Available online at http://bjas.bajas.edu.iq
https://doi.org/10.37077/25200860.2024.37.1.01
College of Agriculture, University of Basrah

Basrah Journal of Agricultural Sciences

ISSN 1814 – 5868

Basrah J. Agric. Sci., 37(1), 1-14, 2024

E-ISSN: 2520-0860

Managing Dust Mite *Oligonychus afrasiaticus* (McGregor) (Acari: Tetranchidae) Infesting Date Palm Orchards By Using Lemongrass Extract and Nanosulfur

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Received 20th August 2023; Accepted 9th December 2023; Available online 12th May 2024

Abstract: The dust mite *Oligonychus afrasiaticus* (McGregor 1939) (Acari: Tetranychidae) poses a significant threat to date palm *Phoenix dactylifera* L. productivity in Iraq. To address this issue, a field study was conducted in a private date palm orchard in Al-Zubair district, Basrah province, Iraq, to assess the efficacy of some treatments in controlling the dust mite population on date palm fruits. The treatments included lemongrass extract, nanosulfur, a combination of lemongrass extract and nanosulfur, liquid sulfur, and a distilled water as control treatment. Treatments were applied by spraying on leaves and fruits at three dates: five weeks, eight weeks, and eleven weeks after pollination. Dust mite mortality rates were measured at intervals of 1, 3, 5, and 7 days after treatment application. Results revealed that the second date, eight weeks after pollination, exhibited the highest mortality rate of 76.77%, significantly outperforming other dates. Among the treatments, liquid sulfur showed the highest efficiency, with an 87.83% mortality rate, followed closely by the combination of lemongrass extract and nanosulfur (84.14%). Nanosulfur alone recorded a mortality rate of 79.26%, while lemongrass extract alone showed a mortality rate of 49.15%. The mortality rate increased over time, reaching 80.79% after 7 days and 65.76% after 1 day. In conclusion, liquid sulfur emerged as the most effective treatment for controlling the dust mite population on date palm fruits. The second date, eight weeks after pollination, was the optimal time for treatment application. These findings offer valuable insights into sustainable and environmentally friendly pest control strategies for date palm cultivation in Iraq.

Keywords: Acaricide activity; Bioactive compounds; GC-MS; Mortality rate; Pest management.

Introduction

The date palm (*Phoenix dactylifera* L.) holds substantial economic importance as a key fruit crop in Iraq, contributing valuable resources for both local consumption and overseas trade (Johnson, 2010). Nevertheless, the consistent productivity of date palm orchards faces ongoing threats from a range of pests, with particular emphasis on the dust mite *Oligonychus afrasiaticus* (McGregor 1939) (Acari: Tetranychidae). This microscopic pest poses a significant challenge by infesting date palm fruits, leading to crop damage and a subsequent reduction in overall yield (Mohammed *et al*., 2023). The dust mite's presence begins during the initial phases of date development, as it creates intricate webs around clusters of dates and rapidly reproduces in large quantities. These webs trap dust, combined with the shed skins (exuviae) from various mite growth stages, resulting in the dates adopting a dusty appearance (Mirza *et al*., 2021).

In recent times, the use of chemical pesticides for pest control has raised noteworthy environmental and health concerns. This has prompted the exploration of alternative, environmentally friendly strategies for managing pest populations (Ngegba *et al*., 2022). Plant-derived extracts and formulations based on nanotechnology have displayed promising potential as safe and efficient substitutes for traditional chemical pesticides across different agricultural contexts. These natural compounds and nanoparticles have been found to possess insecticidal properties, effectively curbing pest populations while minimizing adverse effects on non-target organisms and the ecosystem as a whole (Luiz de Oliveira *et al*., 2018; Khursheed *et al*., 2022). *Cymbopogon citratus* (DC.) Stapf 1906, commonly known as lemongrass, thrives in tropical and subtropical regions. Lemongrass oil has exhibited miticidal properties against certain mite species, including the two-spotted spider mite (*Tetranychus urticae*) (Lim *et al*., 2011), as well as house dust mites (Margulis-Goshen & Magdassi, 2013). Various nanoparticles have been developed as mitecides, insecticides, and fungicides, and have undergone testing against conventional pesticide formulations. Notably, these nanoparticles have demonstrated significantly improved control efficacy compared to standard commercial formulations (Nisha Raj *et al*., 2021). Diverse types of nanoparticles are employed for managing different mite species, such as ZnO and TiO (Senbill *et al*., 2023), along with CuO (Al-Azzazy & Ghani, 2024). Sulfur finds utility in various forms including dust, wettable powder, paste, and liquid. It serves primarily to combat powdery mildews, specific rusts, leaf blights, and fruit rots (Williams & Cooper, 2004). Additionally, sulfur proves effective against spider mites, psyllids, and thrips. Most sulfur-based pesticides are recommended for use on vegetables like beans, potatoes, tomatoes, peas, and on fruit crops such as grapes, apples, pears, cherries, peaches, plums, and date palms (Prischmann *et al*., 2005). Laboratory evaluations have indicated variable toxicity levels of sulfur to spider mites, ranging from minimal to high toxicity (Ali & Fhaid, 2019). Notably, Gavanji *et al*. (2013) concluded that the use of sulfur nanoparticles was significantly more effective in controlling dust mites than the application of bulk sulfur.

