International Journal of Zoology Studies
www.zoologyjournals.com
ISSN: 2455-7269
Received: 15-01-2026, Accepted: 17-02-2026, Published: 03-03-2026
Volume 11, Issue 1, 2026, Page No. 51-60

Toxicological and control efficiency of chitosan and congest against *Eutetranychus orientalis* and *Tydeus californicus* under laboratory and semi-field conditions

Rania H Mahmoud*, Asmaa R Abdel-Khalik, Rania A El-Nahas
Department of Cotton and Field Crops Mite, Plant Protection Research Institute, Agricultural Research Centre, Dokii, Giza, Egypt

Abstract
Eutetranychus orientalis and *Tydeus californicus* infestations are a major threat to eggplant production, requiring effective and environmentally friendly control strategies. Thus, the study aimed to investigate the bioassays, reproductive effects, and semi-field efficacy of congest and chitosan against immature and adult stages of both mite species. Significant acaricidal activity was demonstrated by congest and chitosan against *E. orientalis* and *T. californicus*; compound type, concentration, and exposure duration all had a significant impact on efficacy. Congest continuously demonstrated significantly greater toxicity than chitosan against the two mite species' immature and adult stages in lab bioassays. Congest had the lowest LC_{50} values (0.022-0.029 for *E. orientalis* and 0.025 for *T. californicus*) after seven days of exposure, while chitosan continued to be significantly less toxic despite time-dependent improvement. Both compounds significantly decreased oviposition and larviposition in a concentration-dependent manner, according to reproductive assays; congest caused the most suppression (ODI up to 44.75% in *E. orientalis* and 35.73% in *T. californicus*). Congest significantly reduced mite populations in semi-field conditions; at higher concentrations, it reduced both the immature and adult stages of the two mite species by more than 90% in just seven days. Chitosan, on the other hand, produced a moderate but steady degree of suppression that became more noticeable as exposure time and concentration increased. These results show that while chitosan offers a slower but dependable complementary control effect, congest is very effective for rapid mite suppression.

Keywords: Eggplant, chitosan, comparative, efficacy, control, tetranychidae

Introduction

Eutetranychus orientalis (Klein) (Tetranychidae) is a serious pest of citrus and is reported on about 228 host plants in 62 families of economic importance worldwide, feeding on leaves and reducing photosynthetic capacity and yield. Its pest status has been documented in several regions, and it often occurs with other mite species in orchards (Vela *et al*. 2017; Migeon and Dorkeld 2025) [23]. *Tydeus californicus* (Banks) (Tydeidae) is less studied as a pest but is commonly found in fruit orchards and may interact with other mite species, affecting pest dynamics (Vela *et al*. 2017) [23]. Both species represent challenges in integrated pest management due to variability in susceptibility to control agents and the need to preserve beneficial arthropods.

Eggplant (*Solanum melongena* L.) is a widely cultivated and economically significant vegetable crop in Egypt, valued for its nutritional and market importance in both local consumption and agricultural production systems. Research on Egyptian eggplant highlights its susceptibility to a range of arthropod pests, including phytophagous mites, which can cause considerable damage to foliage and reduce crop yield if not properly managed (Abou Ouf 2016). Studies of mite communities on eggplant in Egypt report that various mite species infest this crop, underscoring the need for effective mite management strategies as part of integrated pest management programs (Abou Ouf 2016; Amer *et al*. 2025) [7]. Therefore, understanding the dynamics of mite pests on eggplant is critical for improving productivity and protecting this economically important crop.

Commercial products such as congest combine abamectin (a macrocyclic lactone acaricide) with imidacloprid (a neonicotinoid insecticide). Abamectin, the principal miticidal component, disrupts the nervous system of arthropods leading to paralysis and death Sparks and Nauen (2015) [22]. Recent field studies evaluating pesticides including congest (a formulation similar or equivalent to congest) against *E. orientalis* found that while all tested acaricides were effective, abamectin-based formulations showed high reduction percentages of mite populations. Among the tested pesticides in citrus orchards, congest recorded the lowest reduction percentage compared with other acaricides, though still contributed to mite control Al Dhafar *et al*. (2024) [6]. These findings suggest that congest-type acaricides have efficacy against *E. orientalis* but may perform differently depending on formulation, application rates, and field conditions—an important consideration for integrating such products into management plans. However, existing literature lacks direct experimental evaluations of congest specifically against *T. californicus* under controlled laboratory or semi-field settings. Abdelmaksoud *et al*. (2020) [1] reported that Congest 15% CS (abamectin + imidacloprid) reduced Tetranychus urticae populations on strawberry plants by 75.9%.

Chitosan is a biodegradable polysaccharide derived from chitin with emerging applications in agricultural pest management due to its low toxicity and eco-friendly profile. It has been studied extensively as a control agent against a variety of arthropods, primarily through formulations including nanoparticles and synergistic combinations

Abenaim and Conti (2023) [3]. Recent reviews emphasize that chitosan, including chitosan coatings, nanoparticles, and chitosan nano-formulations with essential oils or other active ingredients, can exhibit pest control activity. These formulations often enhance penetration, adhesion, or biological activity compared with conventional chitosan; however, results are variable depending on species and formulation. Direct studies specifically evaluating chitosan against *E. orientalis* or *T. californicus* are currently limited or unavailable, highlighting a gap in the literature and a valuable area for future research. Nonetheless, the general bioactivity of chitosan formulations supports its potential inclusion in integrated management strategies for spider mites and related pests.

Effective mite management often relies on integrating chemical control with biological and cultural tools to minimize resistance development and preserve natural enemies. While Congest-type acaricides provide rapid suppression, excessive reliance can select for resistance in mite populations and harm beneficial arthropods Al Dhafar *et al*. (2024) [6].

Chitosan and its derivatives, through modes of action such as plant defense induction and delivery of acaricidal compounds, offer an alternative that may reduce chemical inputs and environmental impact. Combining chitosan formulations with traditional acaricides could improve control while mitigating non-target effects—especially in semi-field or field conditions.

