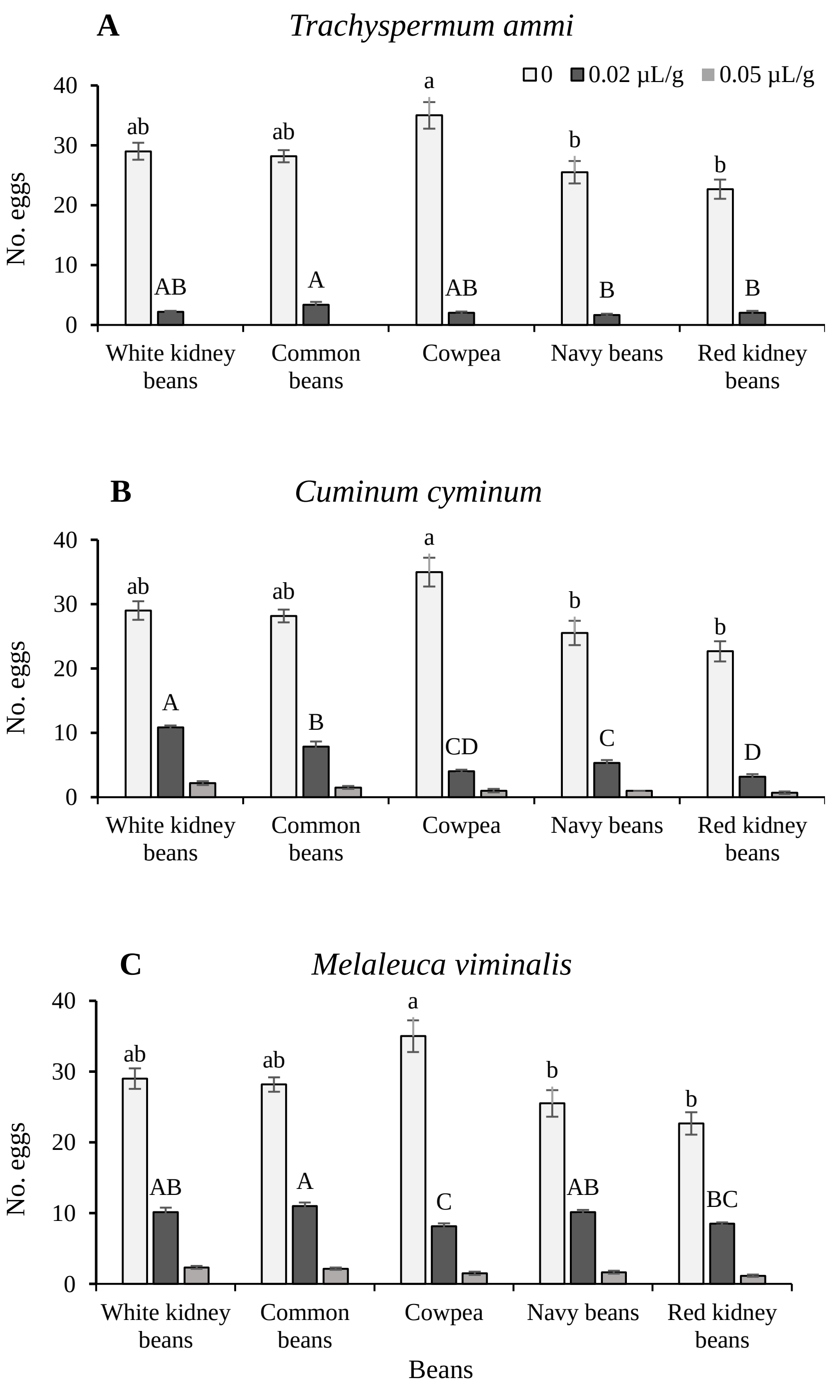

Figure 4 Mean (± SE) number of *Callosobruchus maculatus* eggs when exposed to *Trachyspermum ammi* (A), *Cuminum cyminum* (B), and *Melaleuca viminalis* (C) essential oils. Means followed by the same lowercase letter for control and same uppercase letter for 0.02 μL/g are not significantly different using Tukey-Kramer (HSD) test at $P < 0.05$.