The current work was carried out to assess the activity of bioactive compounds derived from lemongrass and sulfur nanoparticles against *O. afrasiaticus* mite, one of the major date palm pests.

Materials & Methods

Field Experiment

The field experiment was conducted in a privately-owned date palm orchard situated in the Al-Zubair district, west of Basrah province, Iraq, during 2021-2022 season. For this study, a total of 45 date palm trees belonging to the Barhi cultivar were meticulously selected to ensure uniformity in terms of age (15 years old) and height. These trees were grouped into three separate blocks; within each block, there were 15 individual trees. Each tree served as an experimental unit. The experimental treatments involved the utilization of various substances for managing mite infestations, implemented as control measures, as outlined below:

Treatment A involved the use of lemongrass extract at a concentration of 4 $g.L^{-1}$.

Treatment B consisted of nanosulfur applied at a concentration of 500 ppm.

Treatment C combined lemongrass extract and nanosulfur in a balanced 50:50 ratio.

Treatment D utilized liquid sulfur at a concentration of 2 $ml.L^{-1}$.

Treatment E served as the control, employing a water spray.

The treatment was applied by spraying date bunches until run-off on three separate dates: five, eight, and eleven weeks after pollination.

Preparation of plant extract

Lemongrass plant leaves were thoroughly washed with tap water to eliminate any impurities, after which they were carefully air-dried in a controlled laboratory setting. Subsequently, the dried leaves were finely pulverized into a powder using an electric grinder. The resulting plant powders were then stored in sealed glass jars under laboratory storage conditions. Taking 100 grams of the powdered material, it was mixed with 400 mL of 70% ethanol within Erlenmeyer flasks. The mixture underwent agitation at a rate of 100 rpm/min for 24 hours at a temperature of 20°C, facilitating the extraction of active compounds. The resultant extract underwent filtration and concentration under reduced pressure via a rotary evaporator. This concentrated extract was then adjusted to attain a concentration of 20% (w/v) using distilled water. The desired 4% concentration was achieved by dilution with distilled water, followed by the incorporation of 1 ml of Tween 80 and a single drop of paraffin (Chutrtong & Kularbphettong, 2019).

Gas Chromatography-Mass Spectrometry (GC-MS):

Bioactive compounds in the lemongrass plant extract were analyzed through the utilization of a Gas Chromatography-Mass Spectrometer. The system employed was the Agilent technologies 7890B GC system coupled with an Agilent technologies 5977A Mass Spectrometer Detector (MSD) equipped with Electron Impact (EI) single ionization source. Analysis was conducted using a 30-meter capillary column with a 0.25 mm inner diameter and a 0.25-µm film thickness consisting of 5% diphenyl and 95% dimethyl polysiloxane. This analysis was performed at the Nihran Omar, Basrah oil company laboratory (Ababutain, 2019).

Preparation of nanoparticle spray solutions

The nanosulfur used in the study was sourced from US Research Nanomaterials, Inc (USA), and was produced through laser gas phase synthesis. It was characterized with an average particle size (APS) of 47 nm, a purity of 99.9%, and exhibited a light yellow colour. To create a solution with a concentration of 500 ppm, 500 mg of nanosulfur was dissolved per liter of solvent.

Mortality assessment

To evaluate mortality rates, samples of date palm fruits were collected at distinct time intervals (pre-treatment, and 1, 3, 5, and 7 days post-treatment), which applied for all periods after five, eight and 11 weeks. These samples were carefully placed within polyethylene bags and transported to the laboratory at the plant protection department, Agriculture College, Basrah University for meticulously mites recording. Utilizing a dissecting microscope equipped with 2X and 4X magnification, mobile mite individuals were observed and enumerated. The efficiency of the pesticide was quantified using the Henderson-Tilton's equation as follow

$$corrected\ efficacy = 1 - \frac{No.of\ mites\ in\ C\ before\ spraying * No.of\ mites\ in\ T\ after\ spraying}{No.of\ mites\ in\ C\ after\ spraying * No.of\ mites\ in\ T\ before\ spraying} * 100$$

Which: C=Control and T=Treatment

Statistical Analysis:

Data resulting from the experiment underwent statistical analysis employing a factorial experiment using randomized complete block design (RCBD). Subsequent to analysis, The LSD test at 0.05 ($P< 0.05$) was employed for multiple mean comparisons when significant differences were detected within the independent factors and their interactions. The entire statistical analysis procedure was conducted using SPSS v.21 software.