This study was conducted to assess the toxic effects of Conjest and chitosan on immature and adult stages of *E. orientalis* and T.californicus, to determine their impacts on reproductive parameters and deterrent indices, and to evaluate the effectiveness of three concentrations of both compounds under semi-field conditions on eggplant.

Materials and Methods

Eutetranychus orientalis and *T. californicus* were collected from infested eggplant plants at Menoufia Governorate, Egypt. Seedlings of eggplant were planted in pots containing soil and leaf compost. Plants at the appropriate growth stage were infested with *E. orientalis* and T. californicus. The stock culture was maintained in conditions of 25 ± 2°C, 60-70% RH, and 16:8 L:D. After several generations, mites from the stock colony were used for the tests Elhalawany *et al*. (2019) [11]. The identity of Identification of *E. orientalis* and *T. californicus* was conducted using the key given by Krantz and Walter (2009) and Zaher (1984) [17, 24].

Test compounds preparation

a. Chitosan

Common name: Chitosan

Trade name: Chitosol

Molecular formula: $(C_6H_{11}NO_4)_n$

Chemical name: (1,4)-2-Amino-2-desoxy-beta-Dglucan.

The technical-grade active ingredient was obtained from the Royal Company for Agricultural Development, while the commercial formulation chitosole-selanole EC (50%) was provided by Agrochem (Egypt). Prepare a series of three concentrations (0.5, 1.0, and 2.0ml/l).

b. Congest

Common name: Abamectin 3% +Imidacloprid 12%

Trade name: Congest 15% SC.

Molecular formula: $C_{48}H_{72}O_{14}$ + $C_9H_{10}ClN_5O_2$

Chemical name: Abamectin Macrocyclic lactone (mixture, e.g., Abamectin B1a/B1b) and Imidacloprid (1-(6-chloro-3-pyridin-3-ylmethyl)-N-nitroimidazolidin-2-ylideneamine)

Source: Qingdao Audis Bio-Tech company. Local production in Egypt Starchem industrial chemical company. With rate of application 40ml/100l.

Prepare a series of three concentrations (0.05, 0.10, and 0.20ml/l).

Experimental design

Eggplant leaf discs (5 cm in diameter) were inverted and placed on moistened cotton pads supported by sponge material inside experimental foam trays (15 × 20 cm). Moisture was maintained by adding water as required to preserve leaf freshness and prevent the escape of *E. orientalis* and *T. californicus*. Three treatment groups in addition to an untreated control were established. A total of 70 foam trays were used in the experiment, with each treatment replicated ten times.

Laboratory experiment

Thirty adult female of both *E. orientalis* and *T. californicus* individuals were placed on the lower surface of a newly eggplant leaf disc. Three concentrations (0.5, 1.0, and 2.0ml/l) for chitosan and (0.05, 0.10, and 0.20ml/l) for congest and 10 replicates of each concentration were given a prior treatment with a fine camel hairbrush. Mortality was calculated using a binocular microscope at 3, and 7 days post treatments and corrected using Abbott's method (1925), and Finney's (1971) [4, 14] estimates of the LC_{50}, LC_{90}, and slope values were used. The eggplant discs were maintained at room temperature (25±2°C, 70±5% RH). A mite was considered dead when its body or appendages did not move when it was probed with a fine camel brush (Mahmoud *et al*. 2024) [18].

Effect of conjest and chitosan on reproductive parameters and deterrent indices of *E. orientalis* and *T. californicus* females.

Leaf disks of eggplant were painted with various concentrations of tested compounds. Newly emerged females were transferred singly on painted leaf discs. Twenty replicate leaf discs were used per each concentration and similar number of females on clean leaf disks was used as a control. The fecundity and mortality of females were recorded for 7 days. The oviposition deterrent indices (ODI) were calculated as reported by Lundgren (1975) as follow:

ODI = (A-B/A+B) X 100%, where: A: Number of eggs in untreated treatment and B: Number of eggs in treated treatment according by Elhalawany *et al*. (2022) [13].

Semi field Experiment
Eggplant plants were grown in pots under open field at the private farm of Ashmoon locality, Menofia governorate. Each pot contains three two seedlings, after two weeks of planting, the plants was infested with 30 adults of *E. orientalis* and *T. californicus* per each pot. After one week the three concentrations of chitosan and congest was treated. Twenty leaves were chosen randomly from each treatment and the number of adult and motile mite stages was counted before treated and after three, and seven days of application using the aid of a stereomicroscope. Henderson and Tilton's (1955) [15] equation was used to estimate the reduction percentage of the mites (immature and adult).

Statistical Analysis
Probit analysis (Finney, 1971) [14] was used to the data from each dose-response bioassay in order to determine the LC_{50} and LC_{90} values using Ldp line software (Bakr 2005) [8]. Reduction percentage of *E. orientalis and T. californicus* moving stage was analyzed by one-way ANOVA and means were compared by using Tukey's HSD test at α=0.05 in SAS Program version 9.1.3 (SAS Institute, 2003) [20].

