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Chemical profile and repellent effects of two essential oils on *Tribolium confusum* Jacquelin du Val, 1863 (Coleoptera: Tenebrionidae)

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ABSTRACT

The confused flour beetle (*Tribolium confusum* Jacquelin du Val; Coleoptera: Tenebrionidae) is one of the most common pests of stored food products worldwide. Synthetic insecticides are commonly used to control this pest; however, their long-term application poses health risks and environmental concerns. The aim of this study was to evaluate the repellent activity of essential oils (EOs) from *Lavandula angustifolia* Miller and *Origanum vulgare* L. (Lamiaceae) against *T. confusum*. In this study, EOs from *L. angustifolia* and *O. vulgare* were extracted by hydrodistillation and analyzed using gas chromatography-mass spectrometry (GC-MS). The repellent activity of the oils against *T. confusum* adults was evaluated using a two-choice bioassay. The data were statistically analyzed using one-way ANOVA followed by Tukey's HSD test ($P<0.05$). The EO of *O. vulgare* was rich in carvacrol (96.7%), with minor components including thymene (2.01%), thymol (0.72%), and endo-borneol (0.53%). In contrast, *L. angustifolia* EO contained linalyl acetate (24.02%), linalool (15.79%), (+)-2-bornanone (10.74%), and eucalyptol (8.34%). Repellency was significantly higher in *O. vulgare* EO compared to *L. angustifolia* EO. Repellency was tested at concentrations of 1%, 2%, 4%, and 8% using a two-choice filter paper assay. The repellent activity of both oils increased significantly with concentration ($P<0.05$). *O. vulgare* EO showed the highest repellency, reaching 70% at 8% concentration after 1 hour of exposure. In contrast, *L. angustifolia* EO achieved a maximum repellency of 52% at the same concentration. At lower concentrations (1-2%), both oils showed limited efficacy. The results demonstrate that *O. vulgare* EO has promising repellent activity and could be considered a potential botanical insecticide for integrated pest management (IPM) of *T. confusum*.

1. Introduction

The rapid increase in the global population has posed substantial challenges in meeting essential nutritional demands. Cereals, which represent a significant proportion of agricultural commodities in Türkiye, also maintain a critical role in global food production systems (Dörtok and Aksoy 2018; Teke 2019; Küçüktopçu et al. 2023; Yetkin and Atakan 2022; Henteş and Işıkber 2024). The confused flour beetle, *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae), is a persistent and economically important pest of stored cereals and processed cereal products, known for causing extensive damage to a wide variety of commodities (Walter 1990; Demirel et al. 2009; Kumar 2017; Yağcı et al. 2023). The adult measures approximately 1/4 inch in length, displays a characteristic reddish-brown coloration, and is distinguished by antennae terminating in a well-defined, four-segmented club (Walter 1990; Demirel et al. 2009).

Tribolium confusum exhibits a broad global distribution, facilitated by its ability to reproduce within a wide temperature range (19-37.5°C) and survive under very low relative humidity levels (greater than 1%) (Rees 2004). Its economic impact is considerable, attributed to both its global prevalence and its increasing resistance to various insecticides (Kavallieratos et al. 2011; Kavallieratos et al. 2013; Athanassiou and Kavallieratos 2014; Kavallieratos et al. 2015). In addition to its economic significance, *T. confusum* poses potential public health risks through the secretion of defensive chemicals that can cause skin irritation, itching, and respiratory disorders (Mullen and Durden 2019; Kavallieratos et al. 2020).

Historically, methyl bromide was one of the primary fumigants used to control insect pests in stored agricultural products. However, due to its detrimental effects on the ozone layer, its use has been largely phased out in compliance with the Montreal Protocol (Protocol 1987). Following this regulatory transition, phosphine emerged as the most widely used fumigant globally. Despite its effectiveness, the extensive and prolonged use of phosphine has led to the development of resistance in various stored-product insect populations, including T. *confusum* (Afful et al. 2018).