Results

GC-MS analysis of lemongrass extract

The GC-MS analysis of lemongrass extract has identified a total of sixty compounds depicted in fig (1). The names of these compounds, along with their corresponding retention time (RT) and Area (%) identified through the NIST database are listed in table (1). Moreover, the GC-MS analysis of the ethanol extract derived from lemongrass has unveiled a broad spectrum of phytochemicals, potentially contributing to its acaricidal properties. The identified phytocompounds primarily consist of hydrocarbons, fatty acids, essential oils, alcohols, esters, etranyc, and phenols.

Impact of different treatment on date palm dust mite mortality rate.

The data in fig. (2) depict the results of treatments on the mortality rate of date palm dust mites. Among the various treatments evaluated, liquid sulfur exhibited the highest mortality rate at 87.83%. Following this, the combination of lemongrass extract and nanosulfur demonstrated a slightly lower but still notable mortality rate of 84.14%. The application of nanosulfur alone resulted in a mortality rate of 79.24%, indicating its efficacy in controlling the dust mite population. On the other hand, when lemongrass extract was applied alone, the observed mortality rate was 49.15%, which is comparatively lower than the other treatments. These findings suggest that liquid sulfur was the most effective treatment, significantly surpassing the other approaches in terms of dust mite mortality. The combined treatment of lemongrass extract and nanosulfur also showed a significant impact, while using nanosulfur alone demonstrated a slightly reduced but still notable effect. Lemongrass extract alone exhibited the least effectiveness in controlling the dust mite population.