Results
Toxicity effect of congest and chitosan against *Eutetranychus orientalis* immature and adults
The toxicity of congest and chitosan against both immature and adult stages of *E. orientalis* varied markedly according to compound type and exposure duration (Tables 1 and 2). In all cases, congest exhibited substantially higher toxicity than chitosan, and toxicity increased with prolonged exposure from 3 to 7 days.
For immature stages (Table 1 and Figure 1), congest showed high acaricidal activity after 3 days, with an LC_{50} value of 0.065, while chitosan recorded a much higher LC_{50} value of 1.327, indicating low toxicity. After 7 days, the toxicity of Congest increased markedly, as reflected by a significant Reduction in LC_{50} to 0.022, making it the most effective treatment (toxicity index = 100, RR = 1). Chitosan also exhibited improved toxicity over time, with its LC_{50} decreasing to 0.716 after 7 days; however, it remained considerably less effective than Congest, as shown by its low toxicity index (3.07) and high resistance ratio (32.54).
A similar trend was observed for adult stages (Table 2 and Figure 2). After 3 days of exposure, Congest displayed strong toxicity with an LC_{50} of 0.067, whereas chitosan showed weak toxicity with an LC_{50} of 1.470. Extending the exposure to 7 days enhanced the efficacy of both compounds. Congest achieved the highest toxicity against adults, with its LC_{50} declining to 0.029 (toxicity index = 100), while chitosan showed moderate improvement, with an LC_{50} of 0.856. Despite this improvement, chitosan remained far less toxic than congest, as indicated by its low toxicity index (3.07) and high resistance ratio (32.54).
Across both developmental stages, slope values ranged from 1.50 to 2.07, indicating a consistent and reliable dose-response relationship. The non-overlapping confidence limits among treatments and exposure periods confirm significant differences in toxicity. The results clearly demonstrate that congest is highly effective against both immature and adult stages of *E. orientalis*, with toxicity increasing over time. The enhanced efficacy after 7 days suggests cumulative or delayed toxic effects. Although chitosan showed lower overall toxicity, its time-dependent increase in effectiveness indicates potential as a slower-acting acaricidal agent.
Generally, congest was the most potent compound against both immature and adult stages of *Eutetranychus orientalis*, particularly after 7 days of exposure. Chitosan exhibited limited toxicity but showed improved performance with prolonged exposure. These findings support the use of Congest for rapid mite suppression, while chitosan may serve as a complementary option in integrated pest management programs.

Table 1: Toxicity effect of congest and chitosan against *Eutetranychus orientalis* immature stages after 3, and 7 days

Treatments	Time (day)	LC_{50}	Confidence limits of LC_{50}		LC_{90}	Slope	Toxicity index	RR
			Lower	Upper				
Congest	3	0.065 b	0.05	0.078	0.279	2.02±0.32	33.84	2.95
	7	0.022 a	0.006	0.036	0.151	1.53±0.37	100.00	1.00
Cheitosan	3	1.327 d	1.068	1.802	8.792	1.56±0.30	1.65	60.31
	7	0.716 c	0.571	0.848	2.961	2.07±0.32	3.07	32.54

Resistance Ratio (RR), Toxicity index was calculated with respect to the most effective compound LC_{50}

Table 2: Toxicity effect of congest and chitosan against *Eutetranychus orientalis* adult stages after 3, and 7 days

Treatments	Time (day)	LC_{50}	Confidence limits of LC_{50}		LC_{90}	Slope	Toxicity index	RR
			Lower	Upper				
Congest	3	0.067 b	0.053	0.079	0.279	2.02±0.32	33.846	2.955
	7	0.029 a	0.011	0.043	0.151	1.53±0.34	100.0	1.00
Cheitosan	3	1.470 d	1.205	1.965	8.792	1.5±0.31	1.658	60.31
	7	0.856 c	0.683	1.034	2.961	2.07±0.31	3.073	32.54

Resistance Ratio (RR), Toxicity index was calculated with respect to the most effective compound LC_{50}

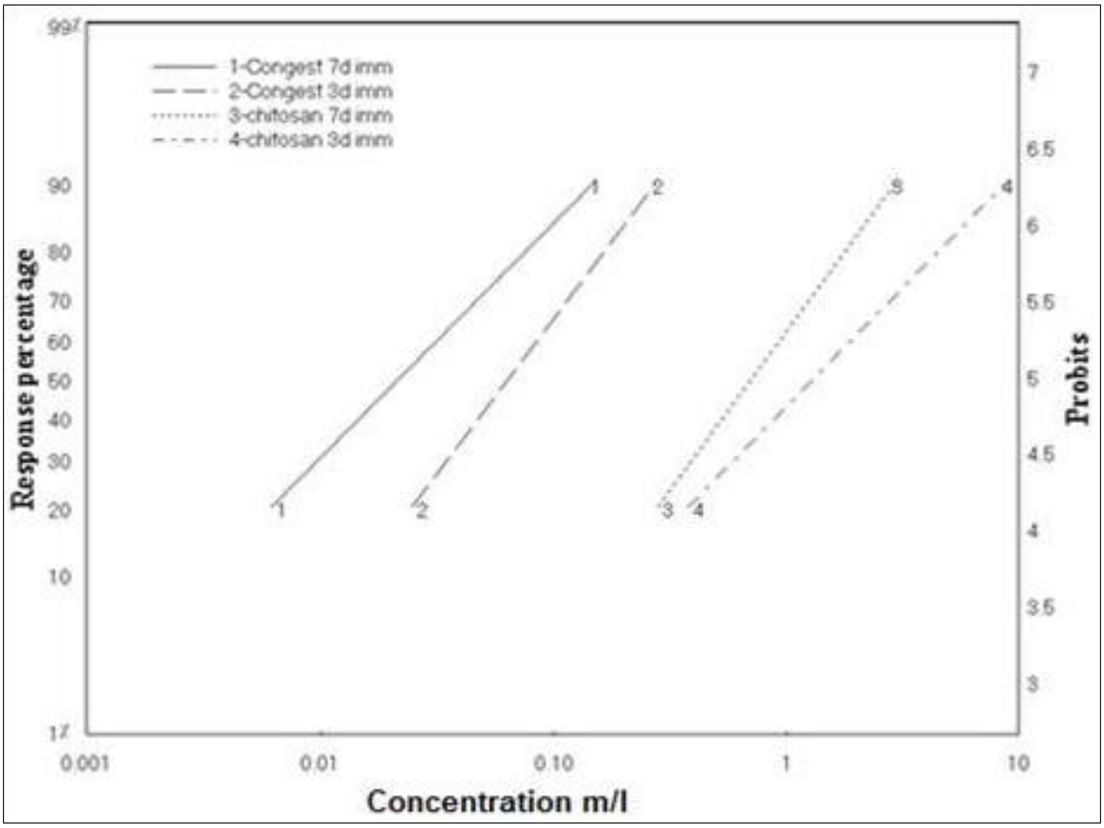

Fig 1: Toxicity effect of congest and chitosan against *Eutetranychus orientalis* immature stages after 3, and 7 days