In response to this challenge, several alternative fumigants have been investigated-such as sulfuryl fluoride, ethyl formate, hydrogen cyanide, and nitric oxide (Navarro and Qian 2007; Yan et al. 2025). However, some of these compounds present limitations in terms of efficacy, human safety, and environmental compatibility (Navarro and Qian 2007). These shortcomings have underscored the need for sustainable pest control strategies and have directed attention toward botanical insecticides,

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particularly essential oils (EOs), which offer promising repellent and insecticidal properties with lower ecological risks.

The limitations associated with conventional fumigants have prompted the development of novel, less toxic, and environmentally sustainable pest management strategies. Plants employ a variety of defense strategies to protect themselves against herbivores and pathogens. One such strategy involves the production of secondary metabolites, which are synthesized within plant cells and exhibit insecticidal and behavior-modifying properties against a wide range of pests (Güncan and Durmuşoğlu 2004). These bioactive compounds are typically classified into groups such as alkaloids, glycosides, phenolics, terpenoids, tannins, and saponins (Shanker and Solanki 2000). In particular, EOs-complex mixtures of volatile organic compounds-primarily consist of terpenic and non-terpenic hydrocarbons and their derivatives (Baser 2009; Sağlam and Özder 2013; Alkan 2023). These botanical products not only provide a renewable and eco-friendly approach to pest control but may also contribute to delaying or preventing resistance development in insect populations.

Several studies have examined the biological activities of EOs derived from *Origanum* and *Lavandula* species, both of which are rich in volatile compounds with insecticidal and repellent properties. For instance, Demirel et al. (2009) evaluated the toxicity of EOs from various *Origanum* species against *T. confusum*, reporting relatively low lethality for *O. vulgare*, while rosemary and thyme oils demonstrated stronger insecticidal effects. More recently, Alkan (2023) investigated the repellent activity of *O. onites* EOs under laboratory conditions and reported a significant repellent effect on *T. confusum*, indicating its potential as a natural alternative for pest control.

While previous research has provided valuable insights into the insecticidal and repellent properties of *Lavandula* and *Origanum* EOs, continued exploration remains important to better understand species-specific effects and application potential. Differences in chemical composition, experimental conditions, and insect responses across studies suggest that further comparative evaluations could enhance our understanding of their practical use in pest management. In this context, the present study investigates the repellent activity of EOs extracted from *L. angustifolia* and *O. vulgare* against *T. confusum*, contributing to the growing body of knowledge on plant-based alternatives within integrated pest management (IPM) programs.

2. Materials and Methods

2.1. Insect rearing

This study was conducted in Adana, Türkiye. A laboratory colony of *T. confusum* was maintained on cracked wheat supplemented with 5% (w/w) brewer's yeast, following the protocol described by Athanassiou et al. (2016). Adults ranging from 7 to 28 days old were used in the bioassays. The cultures were reared in 1000 mL glass jars and maintained in a climate-controlled chamber at 25 ± 1°C and 60 ± 5% relative humidity (R.H.), under continuous darkness.

2.2. Plant material and EOs *extraction*

The plant materials used in this study were collected from Pozantı, Adana, Türkiye, in 2024. The aerial parts of *O. vulgare* and the flowers of *L. angustifolia* were harvested during their full flowering stage. Leaves of *O. vulgare* and flowers of *L. angustifolia* were air-dried in the dark at ambient room temperature prior to extraction. EOs were obtained through hydrodistillation using a Clevenger-type apparatus. For each extraction, 500 g of plant material was distilled with 5000 mL of distilled water for 6 hours.

2.3. Gas chromatography-mass spectrometry (GC-MS) analysis

The chemical composition of the EOs was analyzed using gas chromatography-mass spectrometry (GC-MS). Separation was carried out using a DB-Wax capillary column (60 m × 0.25 mm i.d. × 0.25 µm film thickness; J&W Scientific, Folsom, USA). Helium was used as the carrier gas, at a constant flow rate of 1.1 ml per min. The oven temperature was initially set at 60°C (held for 6 min), then increased at a rate of 1°C per min to 220°C and held for an additional 4 min. The injector, interface, and ion source temperatures were all maintained at 220°C. One microliter of each EO, diluted in 1 mL of dichloromethane, was injected in split mode (50:1 split ratio). Electron impact ionization was conducted at 70 eV. Compound identification was based on comparison with mass spectra in commercial libraries (Wiley 275 Library) and authentic standards. Relative percentages of components were calculated from peak areas in the chromatograms.