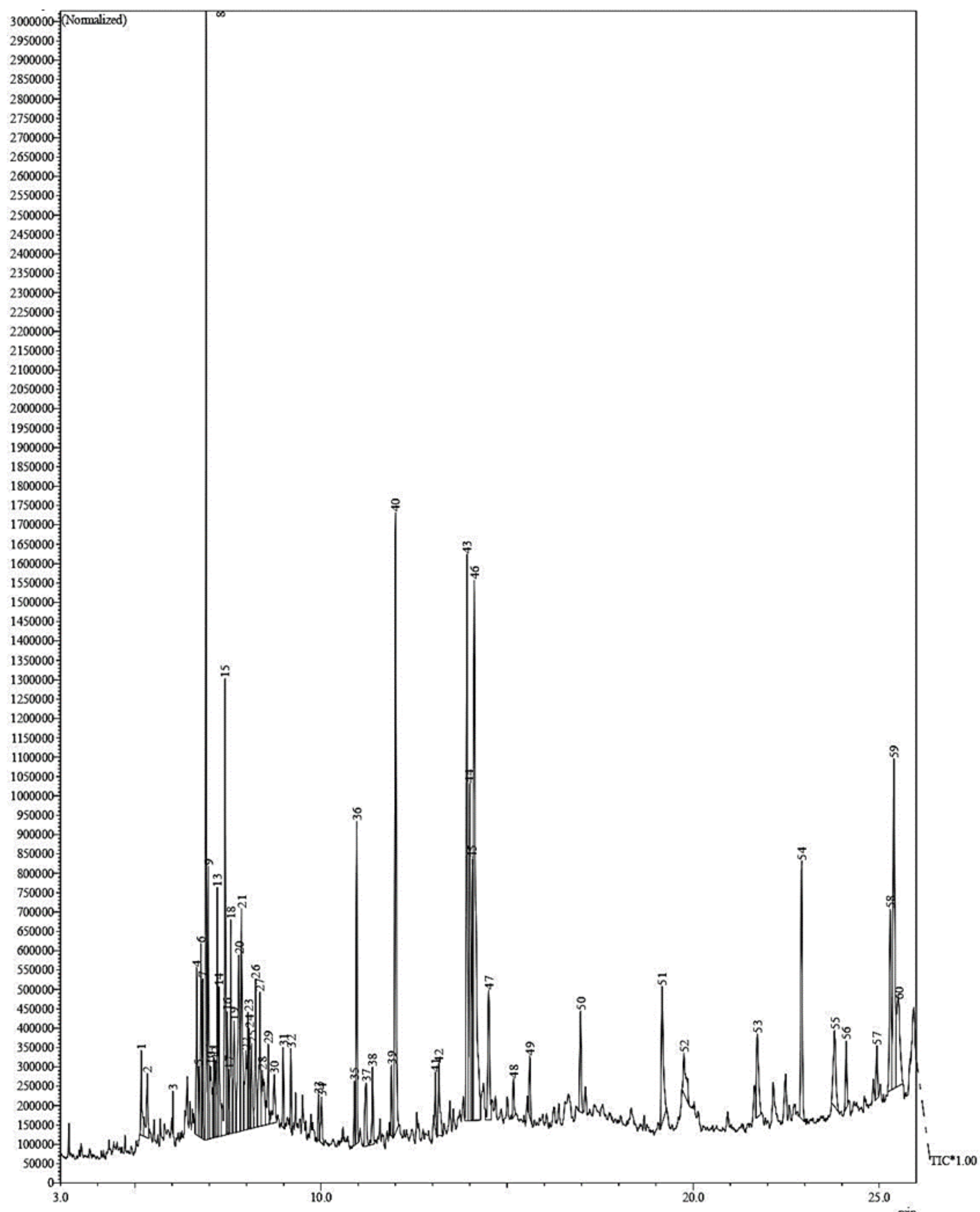

Fig. (1): GC-MS analysis of lemongrass extract.

Table (1): GC-MS analysis of phytochemicals in ethanol extract of lemongrass.

R.Time	Area%	Name
5.171	0.76	5-Hepten-2-one, 6-methyl-
5.333	0.85	Bicyclo[4.1.0]heptan-3-ol, 4,7,7-trimethyl-, (1.alpha.,3.alpha.,4.beta.,6.alpha.)-
6.021	0.20	Linalool
6.661	1.56	4-Vinylphenol
6.717	0.44	Oxiranecarboxaldehyde, 3-methyl-3-(4-methyl-3-pentenyl)-
6.773	1.47	6-Octen-1-ol, 3,7-dimethyl-, I-
6.822	1.05	Neral
6.912	6.70	2,6-Octadien-1-ol, 3,7-dimethyl-, (Z)-
6.972	1.69	2,6-Octadienal, 3,7-dimethyl-, I-
7.018	1.28	Epoxy-linalooloxide
7.126	0.56	2-Undecanone
7.165	0.61	Geranyl formate
7.217	1.86	2-Methoxy-4-vinylphenol
7.258	1.29	Neric acid
7.425	4.02	2,6-Octadienoic acid, 3,7-dimethyl-, I-
7.482	1.02	1,2-trans-1,5-trans-2,5-dihydroxy-4-methyl-1-(1-hydroxy-1-isopropyl)cyclohex-3-ene
7.525	0.43	2,4-Octadienoic acid, 7-hydroxy-6-methyl-, [r-[r*,s*-(E,E)]]-
7.573	1.62	2,6-Octadien-1-ol, 3,7-dimethyl-, acetate
7.663	1.33	Bicyclo[3.1.1]heptan-3-one, 2-hydroxy-2,6,6-trimethyl-
7.794	2.64	2-t-Butylperoxy-2-ethylbutan-1-ol, propionate ester
7.866	2.35	4-Methyl-5H-furan-2-one
7.983	1.37	2-[5-(1-Hydroxy-1-methylethyl)-2,2-dimethyl[1,3]dioxolan-4-yl]propan-2-ol
8.043	0.74	Rhodium, [1,2-bis(.eta.2-ethenyl)-4-ethenylcyclohexane]di-.mu.-chlorodi-
8.075	0.70	Octanal, 7-hydroxy-3,7-dimethyl-
8.138	0.83	6,7-Dioxabicyclo[3.2.1]octane, 1-methyl-
8.242	1.30	3-Cyclohexen-1-ol, 1-methyl-
8.359	1.49	4,4-Dimethyl-cyclohex-2-en-1-ol
8.422	1.05	2-Propenoic acid, 2-methyl-, 3-methyl-2-methylene-3-butenyl ester
8.584	0.84	Dodecanoic acid
8.748	0.80	1-Propanone, 1-(3-acetyl-2,2-dimethylcyclopropyl)-2-methyl-
8.986	0.56	Caryophyllene oxide
9.192	0.49	Selin-6-en-4.alpha.-ol
9.932	0.37	Loliolide
10.017	0.46	Tetradecanoic acid
10.900	0.56	Phthalic acid, isobutyl 2-(2-methoxyethyl)hexyl ester
10.958	2.36	Neophytadiene
11.212	0.85	1-Eicosanol
11.386	0.69	3,7,11,15-Tetramethyl-2-hexadecen-1-ol
11.896	0.53	Geranyl caprylate
12.005	5.96	n-Hexadecanoic acid
13.075	0.45	Bicyclo[3.1.1]heptan-3-one, 2,6,6-trimethyl-, (1.alpha.,2.beta.,5.alpha.)-
13.169	0.95	Hexane, 1-bromo-6-chloro-
13.923	5.29	6-Methyl-4,6-bis(4-methylpent-3-en-1-yl)cyclohexa-1,3-dienecarbaldehyde
13.998	3.52	Phytol
14.067	2.59	cis-7-Dodecen-1-ol
14.120	8.81	9,12,15-Octadecatrienoic acid, (Z,Z,Z)-
14.506	1.74	Cyclopentaneundecanoic acid