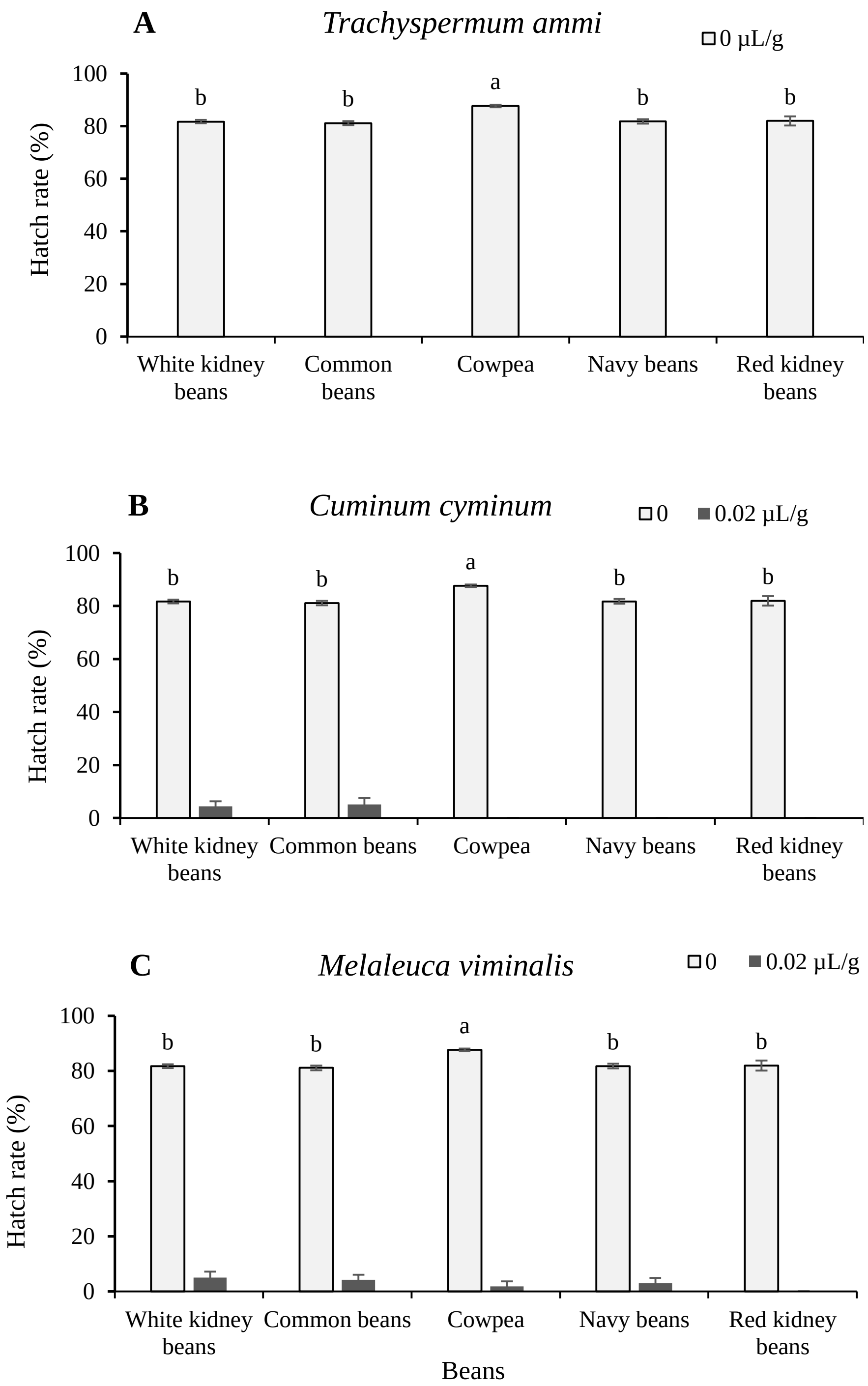

Figure 5 Mean (± SE) hatch rates of *Callosobruchus maculatus* eggs when exposed to *Trachyspermum ammi* (A), *Cuminum cyminum* (B), and *Melaleuca viminalis* (C) essential oils. Means followed by the same lowercase letter for control are not significantly different using Tukey-Kramer (HSD) test at $P < 0.05$.