2.4. Repellency Bioassays

The repellent activity of the EOs was evaluated using the area preference method, as described by Devi et al. (2020) and Hu et al. (2019). Filter paper discs (6 cm diameter) were cut in half. One half was treated with 400 µL of the EOs solution diluted in 1% ethanol and distilled water, at concentrations of 2%, 4%, or 8% (v/v). The other half was treated with 400 µL of 1% ethanol (control).

After allowing solvent evaporation (8-10 minutes), the treated and control halves were rejoined and placed in sterile petri dishes (90 mm diameter). Ten unsexed adult beetles were released into the center of each dish, which was then sealed with adhesive tape. All tests were performed in a controlled environment at 26 ± 2°C and 70 ± 5% R.H. Insect distribution was recorded at 1, 24, and 48 hours post-exposure. The percentage repellency (PR) was calculated using the formula adapted from McDonald et al. (1970):

$$\text{Percentage Repellency (PR)} = \left[\frac{Nc - Nt}{Nc + Nt}\right] \times 100 \qquad [1]$$

Where;
Nc= number of insects on the control half
Nt= number of insects on the treated half.

2.5. Statistical analysis

All experiments were conducted with a minimum of four replicates. Results are presented as mean ± standard deviation (SD). Statistical comparisons between treatments were performed using one-way analysis of variance (ANOVA), using SPSS v20.0 (IBM Corp., Armonk, NY, USA). A significance threshold of $P<0.05$ was adopted for all analyses.

3. Results

The chemical composition of the EOs was determined through GC–MS analysis (Figure 1). EOs from *O. vulgare* consisted of four major compounds, whereas *L. angustifolia* contained a total of 33 identified constituents. In *L. angustifolia*

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EO, the dominant components were linalyl acetate (24.02%), linalool (15.79%), (+)-2-bornanone (10.74%), eucalyptol (8.34%), endo-borneol (7.04%), 3,7-octadiene-2,6-diol, 2,6-dimethyl- (6.72%), and trans-linalool oxide (furanoid) (5.10%) (Figure 1). In contrast, the *O. vulgare* EO was overwhelmingly comprised of carvacrol (96.7%), followed by thymene (2.01%), thymol (0.72%), and endo-borneol (0.53%) (Figure 1).

The repellent activity of both EOs against *T. confusum* was evaluated at varying concentrations and time intervals (1, 24, and 48 hours) (Tables 1 and 2). Repellency increased significantly with both concentration and exposure time (P<0.05). For *L. angustifoli*a, at 1 hour, repellency ranged from 5.0% at 1% concentration to 52.0% at 8%. After 24 hours, repellency values were 10.0%, 30.6%, 31.5%, and 49.5% for 1%, 2%, 4%, and 8% concentrations, respectively. At 48 hours, repellency declined slightly but remained highest at 8% concentration (41.5%).