15.172	0.39	(3,7,7-Trimethyl-bicyclo[2.2.1]hept-2-yl)-methanol
15.611	0.57	Tributyl acetylcitrate
16.974	1.12	9-Octadecenamide, (Z)-
19.168	2.10	Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester
19.751	0.83	Diisooctyl phthalate
21.724	1.32	cis,cis,cis-7,10,13-Hexadecatrienal
22.914	2.81	I-3,7-Dimethylocta-2,6-dien-1-yl palmitate
23.798	1.42	Cycloartanol
24.114	0.70	Squalene
24.937	0.57	Isomyrcenyl acetate
25.296	2.32	(9Z,12Z)-I-3,7-Dimethylocta-2,6-dien-1-yl octadeca-9,12-dienoate
25.394	4.59	(9Z,12Z,15Z)-I-3,7-Dimethylocta-2,6-dien-1-yl octadeca-9,12,15-trienoate
25.525	2.23	Pseudosmilagenin
	100.00	

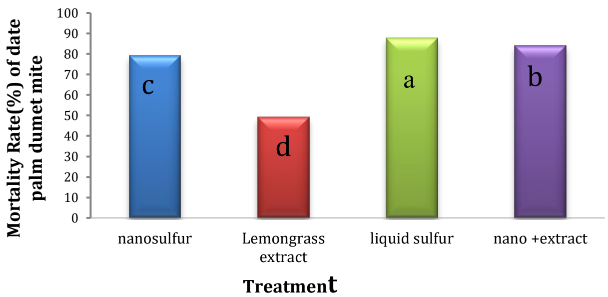

Fig. (2): Effect of the Treatments on Mortality of on Date Palm Dust Mites.

Impact of the treatment application dates after pollination on palm dust mite mortality rate.

Fig. (3) illustrated the impact of different spray dates on the mortality rate of date palm dust mites. The study encompassed three distinct application timings: the first date, occurring five weeks after pollination, resulted in a mortality rate of 75.735%. The second application, undertaken at the eight-week mark post-pollination, yielded a notably higher mortality rate of 76.77%. The third and final application, carried out after eleven weeks of pollination, exhibited a mortality rate of 73.14%. Upon closer examination of these outcomes, it becomes evident that the timing of the spray dates significantly influences the efficacy of the treatment. The second date, conducted at the eight-week interval after pollination, stands out as the most impactful, boasting the highest mortality rate among all three dates. This result suggests that applying the treatment at this particular stage of development yields the most effective control over the dust mite population. Comparatively, the first spray date, administered five weeks after pollination, showcases a mortality rate that is also notably higher than the third application. This highlights the significance of prompt intervention and emphasizes the potential advantages of tackling the matter at the onset of the pollination process. Conversely, the third date, conducted after eleven weeks of pollination, exhibits a slightly lower mortality rate compared to the other two dates. Despite still demonstrating a certain degree of effectiveness, this discovery suggests that delaying the treatment for a longer period may have a slightly diminished impact on dust mite control.

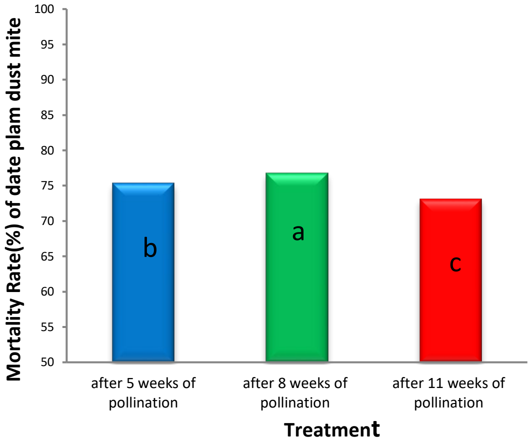

Fig (3): Effect of application dates of the treatment (nanosulfur, lemongrass extract, liquid sulfur and nano+ extract) on palm dust mite mortality rate.