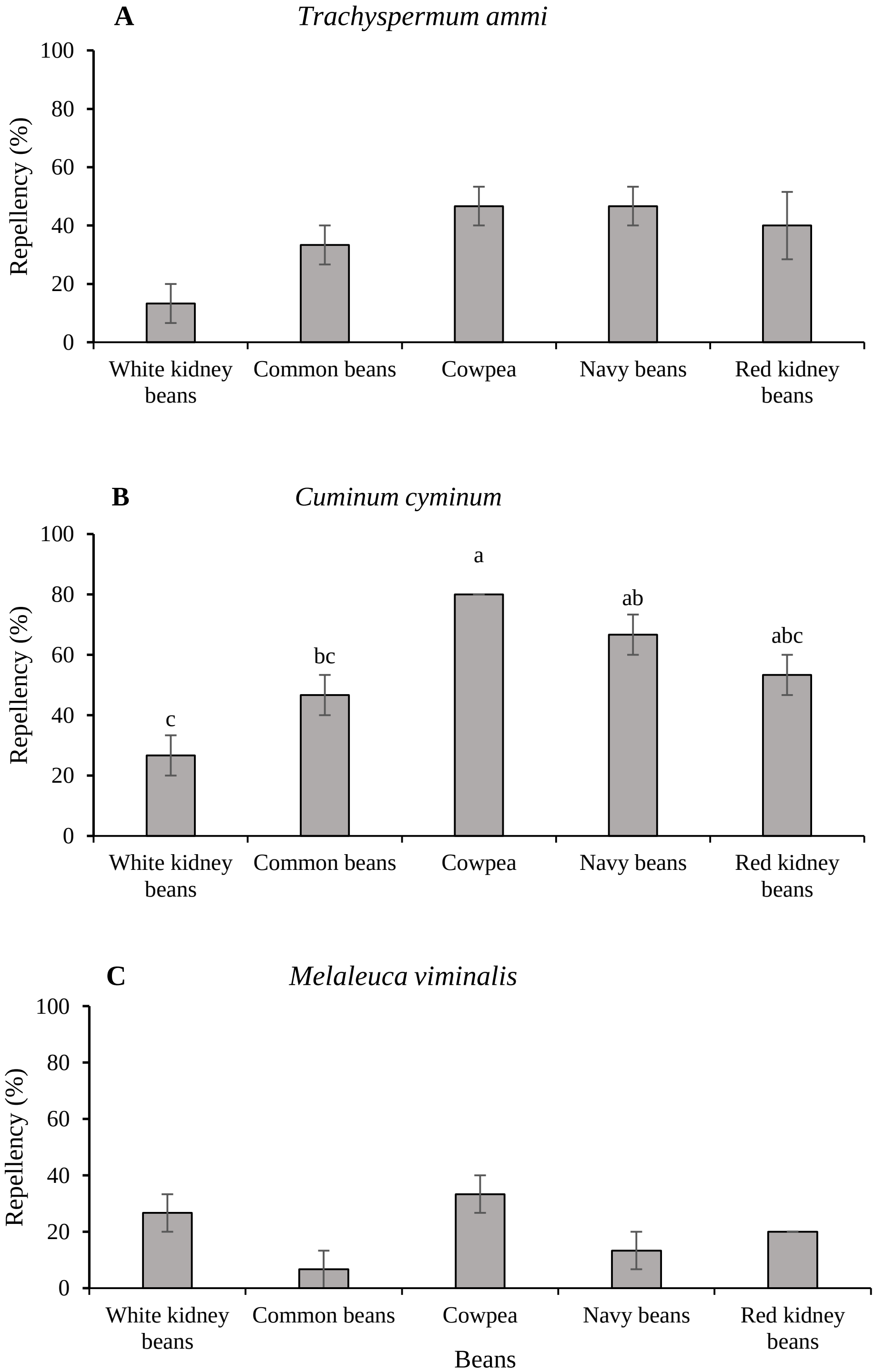

Figure 6 Mean (± SE) repellent effects of *Trachyspermum ammi* (A), *Cuminum cyminum* (B), and *Melaleuca viminalis* (C) essential oils against *Callosobruchus maculatus*. Means followed by different letters are significantly different using Tukey-Kramer (HSD) test at $P < 0.05$.

