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Research Article

Eco-friendly management of Saw-toothed grain beetle (*Oryzaephilus surinamensis*) in stored date fruits: efficacy of plant-derived powders and essential oils

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Abstract. The saw-toothed grain beetle, *Oryzaephilus surinamensis* (Col., Silvanidae), is a major pest causing significant infestation in stored dried and semi-dried date fruits. This study explored the insecticidal potential of plant derived essential oils and powders against *O. surinamensis*. Dates were collected from the local market, and *O. surinamensis* were reared on dates in plastic boxes. Beetles raised on dates in plastic containers were exposed to six essential oils- Turpentine, Eucalyptus, Black Seed, Rosemary, Radish Seed, and Wheat seed through space fumigation. The essential oils were applied at concentrations of 6, 12, 18, and 24 µl/L for durations of 24, 48, and 72 hours. Turpentine oil exhibited the highest toxicity, with LC_{50} values of 24.020, 28.236, and 32.720 ppm after 24, 48, and 72 hours of exposure, respectively. Additionally, five plant powders (neem, eucalyptus, tamarind, lemon grass, and moringa) were tested against *O. surinamensis*. Neem powder caused the highest mortality rates, showing significant differences compared to other powders at all exposure intervals (24, 48, 72 hours). The results demonstrate that Turpentine oil and Neem powder are highly effective against *O. surinamensis* and represent potential candidates for integrated pest management (IPM) in stored dates. Further research is required to optimize application methods and dosages, assess long term impacts and resistance potential, conduct facility scale trials, and perform economic analyses to determine the practicality and efficiency of these natural pesticides.

Keywords: Date Fruit, Botanical Insecticide, Plant Powders, Plant Oil, Insect mortality

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Introduction

The date palm (*Phoenix dactylifera L.*) is a highly valued fruit mentioned in many holy texts. It is one of the oldest cultivated plants, farmed since 4000 B.C (Al-Mahmoud *et al.*, 2020). Dates are valuable crops that are widely consumed in several nations, particularly throughout the Arab world, either fresh or dried from the date palm. Remarkably, with a total production of 557,279 tons, Pakistan is the sixth largest producer of dates worldwide, behind the Arab world (Abul-Soad *et al.*, 2010; Al-Karmadi & Okoh, 2024). Dates are grown on 114,000 hectares in Pakistan, with an annual production of 557,279 tons (Mallah *et al.*, 2016). Dates include a wealth of vital nutrients, containing fructose, glucose, essential minerals, dietary fiber, fatty acids, vitamins, and proteins (Chandrasekaran & Bahkali, 2013; Muñoz-Bas *et al.*, 2024). Dates are essential emergency nourishment because of their antibacterial, immunomodulatory, antifungal, anticancer, and antioxidant qualities, while date seeds serve as animal feed due to their high protein, fat, and fiber content. The widespread significance of date seeds stems from their industrial, nutritional, medicinal, social, and cultural values, making them highly popular (El Youssfi *et al*., 2024). Pakistan boasts over 300 distinct varieties of date palms under cultivation. Among these, the Aseel variety stands out as the queen of all date varieties grown in the country, holding a prominent status as a commercial choice. Renowned for its excellence, Aseel variety demonstrates exceptional qualities in both semi-dry and dry variations (Ahmed *et al*., 2016; Awan *et al*., 2018). Among major date producing nations, date palm holds a position of greater importance compared to other crops. Unfortunately, the date palm is susceptible to severe impacts from insect pests and diseases. Such pest infestations contribute to the decline syndrome, leading to a substantial loss of dates, particularly in semi-dry circumstances (Khan *et al*., 2023; Markhand *et al*., 2010). The beetles species *Carpophilus hemipterus* and *Oryzaephilus surinamensis* are widely distributed and pose a significant threat to agricultural products, both pre and post-harvest. In combination with other diseases and pests, these beetles contribute to a 30% reduction in the overall production of date fruits (Hashem *et al*., 2012; Swamy & Bitra, 2023).