Impact of the durations of treatment exposure on date palm dust mite mortality rate

The findings presented in fig. (4) revealed the effect of different exposure durations on the mortality rate of date palm dust mites. The study involved assessing four distinct time periods: one day, three days, five days, and seven days. The recorded mortality rates for each duration were 65.71%, 75.42%, 78.41%, and 80.79%, respectively.

Examining these results exposes a distinct pattern of enhanced effectiveness as the duration of exposure increases. The initial one-day exposure yielded a mortality rate of 65.71%, which rose noticeably to 75.42% after three days. This trend continues with even greater impact, as the mortality rate reaches 78.41% after five days. The most substantial effect is observed after a full seven days of exposure, resulting in an 80.79% mortality rate. These findings emphasize the notable correlation between the duration of exposure and the mortality of date palm dust mites. Longer durations correlate with heightened efficacy in controlling the mite population. The increasing mortality rates over time signify the cumulative impact of extended exposure, highlighting the importance of sustained treatment to achieve optimal results.

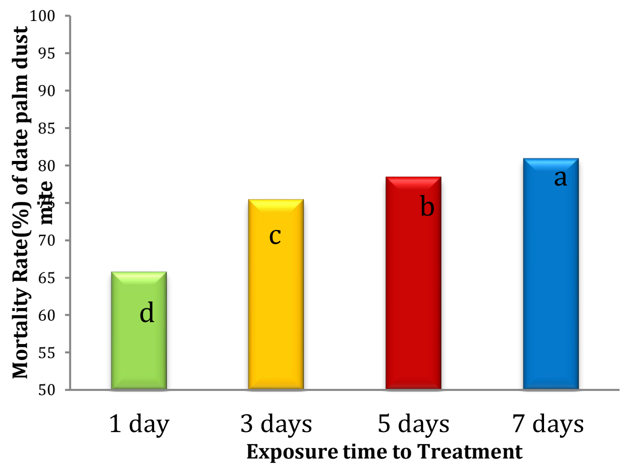

Fig. (4): Effect of the durations of treatment (nanosulfur, lemongrass extract, liquid sulfur and nano+ extract) exposure on date palm dust mite mortality.

Impact of the interaction of the treatments, application date and duration of exposure on the mortality rate of date palm dust mites.

The results presented in tables (2, 3, 4, and 5) provide insight into the complex interactions among treatments, spraying dates, exposure durations, and their combined effects on the mortality rate of date palm dust mites. Despite the statistical analysis ($p<0.05$) revealing a non-significant effect of the interaction between treatments and spraying date on the mortality rate of date palm dust mite, the results in table (2) show the most impact was observed when liquid sulfur was administered during the second spraying date, which occurred eight weeks after pollination. This combination resulted in the highest mortality rate of 89.70%, which significantly exceeded other interactions. In contrast, the application of lemongrass extract alone during the third spraying date (eleven weeks post-pollination) resulted in the lowest rate of 47.28%.

Table (2): Effect of treatment and application date of the mortality rate (%) of date palm dust mite.

Treatment	Spraying date		
	5 weeks after pollination	8 weeks after pollination	11 weeks after pollination
Nanosulfur	79.26a	81.13a	77.38a
Lemongrass extract	49.15a	51.03 a	47.28a
Liquid sulfur	87.82a	89.70 a	85.95a
Nano+ extract	85.24a	85.24 a	81.95a

Analyzing the interaction between treatments and exposure time revealed a significant impact on the mortality rate of date palm dust mites. As depicted in table (3), the most potent synergy between treatment and exposure time was observed after seven days when liquid sulfur was applied, reaching 92.69%; this rate was significantly superior to the rest of the interactions. In contrast, the lowest mortality rate of 44.70% was noted following one day of exposure to lemongrass extract when applied alone.

Table (3): Effect of treatments and duration of exposure time in the mortality rate (%) of date palm dust mite.

Treatment	Exposure time (day)			
	1	3	5	7
Nanosulfur	67.19j	79.14g	82.42f	88.28d
Lemongrass extract	44.70n	47.51m	51.26l	53.14k
Liquid sulfur	77.69h	88.64cd	91.28b	92.69a
Nano+ extract	73.44i	85.39e	88.67cd	89.06c

The results of the statistical analysis confirmed that the interaction between spraying date and exposure time did not show significant differences in the mortality rate of date palm dust mite. However, the results in table 4 showed that the application of treatments after seven days at the second spraying date resulted in the highest mortality rate of 82.35%, indicating a synergistic effect between the precise timing of application and the duration of exposure. Conversely, the lowest rate of 63.73% was observed when treatments were administered after only one day on the third spraying date.

Table (4): Effect of the treatments application date and duration of exposure in the mortality rate (%) of date palm dust mite.