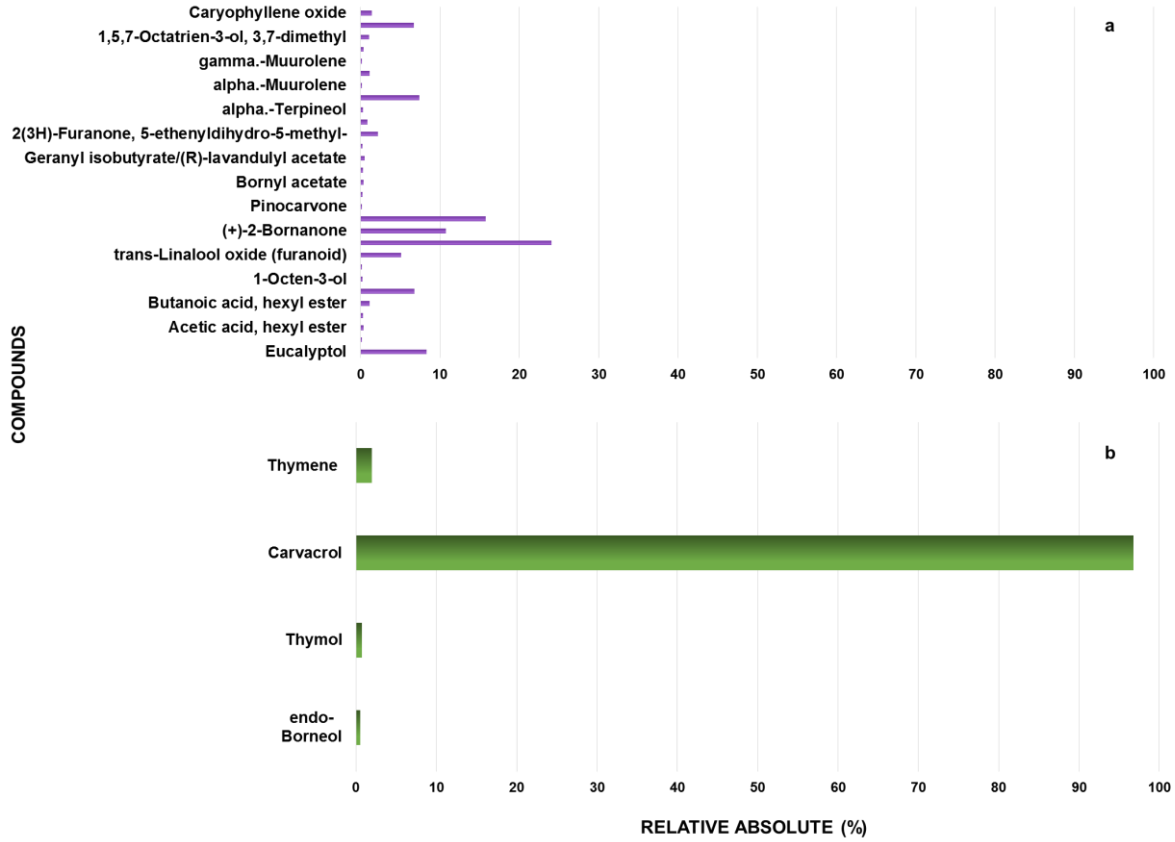


Figure 1. Chemical composition of EOs extracted from *L. angustifolia* (a) and *O. vulgare* (b), analyzed by gas chromatography coupled with mass spectrometry (GC-MS), obtained in Adana, Türkiye.

Table 1. Percentage repellency (mean ± SE) of different concentrations of *L. angustifolia* EOs against *Tribolium confusum* during bioassays conducted in Adana, Türkiye

Concentrations	1h	24h	48h
L.angustifolia 1%	5.0 ± 5.77b*	10.0 ± 5.77b	10.0 ± 6.72c
L.angustifolia 2%	40.0 ± 4.63a	30.0 ± 6.55ab	25.0 ± 3.27b
L.angustifolia 4%	41.8 ± 5.4a	31.5 ± 4.46ab	37.0 ± 2.77ab
L.angustifolia 8%	52.0 ± 1.78a	49.5 ± 4.11a	41.5 ± 2.85a

*Values are presented as means ± standard error (SE) of four replicates. Means within a column followed by different letters are significantly different according to Tukey's test (P<0.05).

Table 2. Percentage repellency (mean ± SE) of varying concentrations of *O. vulgare* EOs on *Tribolium confusum*, evaluated in Adana, Türkiye

Concentrations	1h	24h	48h
O.vulgare 1%	15 ± 2.89c*	10 ± 12.90c	5 ± 6.72c
O.vulgare 2%	35 ± 5.00b	30 ± 5.77bc	30 ± 5.77b
O.vulgare 4%	55 ± 2.89a	50 ± 5.77ab	45 ± 5.00ab
O.vulgare 8%	70 ± 5.77a	65 ± 5.00a	65 ± 5.00a

*Values are presented as means ± standard error (SE) of four replicates. Means within a column followed by different letters are significantly different according to Tukey's test (P<0.05).