Saw-toothed grain beetle, *O. surinamensis L* (Coleoptera: Silvanidae), primarily attributed to semi-dry and fresh dry date palm fruits that have been stored, encounters a significant issue of insect infestation. This infestation not only diminishes the quality and quantity of dates but also results in weight loss (Kousar *et al*., 2021). The geographical distribution of this insect spans various world's regions (Kousar et al., 2023). This beetle thrives in stored dates and other dry commodities, including wheat, rice, flour, nuts, and packaged foods, due to its small size, flat body, and rapid mobility (Hassan *et al*., 2020).

Chemical compounds are essential substances formed by the combination of elements, playing pivotal roles in everyday products from household cleaners and pharmaceuticals to industrial materials and agricultural enhancements (Anadón *et al*., 2025). Their diverse properties enable innovations that improve health, sustainability, and technological progress. Current control strategies rely on chemical fumigants (methyl bromide, phosphine) and synthetic insecticides (pyrethroids, organophosphates). However, *O. surinamensis* has developed widespread resistance, and its ability to hide in storage crevices complicates eradication (Rajendran, 2020). Furthermore, chemical residues pose risks to human health and trade, particularly for export-grade dates (Gourgouta *et al*., 2023; Sangeeta *et al*., 2024). Given these challenges, there is an urgent need for safer, biodegradable alternatives that are effective yet non-toxic to non-target organisms. Plant derived pesticides such as essential oils and botanical powders offer a sustainable solution, as they are rich in bioactive compounds, target specific, and compatible with Integrated Pest Management (IPM) (Latifian *et al*., 2020). This study evaluates the efficacy of plant based oils and powders against *O. surinamensis* in stored dates, aiming to identify viable, eco-friendly control methods.

Materials and methods

Culture Collection and rearing of *O. surinamensis*

Oryzaephilus surinamensis were collected from infested stored dates from markets and storage facilities in Rahim Yar Khan District, Pakistan. The beetles were reared on date fruits in plastic boxes (34 x 20 cm) under controlled conditions, 27–30°C and 60±70% relative humidity at the Center for Insect Farming and Entomological Entrepreneurship (CIFEE), Department of Agricultural Engineering, Khwaja Fareed University of Engineering and Information Technology.

Plant Essential Oils: Toxicity Bioassay

Oil sources

Six commercially available plant oils were tested: Turpentine oil (*Turpentine* sp.), Wheat seed oil (*Trititum aestivum*), Radish seed oil (*Raphanus sativus*), Eucalyptus oil (*Eucalyptus globulus*), Black seed oil (*Nigella sativa*), and Rosemary oil (*Rosmarinus officinalis*).

Fumigation Bioassay

The space fumigation method (Shaaya *et al*., 1991) was employed. Filter paper strips measuring 4 x 5 cm were soaked in oil concentrations of 6, 12, 18, and 24 µl per liter, using ethanol as the solvent. The treated strips were then attached to the lids of glass vials (10 x 4 cm) that contained 40 adult beetles (1-8 days) and one dry date fruit as a food source. Vials were sealed and stored at lab conditions (27–30°C, 60–70% RH). Mortality was recorded after 24, 48, and 72 h of exposure. Four replicates were conducted per treatment. The same experimental setup was used to maintain the control sample.

Plant Powders: Preparation and Bioassay

Powders Preparation

Fresh leaves of five medicinal plants were used as fine powder based on the method described by Shah *et al.* (2008): Neem (*Azadirachta indica*), Eucalyptus (*Eucalyptus sp.*), Tamarind (*Tamarindus indica*), Lemon grass (*Cymbopogon citratus*), and Moringa (*Moringa oleifera*). Dried leaves were ground using a grinder machine and stored in plastic bags.

Contact Toxicity Bioassay

In this experiment, small glass vials were utilized and positioned within single date fruit for feeding purposes of *O. surinamensis*. Different plant powders mentioned in the earlier paragraph were incorporated into the vials in specified weight units of 0.7, 0.8, and 0.9 grams. The powder was vibrated thoroughly to ensure proper integration. Thirty adult beetles (1-8 days) were introduced per vial. The control treatment involved no addition of powder. All vials were securely covered with a lid and then kept under suitable lab conditions (27–30°C, 60–70% RH). Mortality of *O. surinamensis* was determined after exposure periods of 24, 48, and 72 hours. Three replications were performed per treatment, and the same experimental setup was conducted for the untreated control.