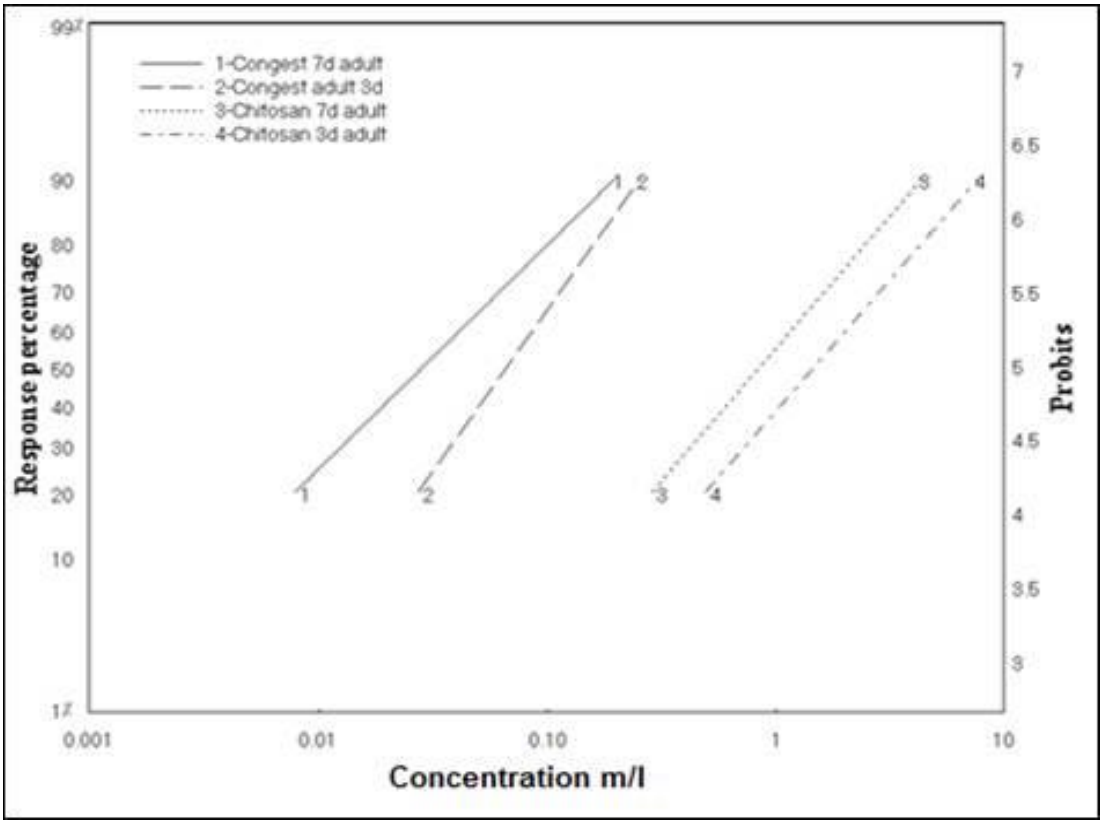

Fig 2: Toxicity effect of congest and chitosan against *Eutetranychus orientalis* adult stages after 3, and 7 days.

Toxicity effect of congest and chitosan against *Tydeus californicus* immature and adults

The toxicity of congest and chitosan against immature and adult stages of *T. californicus* varied according to compound type and exposure duration (Tables 3 and 4). In general, congest showed higher acaricidal activity than chitosan at both developmental stages, and toxicity increased with prolonged exposure from 3 to 7 days.

For immature stages (Table 3 and Figure 3), Congest exhibited high toxicity after 3 days, with an LC_{50} value of 0.054, whereas chitosan showed lower toxicity with an LC_{50} of 0.788. Extending the exposure period to 7 days resulted in increased efficacy of both compounds. Congest recorded the lowest LC_{50} value (0.025), representing the highest toxicity (toxicity index = 100, RR = 1). Chitosan also showed improved toxicity after 7 days, as indicated by a reduction in LC_{50} to 0.497; however, it remained markedly less toxic than Congest, with a low toxicity index (5.03) and a high resistance ratio (19.88).

A comparable pattern was observed for adult stages (Table 4 and Figure 4). After 3 days of exposure, Congest showed strong toxicity with an LC_{50} value of 0.028, while chitosan exhibited lower toxicity (LC_{50} = 0.788). After 7 days, the toxicity of Congest slightly increased, reaching an LC_{50} of 0.025 and achieving the highest toxicity index (100). Chitosan toxicity also improved over time, with its LC_{50} decreasing to 0.386 after 7 days; nevertheless, its efficacy remained substantially lower than that of Congest, as reflected by its low toxicity index (6.48) and elevated resistance ratio (15.44).

Across both life stages and exposure periods, slope values ranged from 1.04 to 2.13, indicating acceptable dose-response relationships. The confidence limits generally did not overlap between treatments, confirming significant differences in toxicity.

The results demonstrate that *T. californicus* is highly susceptible to Congest at both immature and adult stages, particularly with extended exposure. The time-dependent increase in toxicity observed for both compounds suggests cumulative or delayed toxic effects. Although chitosan exhibited lower toxicity, its gradual improvement over time indicates a potential role as a slow-acting acaricidal agent.

Table 3: Toxicity effect of congest and chitosan against *Tydeus californicus* immature stages after 3, and 7 days.