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Similarly, *O. vulgare* showed higher repellency across all time points. At 1 hour, repellency ranged from 15.0% (1%) to 70.5% (8%). After 24 hours, values were 12.0%, 30.5%, 50.5%, and 65.0% for increasing concentrations, respectively. By 48 hours, repellency remained at 65.0% at 8% concentration, while lower concentrations showed reduced effectiveness (e.g., 5.6% at 1%).

One-way ANOVA followed by Tukey's HSD test revealed statistically significant differences among concentrations for both oils. For *L. angustifolia*, repellency varied significantly over time (F_{1h}= 12,321; df_{1h}= 3, 15; P_{1h} < 0.001; F_{24h}= 7, 780; df_{24h}= 3, 15; P_{24h} < 0.001; F_{48h}= 11,959; df_{48h}= 3, 15; P_{48h} < 0.001). Similarly, *O. vulgare* showed highly significant differences (F_{1h}= 30,556; df_{1h}= 3, 15; P_{1h} < 0.001; F_{24h}= 8,871; df_{24h}= 3, 15; P_{24h} < 0.001; F_{48h}= 19,909; df_{48h}= 3, 15; P_{48h} < 0.001).

In general, repellency was highest at 1 hour post-exposure and declined over time for *L. angustifolia*, while *O. vulgare* maintained strong activity for up to 48 hours. At all durations, the 8% concentration induced significantly higher repellency than the lower doses, with *O. vulgare* consistently outperforming *L. angustifolia*.

4. Discussion and Conclusion

This study clearly demonstrates the differing repellent effects of *O. vulgare* and *L. angustifolia* EOs against *T. confusum*, largely attributable to their distinct chemical compositions. *O. vulgare* EO showed a significantly higher repellency, which is likely due to its high carvacrol content-a monoterpenoid phenol known for its neurotoxic effects on insects (Enan 2001; Jukic et al. 2007; Tong and Coats 2010; Anderson and Coats 2012; Evergetis et al. 2018; Giatropoulos et al. 2023). In contrast, *L. angustifolia* EO, dominated by linalyl acetate and other oxygenated monoterpenes, exhibited weaker repellency.

EOs exert diverse biological effects such as toxicity, repellency, and feeding inhibition, primarily due to their rich mixtures of monoterpenes and phenolic compounds (Regnault-Roger et al. 2021). In our chemical analysis, *O. vulgare* EO contained 96.7% carvacrol, consistent with Kim et al. (2010), who reported 67.2% carvacrol as the main repellent and insecticidal agent against *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae). Similarly, our findings align with Alkan (2023), where *O. onites* EO showed 68% repellency at 0.25 µL cm^{-2} after 2 hours; in our study, *O. vulgare* EO achieved 65% repellency at 8% after 48 hours. This suggests that while initial repellency may be high, EO effectiveness tends to decrease over time due to their volatility.

For *L. angustifolia*, the major components identified-linalool and linalyl acetate-are consistent with previous work by Pokajewicz et al. (2021), who found these compounds accounted for over 80% of lavender oil samples. This consistency suggests a stable chemotype across different regions and explains the moderate repellency observed in our study.

EOs are gaining attention as eco-friendly alternatives for stored product pest control due to their low environmental persistence and reduced resistance risk (Chaudhari et al. 2021). Their volatile constituents function as semiochemicals that affect insect behavior via olfactory receptors (Mossa 2016), while compounds such as carvacrol and thymol disrupt neural signaling by inhibiting acetylcholinesterase (Jukic et al. 2007).

In conclusion, both EOs tested showed repellent effects against *T. confusum*, with *O. vulgare* being significantly more effective. The dominance of carvacrol likely contributes to its strong bioactivity. Going forward, efforts should focus on enhancing EO stability in storage environments, evaluating cost-effectiveness, and conducting field trials to support their integration into pest management programs.

References

Afful E, Elliott B, Nayak MK, Phillips TW (2018) Phosphine resistance in North American field populations of the lesser grain borer, *Rhyzopertha dominica* (Coleoptera: Bostrichidae). Journal of Economic Entomology 111: 463-469.

Alkan M (2023) Essential oils of *Origanum* species from Turkey: repellent activity against stored product insect pests. Journal of Agricultural Sciences 29(1): 103-110.