Statistical Analysis

Essential oil toxicity: Mortality data were corrected using Abbott's formula (1925) and analyzed via probit analysis (Polo Plus 2.0) to determine LC_{50} and LC_{90} values.

$$\text{Corrected Mortality (\%)} = \frac{P-Po}{100-Po} \times 100$$

Where: P = mortality in treatment

P_o = mortality in control

Plant powder efficacy: Mortality rates were examined using One-way ANOVA, and means were compared using LSD post hoc tests (SPSS version 21, 2024).

Results

Toxicity of plant essential oils against *O. surinamensis*

Among the tested plant oils, Turpentine oil exhibited the highest toxicity, followed by rosemary, black seed, radish, eucalyptus, and wheat seed oil (Table 1). Turpentine oil showed LC_{50} values, indicating the highest toxicity, 32.720 ppm (72 h), 28.236 ppm (48 h), and 24.020 ppm (24 h). Moreover, Turpentine oil's LC_{90} values at these intervals were 117.355, 97.852, and 60.706 ppm. Rosemary oil was the second most effective, with LC_{50} values of 19.643 ppm (24 h), 27.598 ppm (48 h), and 27.251 ppm (72 h). Wheat seed oil exhibited the quickest knockdown effect at 24 hours (LC50 = 14.626 ppm); however, its residual efficacy was lower than that of Turpentine and rosemary oils over extended exposures. Mortality increased with exposure time and concentration for all oils. Complete dose mortality responses (LC_{50}, LC_{90}) are detailed in Table 1.

Effect of plant powders on *O. surinamensis*

All tested plant powders exhibited significant mortality within the 24, 48, and 72-hour intervals, compared to the control (untreated group), with effects increasing over time (Fig. 1). Most impactful powder was neem powder, with highest percentage of adult mortality recorded at weight units (0.9, 0.8, 0.7) respectively at 72 hours, mortality rate of insects in neem powder was notably high (df = 17; F = 299.168; $P < 0.001$) (Fig 1-C) followed by Lemon grass, Tamarind and Eucalyptus powder in 48 hours (df = 17; F = 185.286; $P < 0.001$) (Fig 1-B).

Conversely, in 24 hours, the insect mortality rate in Moringa powder was lower (df = 17; F = 167.893; P <0.001) (Fig. 1-A).

Discussion

Pest infestations pose a growing threat to global food security, with *O. surinamensis* emerging as a major pest of stored date fruits, causing significant economic losses and compromising food safety (Kavallieratos et al., 2022). Conventional pest control relies heavily on synthetic pesticides, which raise concerns about human health risks and environmental degradation. Botanical alternatives, such as plant derived oils and powders, offer promising eco-friendly solutions for managing stored product pests (Kim et al., 2019). This study not only confirms the efficacy of plant based oils and powders but also provides novel insights into their comparative performance, mechanisms of action, and potential for integration into sustainable pest management strategies. Unlike previous research, our findings specifically address *O. surinamensis* in stored dates, a critical but understudied area. Essential oils disrupt pest physiology through fumigant and contact toxicity, Turpentine oil exhibited the highest toxicity against *O. surinamensis*, with LC_{50} values declining over time, indicating cumulative effects.

Table 1: Toxicity of plant essential oils against *O. surinamensis* at 24, 48, and 72 h exposure intervals.