Treatments	Time (day)	LC_{50}	Confidence limits of LC_{50}		LC_{90}	Slope	Toxicity index	RR
			Lower	Upper				
Congest	3	0.054 a	0.02	0.078	1.035	1.0±0.29	46.296	2.16
	7	0.025 a	0.0071	0.039	0.175	1.50±0.30	100	1.00
Cheitosan	3	0.788 b	0.462	1.086	13.302	1.04±0.31	3.173	31.52
	7	0.497 b	0.356	0.611	1.984	2.13±0.30	5.03	19.88

Resistance Ratio (RR), Toxicity index was calculated with respect to the most effective compound LC_{50}

Table 4: Toxicity effect of congest and chitosan against *Tydeus californicus* adult stages after 3, and 7 days

Treatments	Time (day)	LC_{50}	Confidence limits of LC_{50}		LC_{90}	Slope	Toxicity index	RR
			Lower	Upper				
Congest	3	0.028	0.005	0.048	0.446	1.07±0.32	89.29	1.12
	7	0.025	0.007	0.039	0.175	1.51±0.31	100.0	1.00
Cheitosan	3	0.788	0.628	0.943	3.703	1.91±0.30	3.17	31.52
	7	0.386	0.219	0.515	2.009	1.79±0.29	6.48	15.44

Resistance Ratio (RR), Toxicity index was calculated with respect to the most effective compound LC_{50}

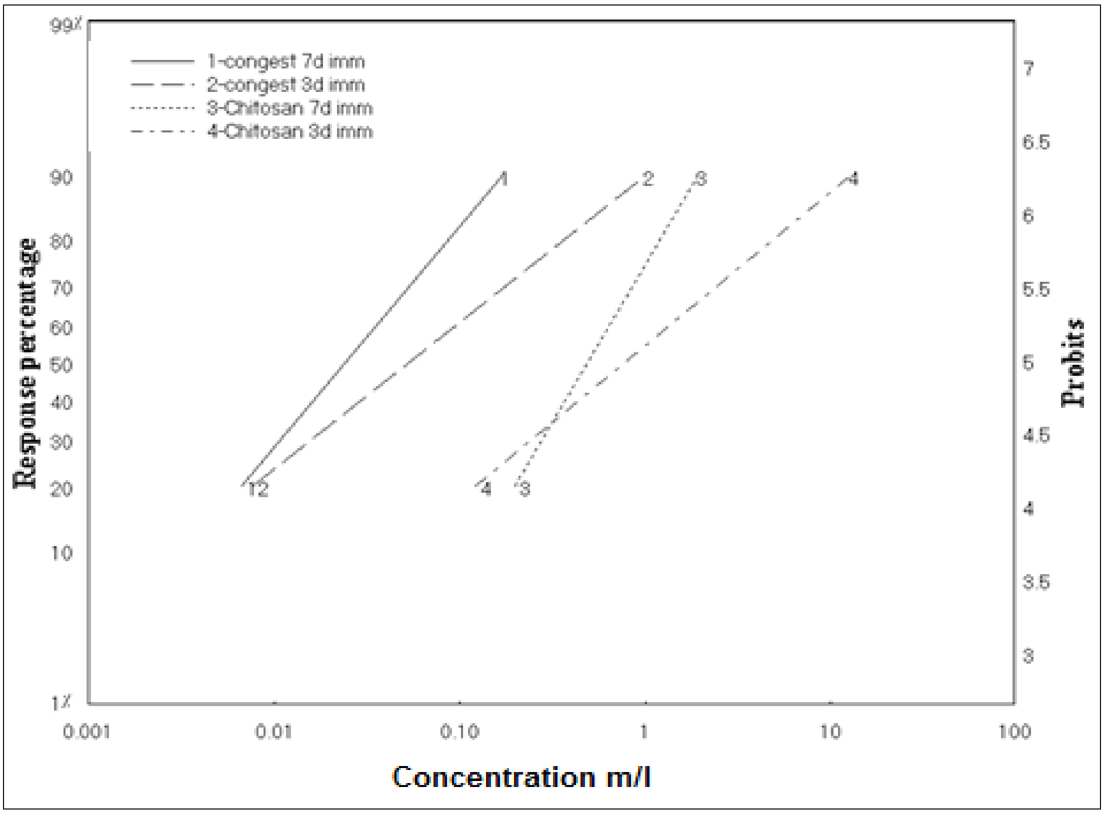

Fig 3: Toxicity effect of Congest and chitosan against *Tydeus californicus* immature stages after 3, and 7 days