A further study reported LC_{50} values for the essential oils against adults of *Tribolium castaneum* Herbst as follows: *C. cyminum* (16.26 µL), *Piper nigrum* L. (15.26 µL), and *Foeniculum vulgare* Mill. (18.55 µL) (Chaubey, 2007). Sahaf and Moharramipour (2008) found that the LC_{50} for different life stages of *C. maculatus* exposed to *T. ammi* oil were 1.01 µL/L air for eggs, 2.50 µL/L air for larvae, and 0.90 µL/L air for adults, indicating that *T. ammi* was more toxic across all growth stages than the other EOs used in their study (*Vitex pseudo-negundo* Hand I. MZT.). Our study confirms that all three tested oils, particularly *T. ammi*, were toxic to adult *C. maculatus*. Other plant EOs also demonstrated fumigant activity against various stored product pests; for instance, *O. gratissimum* oil at 1 µL/L air caused 98%, 99%, and 100% mortality in *Rhyzopertha dominica* F., *Oryzaephilus surinamensis* (L.), and *Callosobruchus chinensis* L., respectively, within 24 hours post-treatment (Ogendo *et al.*, 2008). Ilboudo *et al.* (2010) reported that *Ocimum americanum* L. oil was particularly toxic to adults of *C. maculatus*, with an LC50 of 0.23 µL/L, and was more effective than other tested oils, such as *Hyptis suaveolens* (L.) Poit., *Hyptis spicigera* Lam., and *Lippia multiflora* Moldenke. The comparative analysis of essential oils suggests prioritizing specific oils in pest management strategies. Evaluating the activity of ten Apiaceae species indicated that oils from *Anethum graveolens* (Dill), *Carum carvi* L., and *C. cyminum* exhibited strong fumigant toxicity against the adults of *Sitophilus oryzae* L. The LC_{50} values for these oils were reported as 2.45 mg/L air for *C. carvi*, 3.29 mg/L air for *A. graveolens*, and 4.75 mg/L air for *C. cyminum* (Kim *et al.*, 2013). Additionally, recent findings showed LC_{50} values of 0.421 and 0.271 mL/mL for *M. piperita*, and 0.135 and 0.136 mL/mL for *C. cyminum* oil against *T. castaneum* and *S. oryzae*, respectively (Lashgari *et al.*, 2014).

The susceptibility of insect species to EOs varies. Adults of *O. surinamensis* (LC_{50} = 1.69 µL/L air) were significantly more susceptible to *T. ammi* oil than *R. dominica* (LC_{50} = 19.01 µL/L air) and *Tribolium confusum* Jacquelin du Val. (LC_{50} = 58.70 µL/L air) at 24 h length of exposure to this oil (Shokri Habashi *et al.*, 2011). Ziaee *et al.* (2014) documented high fumigant toxicity of *T. ammi* oil and also essential oil-loaded nanogel against *R. dominica* and *T. confusum* adults. Our results indicated that mortality increased with increasing oil concentration. The findings from Kedia *et al.* (2015) further emphasized the importance of concentration in determining the effectiveness of *C. cyminum* oil. Moreover, the higher sensitivity of *C. chinensis* compared to *S. oryzae* in their studies suggests that optimal concentrations must be identified for each species to enhance EOs' activity.