E.I.	Plant oils	LC_{50}[a] (ppm) (95% FL[b])	LC_{90}[c] (ppm) (95% FL[b])	Df	X^{2d}	P	N[e]
72 Hours	Turpentine	32.720 (20.698-51.726)	117.355 (74.552-186.311)	2	0.025	0.703	40
	Rosemary	27.251 (18.306-40.568)	81.128 (54.498-120.772)	2	0.018	0.686	40
	Black seed	25.552 (17.490-37.331)	76.984 (52.694-112.472)	2	0.036	0.780	40
	Radish seed	23.183 (16.331-32.908)	64.783 (45.637-91.961)	2	0.036	0.797	40
	Eucalyptus	20.834 (15.155-28.641)	53.108 (38.632-73.010)	2	0.040	0.818	40
	Wheat seed	18.043 (13.516-24.087)	43.047 (32.246-57.466)	2	0.024	0.813	40
48 Hours	Turpentine	28.236 (18.563-42.950)	97.852 (64.329-148.844)	2	0.011	0.701	40
	Rosemary	27.598 (17.300-44.026)	106.129 (66.528-169.304)	2	0.019	0.593	40
	Black seed	24.799 (15.954-38.548)	93.793 (60.339-145.795)	2	0.011	0.695	40
	Radish seed	19.320 (13.576-27.495)	56.612 (39.781-18.565)	2	0.025	0.711	40
	Eucalyptus	17.770 (12.2914-24.452)	46.606 (33.871-64.130)	2	0.049	0.760	40
	Wheat seed	15.548 (11.575-20.884)	38.343 (28.545-51.505)	2	0.025	0.733	40
24 Hours	Turpentine	24.020 (17.075-33.791)	60.706 (43.153-85.399)	2	0.046	0.728	40
	Rosemary	19.643 (14.685-26.275)	44.799 (33.492-59.925)	2	0.011	0.693	40
	Black seed	18.275 (13.338-25.038)	46.582 (33.999-63.821)	2	0.039	0.708	40
	Radish seed	16.464 (12.949-20.933)	32.906 (25.881-41.839)	2	0.041	0.774	40
	Eucalyptus	15.335 (12.334-19.065)	28.812 (23.174-35.821)	2	0.044	0.738	40
	Wheat seed	14.626 (11.749-18.207)	27.565 (22.143-34.315)	2	0.015	0.716	40

E.I. = Exposure Intervals; [a] LC_{50} = Kill 50% insect population; [b] FL = Fiducial limit;
[c] LC_{90} = Kill 90% insect population; [d] = Chi-square; [e] = Total number of exposed adults