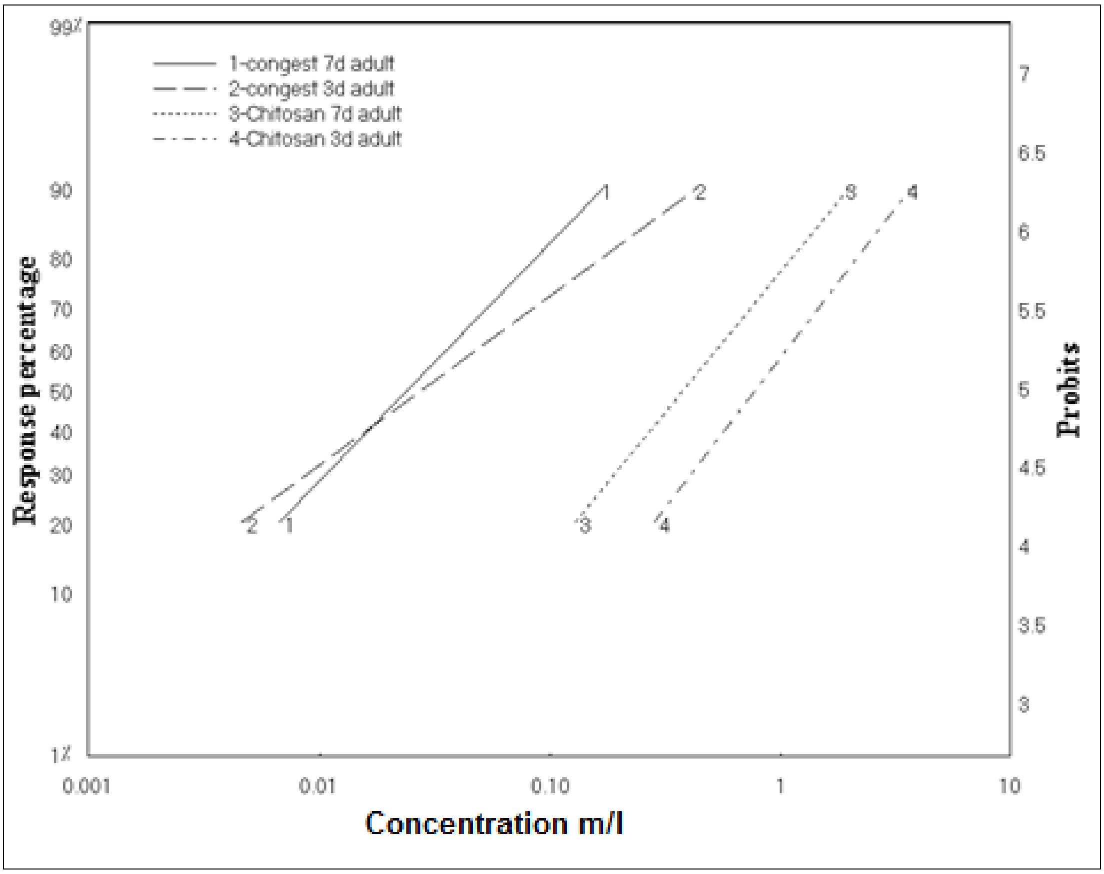

Fig 4: Toxicity effect of Congest and chitosan against *Tydeus californicus* adult stages after 3, and 7 days

Effect of conjest and chitosan on reproductive parameters and deterrent indices of *E. orientalis* and *T. californicus* females

Effect on reproduction of *E. orientalis*

Both Congest and chitosan significantly reduced egg production of *E. orientalis* females compared with the control (Table 5). The reduction in oviposition was concentration dependent for both compounds. In the untreated control, females deposited a mean of 18.60 eggs per female over 7 days. Chitosan treatment resulted in a gradual decline in egg deposition as concentration increased. Mean egg numbers decreased from 14.45 eggs at 0.50 ml/L to 8.80 eggs at 2.00 ml/L, corresponding to oviposition deterrent indices (ODI) of 12.56% and 35.77%, respectively. Significant differences were observed among concentrations ($LSD_{0.05}$ = 1.23). Congest exhibited a stronger inhibitory effect on reproduction than chitosan at all tested concentrations. Egg deposition declined from 12.75 eggs per female at 0.05 ml/L to 7.10 eggs at 0.20 ml/L, with ODI values increasing from 18.66% to 44.75%. The highest concentration of Congest caused the greatest reduction in oviposition, significantly differing from both chitosan treatments and the control (F = 79.02).

Effect on reproduction of *T. californicus*

A similar concentration-dependent reduction in larviposition was observed for *T. californicus* (Table 6). Females in the control treatment produced a mean of 12.25 larvae per female over 7 days. Chitosan significantly reduced larviposition, with mean larval numbers decreasing from 8.70 at 0.50 ml/L to 6.90 at 2.00 ml/L. Corresponding ODI values ranged from 16.95% to 27.94%, indicating moderate reproductive suppression. Congest caused a more pronounced reduction in larviposition than chitosan. Mean larviposition declined from 8.40 larvae per female at 0.05 ml/L to 5.80 larvae at 0.20 ml/L, with ODI values increasing from 18.64% to 35.73%. Differences among treatments were statistically significant (F = 48.06; $LSD_{0.05}$ = 0.87). The results demonstrate that both congest and chitosan significantly suppressed reproduction of *E. orientalis* and *T. californicus* in a concentration-dependent manner. Congest consistently showed stronger oviposition and larviposition deterrent effects, suggesting a greater impact on reproductive physiology or behavior.

Congest was more effective than chitosan in reducing egg and larval production of both mite species, particularly at higher concentrations. Chitosan exhibited moderate but significant reproductive inhibition. These findings indicate that Congest provides superior reproductive control, while chitosan may serve as a complementary, environmentally safer option within integrated mite management programs.

Table 5: Effect of congest and chitosan concentrations on reproduction and oviposition deterrent indices (ODI) of *Eutetranychus orientalis*

Treatments	Concentration ml/l	Mean number of eggs deposited/ female/ 7days	
		No. of eggs ± SD	% ODI
Chitosan	0.50	14.45±1.79 b	12.56
	1.00	10.70±2.18 d	26.96

	2.00	8.80±2.12 e	35.77
Congest	0.05	12.75±2.15 c	18.66
	0.10	9.45±2.01 e	32.62
	0.20	7.10±1.74 f	44.75
Control		18.60±1.73 a	
F		79.02	
LSD at 0.05		1.23	

Means followed in the same column by the same letter are not significantly different (P ≤ 0.05)

Table 6: Effect of Congest and Chitosan concentrations on reproduction and larviposition deterrent indices (ODI) of *Tydeus californicus*

Treatments	Concentration ml/l	Mean number of larviposition/ female/ 7days	
		No. of larviposition ± SD	% ODI
Chitosan	0.50	8.70±1.56 b	16.95
	1.00	7.60±1.23 cd	23.43
	2.00	6.90±1.29 de	27.94
Congest	0.05	8.40±1.23 bc	18.64
	0.10	6.20±1.28 ef	32.79
	0.20	5.80±1.44 f	35.73
Control		12.25±1.68 a	
	F	48.06	
LSD at 0.05		0.87	

Means followed in the same column by the same letter are not significantly different (P ≤ 0.05)

Semi-field experiment

Semi-field efficacy against immature stages of *E. orientalis*

Under semi-field conditions, both Congest and chitosan significantly reduced populations of immature *E. orientalis* on eggplant compared with the untreated control (Table 7). Reduction percentages increased with concentration and exposure time for both compounds. After 3 days, Congest caused a pronounced reduction in immature populations, with reduction percentages ranging from 48.73% at 0.05 ml/L to 85.54% at 0.20 ml/L. The highest concentration of Congest resulted in the lowest mean number of immatures (47.0 individuals), significantly differing from lower concentrations and the control. After 7 days, efficacy further increased, reaching 90.65% and 92.57% reduction at 0.10 and 0.20 ml/L, respectively. Chitosan also significantly suppressed immature populations, although its efficacy was lower than that of congest. After 3 days, reduction percentages ranged from 48.18% to 63.91%, depending on concentration. After 7 days, the highest chitosan concentration (2.00 ml/L) achieved a substantial reduction of 83.13%, while lower concentrations resulted in moderate suppression (58.88-64.76%). No significant reduction was observed in the control treatment.