In our study, significant oviposition deterrence was observed with *T. ammi* and *C. cyminum* oils, suggesting that these oils could disrupt the reproductive cycle of *C. maculatus*, thereby reducing its population growth. This finding is consistent with earlier studies, such as the one by Boeke *et al.* (2004), who mentioned that *C. maculatus* adults on beans treated with *Capsicum frutescens* L., *Tagetes minuta* L., and *Tephrosia vogelii* Hook f. laid fewer eggs in the first 24-h period than the ones on untreated beans. Additionally, the work by Nyamador *et al.* (2010) indicated that the eggs and adults of *C. maculatus* were susceptible to EOs, whereas *Callosobruchus subinnotatus* (Pic.) showed greater tolerance, suggesting that pest management strategies may need to be tailored to species-specific responses to EOs. This differential sensitivity is crucial for developing targeted interventions that maximize efficacy against specific pests. Based on their investigations, *Cymbopogon giganteus* Chiov. oil was toxic to adults of both species, while *Cymbopogon nardus* (L.) oil showed better ovicidal activity.

The findings from this study highlight the significant potential of *C. cyminum* oil as a natural repellent against *C. maculatus*. The observed high repellent activity aligns with previous research indicating that various EOs can effectively deter insect pests. For instance, Boeke *et al.* (2004) investigated 33 African plant oils. They reported that *Clausena anisata*

(Willd.) Hook, *Dracaena arborea* (Willd.) Link, *T. vogelii*, *Momordica charantia* L., and *Blumea aurita* (L.) showed repellent properties against *C. maculatus*. This finding suggests that traditional knowledge regarding plant-based repellents can be leveraged to enhance modern pest management practices. Moreover, the comprehensive evaluation by Upadhyay *et al.* (2007) into 14 essential oils, including *C. cyminum*, underscores the multifaceted role of plant oils in managing pest populations. The reported repellent and antifeedant effects indicated that these oils not only had the potential to repel pests but also to inhibit their feeding behavior, thus potentially reducing damage to stored products. The findings from Khodadoust *et al.* (2011) further confirmed the effectiveness of *C. cyminum* and *T. ammi* oils against other pests, showcasing their broad-spectrum efficacy. As reported in their study, 0.7 µL of *C. cyminum* and *T. ammi* oil had 100% and 73.33% repellency against *T. confusum*, and 100% and 80% repellency against *Ephestia kuehniella* Zeller, respectively.

In conclusion, the results underscore the potential of specific essential oils as eco-friendly alternatives for managing *C. maculatus* populations, thereby contributing to sustainable agricultural practices in stored legume pest control. This is particularly crucial in light of growing concerns about pesticide resistance and the environmental impacts of chemical use in agriculture. Future research should focus on field trials and the formulation of these EOs to develop practical applications in agricultural settings, ensuring a balance between pest management and environmental sustainability. Overall, this study contributes valuable insights into the potential of essential oils as natural pest control agents, paving the way for innovative strategies in stored legume pest management.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Author contributions

Masumeh Ziaee and Seyed Ali Hemmati conceived and designed the experiments; Marziyeh Namdari performed the experiments; Masumeh Ziaee analyzed the data and wrote the original draft of the paper; Seyed Ali Hemmati reviewed and edited the paper. Fatemeh Nasernakhaei was involved in the methodology. All authors have read and approved the final manuscript.

Acknowledgements

This research was financially supported by Shahid Chamran University of Ahvaz, Ahvaz, Iran (Grant No. SCU.AP1402.39134), which is greatly appreciated.

References

Ahmad, M. F., Ahmad, F. A., Alsayegh, A. A., Zeyaullah, M., AlShahrani, A. M., Muzammil, K., Saati, A. A., Wahab, S., Elbendary, E. Y., Kambal, N., Abdelrahman, M. H. and Hussain, S. 2024. Pesticides impacts on human health and the environment with their mechanisms of action and possible countermeasures. Heliyon, 10: e29128.

Ahmad, R., Hassan, S., Ahmad, S., Nighat, S., Devi, Y. K., Javeed, K., Usmani, S., Ansari, M. J., Erturk, S. and Alkan, M. 2021. Stored grain pests and current advances for their management. In: Ahiduzzaman, M. D (Ed.), Postharvest Technology-Recent Advances, New Perspectives and Applications. IntechOpen Limited, London, pp. 1-37.