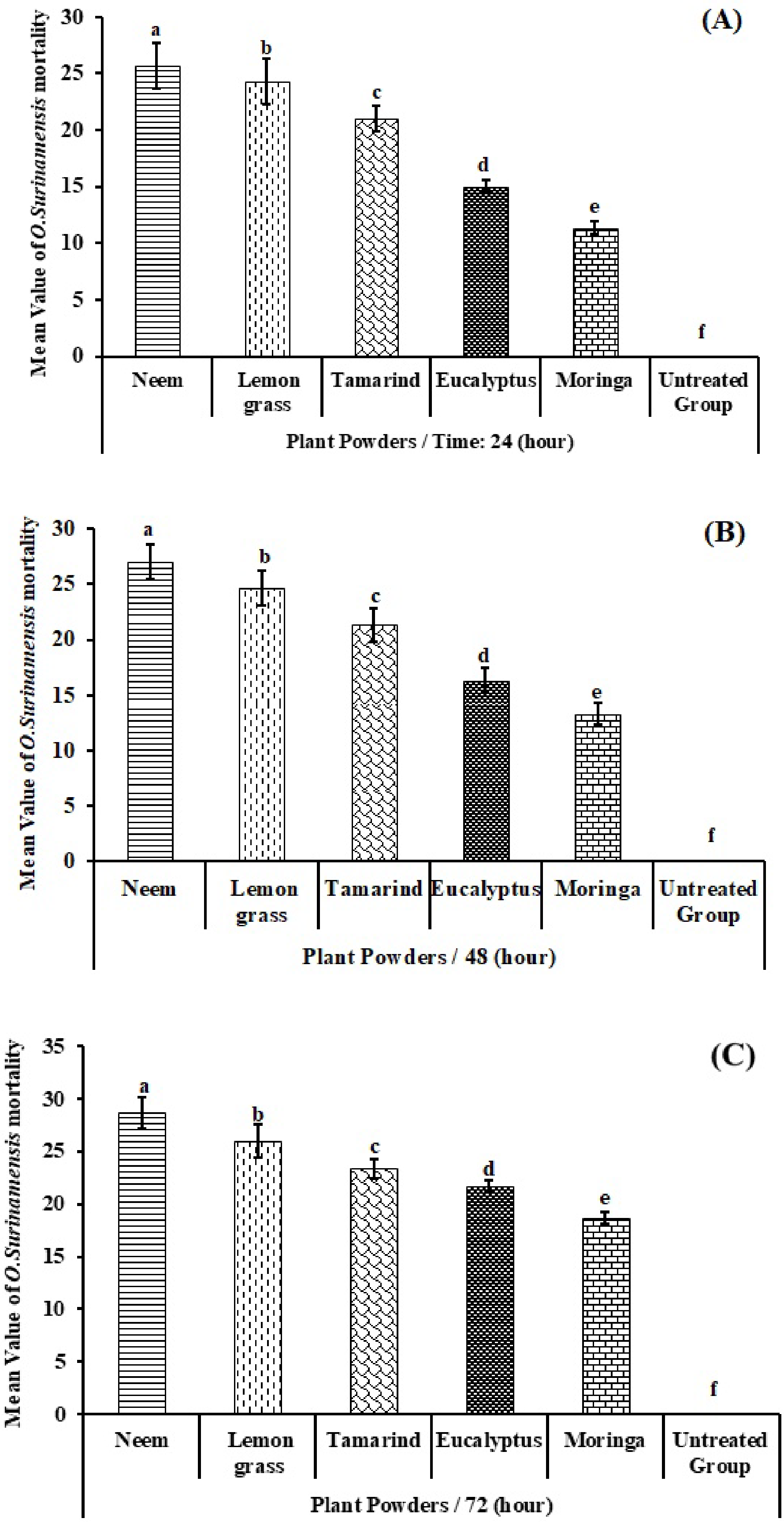

Fig. 1: Effect of medicinal plant powders on *O. surinamensis* after 24 (A), 48 (B), and 72 (C) hours. The mean ± SE of adult mortality was observed in 2024. Different alphabetic letters indicate significant differences in adult mortality across various times and powder toxicities ($p < 0.00$, Tukey test).

This cumulative toxicity is a novel observation for *O. surinamensis* and suggests that prolonged exposure to turpentine oil could enhance its practical efficacy in storage facilities (Lomtadze *et al.*, 2018). These findings align with research demonstrating the fumigant potency of essential oils against other stored product pests like *Tribolium castaneum* and *Tenebrio molitor* (Kavallieratos et al., 2024). Rosemary and black seed oils also showed significant insecticidal activity, with LC_{50} values of 27.251 ppm and 25.552 ppm at 72 h, respectively. While these oils have been studied for their efficacy against coleopteran pests such as *Sitophilus oryzae* and *Lasioderma serricorne* (Kim *et al.*, 2003), our work is the first to document their potency against *O. surinamensis*, highlighting their broad spectrum potential. Among plant powders, neem (*Azadirachta indica*) demonstrated the highest mortality rates, attributed to its active compound, azadirachtin.

This result is consistent with existing literature, but our study further reveals that eucalyptus, tamarind, lemongrass, and moringa powders also exhibit dose and time dependent toxicity, with mortality increasing significantly after 48–72 h of exposure. This delayed but substantial effect is particularly notable for moringa and eucalyptus, which have not been previously evaluated for their long term impact on *O. surinamensis*. Eucalyptus, tamarind, lemongrass, and moringa powders also exhibited dose and time dependent toxicity, with mortality increasing significantly after 48–72 h of exposure. Field studies support these findings; for instance, eucalyptus and moringa extracts have proven effective against wheat aphids (Shah et al., 2017). The integration of plant based oils and powders into Integrated Pest Management (IPM) strategies could reduce reliance on synthetic chemicals while mitigating environmental and health risks.