Semi-field efficacy against adult stages of *E. orientalis*

A similar trend was observed for adult stages under semi-field conditions (Table 8). Congest exhibited strong adulticidal activity, with reduction percentages increasing from 69.02% at 0.05 ml/L to 79.30% at 0.20 ml/L after 3 days. After 7 days, Congest achieved high levels of control, particularly at 0.20 ml/L, which resulted in a 93.51% reduction in adult populations. Chitosan showed moderate efficacy against adult mites. After 3 days, reduction percentages ranged from 59.12% to 66.72%, while after 7 days, reductions increased to 71.67-79.88%, with the highest concentration providing the greatest suppression. Adult populations in the control plots remained relatively unchanged throughout the experimental period.

Statistical analysis confirmed significant differences among treatments, concentrations, and exposure times, as indicated by Tukey's test (P < 0.05). The semi-field results confirm the high efficacy of congest against both immature and adult stages of *E. orientalis*, particularly at higher concentrations and longer exposure periods. Chitosan exhibited moderate but consistent population suppression, with improved performance over time, suggesting a slower mode of action.

Table 7: Effect of three concentrations of congest and chitosan against *Eutetranychus orientalis* immature stages on eggplant under semi field conditions.

Treatments	Conc. (m/l)	Pre-count	3 days		7 days	
			Mean no.	Reduction %	Mean no.	Reduction %
Congest	0.05	307.0 c	154.0±4.0 c	48.73±1.8 c	59.0±5.0 d	80.25±1.5 c
	0.10	297.0 d	104.0±4.0 d	64.20±2.0 b	27.0±1.0 ef	90.65±0.5 a
	0.20	332.0 b	47.0±3.0 f	85.54±0.8 a	24.0±4.0 f	92.57±1.2 a
Cheitosan	0.50	345.0 a	175.0±5.0 b	48.18±0.7 c	138.0±3.0 b	58.88±0.3 e
	1.00	283.0 e	100.0±4.0 d	63.89±0.7 b	97.0±2.0 c	64.76±0.4 d
	2.00	201.0 f	71.0±1.0 e	63.91±0.1 b	33.0±3.0 e	83.13±1.4 b
Control		329.0 b	322.0±1.0 a	-	320.0±0.99 a	-
HSD 0.05		9.18	9.60	3.76	8.43	2.73

Means±SD have the same letters within the same column been not significantly different at p < 0.05 according to Tukey test

Table 8: Effect of three concentrations of congest and chitosan against *Eutetranychus orientalis* adult stages on eggplant under semi field Conditions.

Treatments	Conc. (m/l)	Pre-count	3 days		7 days	
			Mean no.	Reduction %	Mean no.	Reduction %
Congest	0.05	221.0 bc	67.0±7.0 d	69.02±3.0 bc	45.0±5.0 c	78.61±2.6 bc
	0.10	206.7 c	52.0±2.0 e	74.28±0.2 ab	31.0±1.0 d	84.25±0.1 b
	0.20	227.0 b	46.0±4.0 e	79.30±1.5 a	14.0±4.0 e	93.51±1.9 a
Cheitosan	0.50	285.0 a	114.0±4.0 b	59.12±0.7 e	77.0±7.0 b	71.67±2.1 d
	1.00	213.0 bc	81.0±1.0 c	61.05±1.9 de	54.0±4.0 c	73.40±0.3 cd
	2.00	105.0 d	34.0±4.0 f	66.72±5.5 cd	20.0±3.0 de	79.88±4.0 b
Control		275.0 a	269.0±2.0 a	-	262.0±1.2 a	-
HSD 0.05		17.95	10.64	7.53	11.34	6.18

Means±SD have the same letters within the same column been not significantly different at $p < 0.05$ according to Tukey test

Effect on *Tydeus californicus* immature stages

Both congest and chitosan significantly reduced the population of *T. californicus* immature stages compared with the untreated control under semi-field conditions ($p < 0.05$). The reduction effect increased with concentration and exposure time Table (9). After 3 days, congest showed a clear concentration-dependent effect, where the highest concentration (0.20 ml/L) caused the greatest reduction (84.55%), followed by 0.10 ml/L (64.11%) and 0.05 ml/L (48.95%). Chitosan also significantly reduced immature populations, with the highest reduction recorded at 2.00 ml/L (80.01%), whereas lower concentrations (0.50 and 1.00 ml/L) showed moderate reductions (49.11% and 64.23%, respectively). After 7 days, congest treatments maintained very high efficacy, achieving reductions above 90% at all tested concentrations, with the highest reduction at 0.20 ml/L (92.65%). Chitosan efficacy increased over time, reaching 83.94% reduction at 2.00 ml/L, while lower concentrations resulted in moderate reductions (61.41-66.53%). The control showed no noticeable reduction throughout the experiment.

Effect on *Tydeus californicus* adult stages

All tested treatments significantly suppressed adult populations of *T. californicus* compared with the control ($p < 0.05$). Congest treatments were more effective than chitosan, particularly at higher concentrations and longer exposure periods Table (10). At 3 days post-treatment, congest caused substantial reductions ranging from 68.33% to 78.35%, with the highest effect at 0.20 ml/L. Chitosan showed moderate adult reduction at this interval, with the maximum reduction observed at 2.00 ml/L (68.02%). After 7 days, congest at 0.20 ml/L achieved the highest reduction (93.52%), followed by 0.10 ml/L (83.28%) and 0.05 ml/L (77.01%). Chitosan efficacy increased with concentration, reaching 85.48% reduction at 2.00 ml/L, while lower concentrations resulted in significantly lower reductions (71.84-75.19%). Adult populations in the control remained nearly unchanged.