Anderson JA, Coats JR (2012) Acetylcholinesterase inhibition by nootkatone and carvacrol in arthropods. Pesticide Biochemistry and Physiology 102: 124-128.

Athanassiou CG, Kavallieratos NG (2014) Evaluation of spinetoram and spinosad for control of *Prostephanus truncatus*, *Rhyzopertha dominica*, *Sitophilus oryzae* and *Tribolium confusum* on stored grains under laboratory tests. Journal of Pest Science 87: 469-483.

Athanassiou CG, Kavallieratos NG, Chiriloaie A, Vassilakos TN, Fatu V, Drosu S, Dudoiu R, Ciobanu M, Dudoiu R (2016) Insecticidal efficacy of natural diatomaceous earth deposits from Greece and Romania against four stored grain beetles: The effect of temperature and relative humidity. Bulletin of Insectology 69: 25-34.

Baser KHC (2009) Essential oils and aromatherapy. Fitomed 7: 8-25.

Chaudhari AK, Singh VK, Kedia A, Das S, Dubey NK (2021) Essential oils and their bioactive compounds as eco-friendly novel green pesticides for management of storage insect pests: prospects and retrospects. Environmental Science and Pollution Research 28(15): 18918-18940.

Demirel N, Kurt S, Gunes U, Uluc FT, Cabuk F (2009) Toxicological responses of confused flour beetle, *Tribolium confusum* du Val (Coleoptera: Tenebrionoidea) to various isothiocyanate compounds. Asian Journal of Chemistry 21: 6411-6416.

Devi MA, Sahoo D, Singh TB, Rajashekar Y (2020) Toxicity, repellency and chemical composition of essential oils from *Cymbopogon* species against red flour beetle *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae). Journal of Consumer Protection and Food Safety 15: 181-191.

Dörtok A, Aksoy A (2018) Estimation Model With Simultaneous Process of Turkey's Wheat Industry. KSU Journal of Agriculture and Nature 21(4): 580-586.

Enan EE (2001) Insecticidal activity of essential oils: Octopaminergic sites of action. Comparative Biochemistry and Physiology Part C 130: 325-337.

Evergetis E, Bellini R, Balatsos G, Michaelakis A, Carrieri M, Veronesi R, Papachristos DP, Puggioli A, Kapsaski-Kanelli VN, Haroutounian SA (2018) From bio-prospecting to field assessment: the case of carvacrol rich essential oil as a potent mosquito larvicidal and repellent agent. Frontiers in Ecology and Evolution 6: 204.

Giatropoulos A, Koliopoulos G, Pantelakis PN, Papachristos D, Michaelakis A (2023) Evaluating the sublethal effects of *Origanum vulgare* essential oil and carvacrol on the biological characteristics of *Culex pipiens* biotype molestus (Diptera: Culicidae). Insects 14: 400.

Güncan A, Durmuşoğlu E (2004) An evaluation on natural insecticides of herbal origin. Hasad dergisi 233: 26-32.

Henteş S, Işıkber AA (2024) Insecticidal efficacy of local diatomaceous earth compositions with different particle sizes against stored grain pests. Turkish Journal of Entomology 48(3): 353-365.

Hu J, Wang W, Dai J, Zhu L (2019) Chemical composition and biological activity against *Tribolium castaneum* (Coleoptera: Tenebrionidae) of

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Artemisia brachyloba essential oil. Industrial Crops and Products 128: 29-37.

Jukic M, Politeo O, Maksimovic M, Milos M, Milos M (2007) In vitro acetylcholinesterase inhibitory properties of thymol, carvacrol and their derivatives thymoquinone and thymohydroquinone. Phytotherapy Research 21(3): 259-261.

Kavallieratos NG, Athanassiou CG, Hatzikonstantinou AN, Kavallieratou HN (2011) Abiotic and biotic factors affect efficacy of chlorfenapyr for control of stored-product insect pests. Journal of Food Protection 74: 1288-1299.

Kavallieratos NG, Athanassiou CG, Boukouvala MC (2013) Insecticidal effect of chlorantraniliprole against major stored product insect pests in different grain commodities under laboratory tests. Pest Management Science 69: 1141-1154.