Spraying date	Exposure time (day)			
	1	3	5	7
5 weeks after pollination	66.07a	75.73a	78.72a	80.95a
8 weeks after pollination	67.47a	77.14a	80.13a	82.13a
11 weeks after pollination	63.73a	76.39a	76.38a	79.07a

The data presented in table (5) depict the three-way interaction among the study factors concerning the mortality rate of date palm dust mites. Although there is some variability in how these factors interact with one another and affect the mortality rate, it is noteworthy that these variations did not reach statistical significance. The results indicate that the highest mortality rate was recorded seven days after spraying with liquid sulphur on the second date and reached 94.57%, while the lowest mortality rate was recorded one day after spraying with lemongrass extract on the second date and reached 42.83%.

Table (5): Mortality rate (%) of date palm dust mite under different treatments, application date and exposure time.

Treatments	**Application date**	**Exposure time (day)**			
		1	**3**	**5**	**7**
Nanosulfur	5 weeks after pollination	67.19a	79.14a	82.42a	88.28a
	8 weeks after pollination	69.07a	81.02a	84.30a	90.15a
	11 weeks after pollination	65.32a	77.27a	80.55a	86.40a
Lemongrass extract	5 weeks after pollination	44.70a	47.52a	51.27a	53.14a
	8 weeks after pollination	46.58a	49.39a	53.14a	55.01a
	11 weeks after pollination	42.83a	45.64a	49.39a	51.27a
Liquid sulfur	5 weeks after pollination	77.69a	89.64a	91.28a	92.69a
	8 weeks after pollination	79.57a	91.51a	93.16a	94.57a
	11 weeks after pollination	75.82a	87.77a	89.41a	90.82a
Nano+ extract	5 weeks after pollination	74.69a	86.64a	89.92a	89.69a
	8 weeks after pollination	74.69a	86.64a	89.69a	89.92a
	11 weeks after pollination	70.94a	82.89a	86.17a	87.81a

Discussion

A combination of lemongrass extract (4 $g.L^{-1}$) and nanosulfur (500 ppm) in a 50:50 ratio was found to be highly effective in killing date palm dust mites. Although this approach exhibited a slightly lower efficacy compared to the traditional treatment method involving liquid sulfur spraying, it still demonstrated significant impact. Sulfur is primarily recognized for its fungicidal properties; however, its insecticidal characteristics, particularly against mites, have been extensively documented. In various regions, sulfur has been employed to manage date palm dust mites (El-halawany *et al*., 2017; Ali & Fhaid, 2019). The effectiveness of sulfur in reducing these mites can be attributed to its vapor, which hampers their feeding and reproduction abilities, leading to a rapid decline in their population (Prischmann *et al*., 2005). While nanoparticles have exhibited activity against diverse arthropod species, limited research has been conducted on their impact on date palm dust mites. Notably, Almrsomy *et al*. (2020) found that the Fenpyroximate 5% SC pesticide, in its nanoparticle formulation and applied at half the recommended concentration, outperformed the traditional pesticide form used at the recommended concentration. This application significantly affected all developmental stages of the date palm dust mite. Additionally, Ghani *et al*. (2024) evaluated the miticidal effectiveness of synthesized silver nanoparticles against the *O. afrasiaticus* mite, a pest affecting date palms. The study's results demonstrated notable miticidal activity against both the mobile stages and deposited eggs of this pest.

The results obtained through GC-MS analysis of lemongrass extracts in the current study highlighted the presence of numerous significant chemical compounds, including etranyc, essential oils, phenols, esters, and fatty acids (Table 1). These compounds have been previously documented to exhibit a range of acaricide activities. For instance, Linalool, an aromatic monoterpenes alcohol, has been identified for its acaricidal potential (de Melo *et al*., 2018), while Neral, a monoterpenes aldehyde, has also demonstrated acaricidal properties (Hussain *et al*., 2023). Similarly, undecanone (Pohlit *et al*., 2011) and cis-Geraniol, identified as 2, 6-octadien-1-ol 3, 7-dimethyl-, have been associated with acaricide effects (Park *et al*., 2018).

Certain plant extracts exhibit high efficacy against insects and mites that have developed resistance to synthetic insecticides and acaricide. This effectiveness can be attributed to the presence of various metabolites with distinct modes of action. Notable chemicals such as alkaloids, glycosides, essential oils, and phenols have been identified as pivotal in initiating mechanisms of action for both *in vitro* and *in vivo* activities, leading to mortality among mites (Kemal *et al*., 2020; Ruiz-Jimenez *et al*., 2021).