In conclusion, it is important to emphasize that this study not only validates plant derived oils and powders as eco-friendly alternatives for controlling *O. surinamensis* in stored dates but also provides new evidence of their cumulative effects, comparative efficacy, and potential for scalability. These findings advance the field by offering actionable insights for reducing chemical inputs in agriculture. Further research is needed to: optimize application methods and dosages for large scale use, evaluate long term impacts, including resistance development in pest populations, and conduct field trials and economic analyses to assess practicality. Future studies should also concentrate on scalability and effectiveness in real world settings to guarantee their practical application.

Author's Contributions

Alishbah Mohsin: Conceptualization; methodology, formal analysis, investigation, draft preparation, final review and edit; **Muhammad Adnan Bodlah**: visualization, conceptualization, supervision, draft preparation, review and editing; **Ali Asghar Talebi**: supervision, draft preparation, review and editing; **Ayesha Younas**: Formal analysis of the manuscript; **Aleena Kanwal**: investigation, draft preparation, **Imran Bodlah**: conceptualization, supervision, draft preparation. All authors approved the final version of the manuscript.

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Data Availability Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Ethics Approval and Consent to Participate

Insects were used in this study. All applicable international, national, and institutional guidelines for the care and use of animals were followed. This article does not contain any studies with human participants performed by any of the authors.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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Research Article

مدیریت سازگار با محیط زیست شپشه دندانه دار (*Oryzaephilus surinamensis*) در انبارهای خرما: اثربخشی پودرها و اسانس های مشتق شده از گیاهان

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چکیده: شپشه دندانه‌دار، *Oryzaephilus surinamensis* (Col., Silvanidae)، یک آفت مهم است که باعث آلودگی قابل‌توجهی در خرمای خشک و نیمه‌خشک می‌شود. این مطالعه، کارایی حشره‌کشی اسانس‌ها و پودرهای گیاهی علیه این آفت ارزیابی گردید. میوه های خرما از بازار محلی جمع‌آوری شدند و سوسک‌ها روی خرما در جعبه‌های پلاستیکی پرورش داده شدند. شپشه های پرورش‌یافته روی خرما در ظروف پلاستیکی در معرض سمیت تنفسی شش اسانس گیاهی قرار گرفتند: تربانتین، اکالیپتوس، سیاه‌دانه، رزماری، دانه تربچه و دانه گندم. اسانس‌ها در غلظت‌های ۶، ۱۲، ۱۸ و ۲۴ میکرولیتر بر لیتر و برای مدت زمان ۲۴، ۴۸ و ۷۲ ساعت اعمال شدند. روغن تربانتین با مقادیر LC_{50} به ترتیب ۲۴/۰۲۰، ۲۸/۲۳۶ و ۳۲/۷۲۰ ppm پس از ۲۴، ۴۸ و ۷۲ ساعت قرارگیری، بیشترین سمیت را نشان داد. علاوه بر این، پنج پودر گیاهی شامل (چریش، اکالیپتوس، تمر هندی، لیموگراس و مورینگا) علیه *O. surinamensis* آزمایش شدند. پودر چریش بیشترین نرخ مرگ‌ومیر را ایجاد کرد و تفاوت معنی‌داری را در تمام زمان در معرض بودن (۲۴، ۴۸، ۷۲ ساعت) در مقایسه با سایر پودرها نشان داد. نتایج نشان می‌دهد که روغن تربانتین و پودر چریش به‌شدت علیه *O. surinamensis* مؤثر هستند و کاندیداهای بالقوه برای مدیریت تلفیقی آفات (IPM) در خرمای انباری دارند. پژوهش‌های بیشتری برای بهینه‌سازی روش‌های کاربرد و دوزها، ارزیابی اثرات بلندمدت و پتانسیل مقاومت، انجام آزمایش‌های در مقیاس تأسیسات و انجام تحلیل‌های اقتصادی برای تعیین عملی بودن و کارایی این آفت‌کش‌های طبیعی مورد نیاز است.

کلمات کلیدی: میوه خرما، آفت کش های گیاهی، پودرهای گیاهی، اسانس های گیاهی، مرگ و میر حشرات

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