Kavallieratos NG, Athanassiou CG, Korunić Z, Mikeli NH (2015) Evaluation of three novel diatomaceous earths against three stored-grain beetle species on wheat and maize. Crop Protection 75: 132-138.

Kavallieratos NG, Andrić G, Pražić Golić M, Nika EP, Skourti A, Kljajić P, Papanikolaou NE (2020) Biological features and population growth of two Southeastern European *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae) strains. Insects 11(4): 218.

Kim SI, Yoon JS, Jung JW, Hong KB, Ahn YJ, Kwon HW (2010) Toxicity and repellency of origanum essential oil and its components against *Tribolium castaneum* (Coleoptera: Tenebrionidae) adults. Journal of Asia-Pacific Entomology 13(4): 369-373.

Kumar R (2017) Insect pests on stored grain: Biology, behavior, and management strategies. Apple Academic Press, Waretown, NJ.

Küçüktopçu Y, Can B, Saruhan İ (2023) Effects of Some Plant Extracts on Larva and Adult Stages of *Tribolium confusum* Jacquelin Du Val (Coleoptera: Tenebrionidae). KSU Journal of Agriculture and Nature 26(3): 570-578.

McDonald LL, Guy RH, Speirs RD (1970) Preliminary evaluation of new candidate materials as toxicants, repellents, and attractants against stored product insects. Marketing Research Report No. 882, USDA Agricultural Research Service, Washington, DC.

Mossa ATH (2016) Green pesticides: Essential oils as biopesticides in insect-pest management. Journal of Environmental Science and Technology 9: 354-378.

Mullen GR, Durden LA (2019) Medical and veterinary entomology. Academic Press, London.

Navarro S, Qian F (2007) Restrictions to the Use of Fumigants and Opportunities for Substitution with Modified Atmospheres. Journal of Grain Storage 2: 25-29.

Pokajewicz K, Białoń M, Svydenko L, Fedin R, Hudz N (2021) Chemical composition of the essential oil of the new cultivars of *Lavandula angustifolia* Mill. Bred in Ukraine. Molecules 26(18): 5681.

Protocol M (1987) Montreal protocol on substances that deplete the ozone layer. Washington, DC: US Government Printing Office 26: 128-136.

Rees D (2004) Insects of stored products. CSIRO Publishing, Collingwood, Australia.

Regnault-Roger C, Vincent C, Arnason JT (2021) Essential oils in insect control: Low-risk products in a high-stakes world. Annual Review of Entomology 66: 371-389.

Sağlam Ö, Özder N (2013) Fumigant toxicity of monoterpenoid compounds against the confused flour beetle, *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae). Türk Entomoloji Dergisi 37: 457-466.

Shanker C, Solanki KR (2000) Botanical insecticides: a historical perspective. India. Asian Agrihistory 4(2): 21-30.

Teke MA (2019) Insecticidal and behavioral effects of some plant essential oils on *Sitophilus granarius* L. (Coleoptera: Curculionidae) and *Tribolium castaneum* (herbst) (Coleoptera: Tenebrionidae), PhD Thesis.

Tong F, Coats JR (2010) Effects of monoterpenoid insecticides on [3H]-TBOB binding in house fly GABA receptor and 36 Cl- uptake in American cockroach ventral nerve cord. Pesticide Biochemistry and Physiology 98: 317-324.

Walter VE (1990) Stored Product Pests. In Handbook of Pest Control, Franzak & Foster Co., Cleveland, OH. pp. 526-529.

Yağcı M, Erdoğuş FD, Fırat TA, Ertürk S (2023) Pathogenicity of four native isolates of entomopathogenic nematodes against *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae). Journal of Plant Diseases and Protection 130: 85-92.

Yan D, Liu J, Wang X, Fang W, Li Y, Cao A, Wang Q (2025) A review on the mechanisms of fumigant action. New Plant Protection 2(1): e27.

Yetkin MS, Atakan E (2022) Determination of pests in stored wheat and corn in Tarsus and Akdeniz districts of Mersin province, Turkey. Journal of Agriculture Faculty of Ege University 59(3): 471-483.

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