Boeke, S. J., Baumgart, I. R., van Loon, J. J. A., van Huis, A., Dicke, M. and Kossou, D. K. 2004. Toxicity and repellence of african plants traditionally used for the protection of stored cowpea against *Callosobruchus maculatus*. Journal of Stored Products Research, 40: 423-438.

Chaubey, M. K. 2007. Toxicity of essential oils from *Cuminum cyminum* (Umbelifera), *Piper nigrum* (Piperaceae) and *Foeniculum vulgare* (Umbelifera) against stored products beetle

Tribolium castaneum Herbst (Coleoptera: Tenebrionidae). EJEAFChe, Electronic Journal of Environmental, Agricultural and Food Chemistry 6: 1719-1727.

Elhag, E. A. 2000. Deterrent effects of some botanical products on oviposition of the cowpea bruchid *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). International Journal of Pest Management, 46: 109-113.

Enan, E. 2001. Insecticidal activity of essential oils: Octopaminergic sites of action. Comparative Biochemistry and Physiology-Part C: Toxicology Pharmacology, 130: 325-337.

Hill, D. S. 2002. Types of damage. In: Pests of stored foodstuffs and their control. Kluwer Academic Publishers, Malaysia, 71-78.

IBM Corp. 2007. IBM SPSS Statistics for Windows Version 16.0, SPSS Inc, IBM Corporation, Chicago.

Ilboudo, Z., Dabiré, L. C. B., Nébié, R. C. H., Dicko, I. O., Dugravot, S., Cortesero, A. M. and Sanon, A. 2010. Biological activity and persistence of four essential oils towards the main pest of stored cowpeas, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). Journal of Stored Products Research, 46: 124-128.

Isman, M., Miresmailli, S. and Machial, C. 2010. Commercial opportunities for pesticides based on plant essential oils in agriculture, industry and consumer products. Phytochemistry Reviews, 10: 197-204.

Isman, M. B. 2000. Plant essential oils for pest and disease management. Crop Protection, 19: 603-608.

Ivanova, S., Gvozdeva, Y., Staynova, R., Grekova-Kafalova, D., Nalbantova, V., Benbassat, N., Koleva, N. and Ivanov, K. 2025. Essential oils–a review of the natural evolution of applications and some future perspectives. Pharmacia, 72: 1-12.

Kedia, A., Prakash, B., Mishra, P. K., Dwivedy, A. K. and Dubey, N. K. 2015. Biological activities of *Cuminum cyminum* seed oil and its major components against *Callosobruchus chinensis* and *Sitophilus oryzae*. Journal of Asia-Pacific Entomology, 18: 383-388.

Keita, S. M., Vincent, C., Schmit, J. P., Arnason, J. T. and Bélanger, A. 2001. Efficacy of essential oil of *Ocimum basilicum* L. and *O. gratissimum* L. applied as an insecticidal fumigant and powder to control *Callosobruchus maculatus* (Fab.) [Coleoptera: Bruchidae]. Journal of Stored Products Research, 37: 339-349.

Keita, S. M., Vincent, C., Schmit, J. P., Ramaswamy, S. and Belanger, A. 2000. Effect of various essential oils on *Callosobruchus maculatus* (F.)(Coleoptera: Bruchidae). Journal of Stored Products Research, 36: 355-364.

Khodadoust, M., Moharramipour, S. and Imani, S. 2011. Repellent activity of *Cuminim cyminum* and *Carum copticum* essential oils on two stored product pests. In: The Second National Conference on Pest Control Management, Shahid Bahonar University, Kerman, PESTMAN02_028.

Kim, S.-W., Kang, J. and Park, I.-K. 2013. Fumigant toxicity of apiaceae essential oils and their constituents against *Sitophilus oryzae* and their acetylcholinesterase inhibitory activity. Journal of Asia-Pacific Entomology, 16: 443-448.

Lashgari, A., Mashayekhi, S., Javadzadeh, M. and Marzban, R. 2014. Effect of *Mentha piperita* and *Cuminum cyminum* essential oil on *Tribolium castaneum* and *Sitophilus oryzae*. Archives of Phytopathology and Plant Protection, 47: 324-329.