The effectiveness of the treatment during the second date (after eight weeks of pollination) may have resulted from a confluence of factors including the stages of development of date palm fruits and dust mites, population dynamics of the pest, interactions between the treatment and the environment, and potential for synergistic interactions. This etranychi how important it is to take these complex elements into consideration when developing strategies for effective pest control (El-Halawany *et al*. 2017; Latifian 2017). Also results of this study showed, extended exposure durations yielded heightened rates of mortality among date palm mites. As the period of exposure increased from one to seven days, there was a noticeable escalation in the rate of date palm mite mortality. This observation underscores the requirement for a duration of time for treatments to exert their acaricidal effects on date palm mites, as postulated by Fu *et al*. (2021). These findings align consistently with prior research, as seen in studies by Ali & Fahid (2019) and Zhu *et al*. (2023). Prolonged exposure periods enhance the penetration and interaction of bioactive compounds with the physiological processes of date palm mites, leading to increased mortality rates, as demonstrated by Jian et al. (2022).

Conclusion

This research emphasizes the effectiveness of nanosulfur, particularly in combination with lemongrass extract, for its acaricidal potential in the cultivation of date palms. The highest mortality rate of dust mites is achieved when the treatment is applied during the second spraying date, which takes place eight weeks after pollination. Furthermore, extended exposure durations enhance the treatment's impact on mite mortality rates. These findings highlight the intricacy of developing effective pest management strategies for date palm cultivation.

Acknowledgment

We would like to extend our gratitude to the University of Basrah, particularly the College of Agriculture, and the Date Palm Research Centre for providing the essential resources and support to conduct this research.

Contributions of authors

H.M.A., carried out the experiment in the field and collected the data

K.A.F., constructed the idea and hypothesis for research; planned the methodology; project administration.

K.M.A., data analysis; wrote the manuscript

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Conflicts of interest

The authors declare no conflicts of interest.

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تقييم استخدام مستخلص عشبة الليمون والكبريت النانوي لإدارة انتشار حلم غبار النخيل ***Oligonychus afrasiaticus*** **(McGregor) (Acari Tetranchidae)** في بساتين نخيل التمر-نهج صديق للبيئة

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المستخلص: يشكل حلم الغبار *Oligonychus afrasiaticus* (McGregor) (Acari Tetranchidae) تهديداً كبير لإنتاجية نخيل التمر *Phoenix dactylifera* L. في العراق. لمعالجة هذه المشكلة، أجرينا دراسة حقلية في احد بساتين نخيل التمر بمنطقة الزبير في محافظة البصرة بالعراق لتقييم فعالية مختلف المعاملات في السيطرة على عدد حلم الغبار على ثمار نخيل التمر. شملت المعاملات مستخلص عشبة الليمون و الكبريت النانوي وتركيبة من مستخلص عشبة الليمون والكبريت النانوي فشلا عن الكبريت السائل وماء مقطر كمجموعة مقارنة. تم رش المعاملات على الأوراق والثمار في ثلاث مواعيد وكانت بعد خمسة أسابيع وثمانية أسابيع وأحد عشر أسبوعًا من التلقيح. تم قياس نسبة وفيات حلم الغبار بعد 1و 3 و 5 و7 أيام بعد المعاملة. أظهرت النتائج أن الموعد الثاني (ثمانية أسابيع بعد التلقيح) كان له أعلى نسبة وفيات بلغت 76.77%، والتي كانت أفضل بشكل ملحوظ من بقية المواعيد. بين المعاملات، أظهر الكبريت السائل أعلى كفاءة بنسبة وفيات بلغت 87.83%، تلتها معاملة الخلط بين مستخلص عشبة الليمون والكبريت النانوي (84.14%) بينما سجلت معاملة الكبريت النانوي بمفرده نسبة وفيات بلغت 79.26%، في حين بلغت نسبة الوفيات في معاملة مستخلص عشبة الليمون بمفردها 49.15%. زادت نسبة الوفيات مع مرور الوقت، حيث وصلت إلى 80.79% بعد سبعة أيام و 65.76% بعد 1 يوم. في الختام، اثبتت نتائج هذه الدراسة أن الكبريت السائل هو أكثر المعاملات فعالية للسيطرة على انتشار حلم الغبار على ثمار نخيل التمر وان الموعد الثاني (ثمانية أسابيع بعد التلقيح) كان الوقت الامثل لتطبيق المعاملة. توفر هذه النتائج رؤى قيمة حول استراتيجيات مستدامة وصديقة للبيئة لمكافحة الآفات في زراعة نخيل التمر في العراق.

الكلمات المفتاحية :نشاط مبيد للقراد؛ مركبات فعالة؛ كروماتوغرافيا الغاز-مطياف الكتلة؛ نسبة الوفيات؛ إدارة الآفات.