Nikooei, M. and Moharramipour, S. 2011. Fumigant toxicity and repellency effects of essential oil of *Salvia mirzayanii* on *Callosobruchus maculatus* (Col.: Bruchidae) and *Tribolium confusum* (Col.: Tenebrionidae). Journal of Entomological Society of Iran, 30: 17-30.

Nyamador, W. S., Ketoh, G. K., Amévoin, K., Nuto, Y., Koumaglo, H. K. and Glitho, I. A. 2010. Variation in the susceptibility of two *Callosobruchus* species to essential oils. Journal of Stored Products Research, 46: 48-51.

Ogendo, J. O., Kostyukovsky, M., Ravid, U., Matasyoh, J. C., Deng, A. L., Omolo, E. O., Kariuki, S. T. and Shaaya, E. 2008. Bioactivity of *Ocimum gratissimum* L. oil and two of its constituents against five insect pests attacking stored food products. Journal of Stored Products Research, 44: 328-334.

Pathak, V. M., Verma, V. K., Rawat, B. S., Kaur, B., Babu, N., Sharma, A., Dewali, S., Yadav, M., Kumari, R., Singh, S., Mohapatra, A., Pandey, V., Rana, N. and Cunill, J. M. 2022. Current status of pesticide effects on environment, human health and it's eco-friendly management as bioremediation: A comprehensive review. Frontiers in Microbiology, 13: 962619.

Raja, N., Albert, S., Ignacimuthu, S. and Dorn, S. 2001. Effect of plant volatile oils in protecting stored cowpea *Vigna unguiculata* (L.) walpers against *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) infestation. Journal of Stored Products Research, 37: 127-132.

Rees, D. 2007. Insects of stored grain: A pocket reference. Second edition. CSIRO Publishing, Australia.

Robertson, J. L., Smith, K. C., Savin, N. E. and Lavigne, R. J. 1984. Effects of dose selection and sample size on the precision of lethal dose estimates in dose mortality regression. Journal of Economic Entomology, 77: 833-837.

Sahaf, B. Z. and Moharramipour, S. 2008. Fumigant toxicity of *Carum copticum* and *Vitex pseudo-negundo* essential oils against eggs, larvae and adults of *Callosobruchus maculatus*. Journal of Pest Science, 81: 213-220.

Sharifi-Rad, J., Sureda, A., Tenore, G. C., Daglia, M., Sharifi-Rad, M., Valussi, M., Tundis, R., Sharifi-Rad, M., Loizzo, M. R., Ademiluyi, A. O., Sharifi-Rad, R., Ayatollahi, S. A. and Iriti, M. 2017. Biological activities of essential oils: From plant chemoecology to traditional healing systems. Molecules, 22.

Shokri Habashi, A., Safaralizadeh, M. H. and Safavi, S. A. 2011. Fumigant toxicity of *Carum copticum* L. oil against *Tribolium confusum* Du Val, *Rhyzopertha dominica* F. and *Oryzaephilus surinamensis* L. Munis Entomology & Zoology, 6: 282-289.

Stathas, I. G., Sakellaridis, A. C., Papadelli, M., Kapolos, J., Papadimitriou, K. and Stathas, G. J. 2023. The effects of insect infestation on stored agricultural products and the quality of food. Foods, 12: 2046.

Upadhyay, R. K., Gayatri, J. and Neeraj, Y. 2007. Toxicity, repellency and oviposition inhibitory activity of some essential oils against *Callosobruchus chinensis*. Journal of Applied Bioscience, 33: 21-26.

Zandi Sohani, N. and Ramazani, L. 2012. Investigation into insecticidal activity of *Mentha arvensis* and *Mentha pulegium* essential oils on *Callosobruchus maculatus*. Plant Protection (Scientific Journal of Agriculture), 35: 1-11.

Ziaee, M., Moharramipour, S. and Mohsenifar, A. 2014. Toxicity of *Carum copticum* essential oil-loaded nanogel against *Sitophilus granarius* and *Tribolium confusum*. Journal of Applied Entomology, 138: 763-771.

سمّیت تنفسی، بازدارندگی تخم‌ریزی، و دورکنندگی سه اسانس گیاهی علیه سوسک چهار نقطه‌ای حبوبات *Callosobruchus maculatus* روی پنج نوع لوبیا

مرضیه نامداری[۱]، معصومه ضیائی[۱]، سیدعلی همتی[۱]* و فاطمه ناصرنخعی[۲]

۱- گروه گیاه‌پزشکی، دانشکده کشاورزی، دانشگاه شهید چمران اهواز، اهواز، ایران.
۲- گروه مهندسی تولید و ژنتیک گیاهی، دانشکده کشاورزی، دانشگاه شهید چمران اهواز، اهواز، ایران.
پست الکترونیکی نویسنده مسئول مکاتبه: sa.hemmati@scu.ac.ir
دریافت: ۲۸ تیر ۱۴۰۴؛ پذیرش: ۲۸ مهر ۱۴۰۴

چکیده: یکی از مخرب‌ترین آفاتی که حبوبات انباری را تحت تأثیر قرار می‌دهد، سوسک چهار نقطه‌ای حبوبات *Callosobruchus maculatus* (F.) است. در این پژوهش سمّیت تنفسی، بازدارندگی تخم‌گذاری و دورکنندگی اسانس زنیان *Trachyspermum ammi* (L.) Sprague، زیره سبز *Cuminum cyminum* (L.) و شیشه شور *Melaleuca viminalis* (Sol. ex Gaertn.) روی حشرات کامل سوسک چهار نقطه‌ای حبوبات مورد بررسی قرار گرفت. غلظت کشنده ۵۰ درصد (LC_{50}) برای اسانس‌های گیاهی به مقدار ۱/۷۲۷ میکرولیتر بر لیتر هوا برای *T. ammi*، ۱/۲۱۹ میکرولیتر بر لیتر هوا برای *C. cyminum* و ۱/۶۲۲ میکرولیتر بر لیتر هوا برای *M. viminalis* تعیین شد که با افزایش غلظت اسانس‌ها میزان مرگ و میر در حشرات کامل افزایش یافت. بازدارندگی تخم‌گذاری روی انواع مختلف لوبیا شامل لوبیاسفید، لوبیاچیتی، لوبیاچشم‌بلبلی، لوبیاعربی و لوبیاقرمز ارزیابی شد. به‌ویژه، اسانس *T. ammi* در غلظت پنج میکرولیتر بر گرم از بذور به‌طور کامل مانع تخم‌گذاری شد، درحالی‌که، غلظت دو میکرولیتر بر گرم از بذور آن منجر به نرخ بازدارندگی ۹۴-۸۸ درصد شد. در مقابل، اسانس *M. viminalis* کم‌ترین بازدارندگی را در غلظت مشابه ایجاد کرد که بین ۷۷-۶۰ درصد متغیر بود. تغییر معنی‌داری در گروه شاهد ازنظر تخم‌گذاری حشرات روی انواع لوبیا وجود داشت، به‌طوری‌که، بیش‌ترین تعداد تخم روی لوبیا چشم‌بلبلی و سپس لوبیاسفید و لوبیاچیتی مشاهده شد. همه اسانس‌ها به‌طور مؤثری تعداد تخم‌های گذاشته شده و نرخ تفریخ آن‌ها را کاهش دادند. بالاترین کارایی دورکنندگی روی لوبیا چشم‌بلبلی مشاهده شد به‌طوری‌که فعالیت دورکنندگی اسانس *C. cyminum* حدود ۸۰ درصد بیش‌تر از اسانس‌های *T. ammi* با ۴۶/۶۶ درصد و *M. viminalis* با ۳۳/۳۳ درصد بود. یافته‌های به‌دست آمده در این پژوهش، پتانسیل این اسانس‌ها را به‌عنوان جایگزین‌های طبیعی برای مدیریت آلودگی سوسک چهار نقطه‌ای حبوبات آشکار می‌نماید.

واژگان کلیدی: لوبیا، تلفات، اسانس، تخم‌گذاری، دورکنندگی