Congest proved to be highly effective against both immature and adult stages of T. californicus, achieving over 90% reduction within seven days, especially at 0.20 ml/L. Chitosan also demonstrated considerable control potential at higher concentrations, although its efficacy was comparatively lower. These findings support the potential use of Congest and chitosan as effective components in integrated mite management programs on eggplant under semi-field conditions.

Table 9: Effect of three concentrations of congest and chitosan against *Tydeus californicus* immature stages on eggplant under semi field conditions.

Treatments	Conc. (m/l)	Pre-count	3 days		7 days	
			Mean no.	Reduction %	Mean no.	Reduction %
Congest	0.05	257.0 b	129.0±9.0 b	48.95±2.2 c	21.0±1.0 d	91.57±0.20 a
	0.10	241.0 c	85.0±5.0 d	64.11±2.0 b	22.0±2.0 d	90.57±0.90 a
	0.20	211.0 de	32.0±2.0 e	84.55±1.2 a	15.0±2.0 e	92.65±1.10 a
Cheitosan	0.50	206.0 e	103.0±3.0 c	49.11±0.0 c	77.0±2.0 b	61.41±0.10 d
	1.00	219.0 d	77.0±4.0 d	64.23±1.5 b	71.0±1.0 c	66.53±0.20 c
	2.00	122.0 f	24.0±4.0 e	80.01±3.0 a	19.0±2.0 de	83.94±1.40 b
Control		287.0 a	282.0±0.2 a	-	278.0±0.10 a	-
HSD 0.05		10.69	12.94	5.17	4.47	2.26

Means±SD have the same letters within the same column been not significantly different at $p < 0.05$ according to Tukey test.

Table 10: Effect of three concentrations of Congest and chitosan against *Tydeus californicus* adult stages on eggplant under semi field conditions

Treatments	Conc. (m/l)	Pre-count	3 days		7 days	
			Mean no.	Reduction %	Mean no.	Reduction %
Congest	0.05	219.0 d	68.0±8.0 c	68.33±4.3 b	49.0±1.0 c	77.01±0.0 c
	0.10	258.0 b	65.0±5.0 c	74.29±2.8 ab	42.0±2.0 c	83.28±0.30 b
	0.20	301.0 a	64.0±4.0 c	78.35±1.2 a	19.0±3.0 d	93.52±1.0 a
Cheitosan	0.50	237.0 c	95.0±5.0 b	59.20±0.9 d	65.0±5.0 b	71.84±1.3 d
	1.00	265.0 b	100.0±4.0 b	61.59±0.8 cd	64.0±4.0 b	75.19±1.1 c
	2.00	191.0 e	60.0±5.0 c	68.02±2.5 bc	27.0±2.0 d	85.48±1.0 b
Control		223.0 d	219.0±0.10 a	-	217.0±0.2 a	-
HSD 0.05		13.28	13.78	6.65	8.09	2.50

Means±SD have the same letters within the same column been not significantly different at $p < 0.05$ according to Tukey test

Discussion

The present study demonstrated clear differences in the acaricidal and reproductive effects of congest and chitosan against *E. orientalis* and *T. californicus* under laboratory and semi-field conditions. In all experiments, Congest consistently exhibited higher toxicity and stronger reproductive suppression than chitosan, with efficacy increasing with exposure time and concentration. These patterns agree with previous studies showing that synthetic or combined acaricides generally provide faster and stronger mite suppression than biopolymer-based products. The high toxicity of congest observed in the current study, particularly after 7 days, is consistent with reports that abamectin- and imidacloprid-based formulations exhibit strong time-dependent acaricidal activity against phytophagous mites (Abdelmaksoud *et al*. 2020; Al Dhafar *et al*. 2024) [1, 6]. However, some field studies have ranked Congest as less effective than other acaricides such as abamectin alone or fenpyroximate (Abdelmaksoud *et al*. 2020; Al Dhafar *et al*. 2024) [1, 6]. These discrepancies may be attributed to differences in mite species, host plants, environmental conditions, formulation type, and application regimes. Under controlled and semi-field conditions, as in the present study, Congest showed pronounced cumulative toxicity, resulting in LC_{50} values and population reductions exceeding 90%, confirming its strong potential for rapid mite control.

Chitosan exhibited significantly lower acute toxicity than congest against both mite species and life stages, which is in line with previous studies reporting relatively high LC_{50} values for chitosan and nano-chitosan compared with conventional acaricides (Shalaby *et al*. 2019; Alakhdar 2020) [5, 21]. Nevertheless, the gradual increase in chitosan efficacy over time observed in this study supports earlier findings that chitosan acts as a slow-acting compound, possibly through physiological disruption rather than rapid neurotoxicity (Rabea 2005; Abenaim and Conti 2023) [3, 19]. The time-dependent improvement in toxicity and population reduction suggests cumulative or delayed effects, which may be related to interference with cuticle integrity, feeding behavior, or metabolic processes.

The reproductive suppression caused by both compounds further supports their sublethal impacts. Congest significantly reduced oviposition and larviposition of *E. orientalis* and *T. californicus*, which agrees with previous studies reporting strong reproductive inhibition by chemical acaricides (Abdou *et al*. 2023; Elhalawany *et al*. 2022) [2, 13]. Chitosan also caused moderate but significant reductions in reproduction, consistent with studies showing that chitosan and its derivatives adversely affect reproductive systems and fertility in arthropods and mollusks (Kandil *et al*. 2020; Rabea 2005) [16, 19]. The higher oviposition deterrent indices recorded with Congest indicate a stronger impact on reproductive physiology or behavior, whereas chitosan appears to exert its effects more gradually.

Importantly, the responses of *T. californicus* in the present study indicate high susceptibility to Congest, while chitosan showed moderate toxicity and reproductive inhibition. This contrasts with some reports where chemical insecticides negatively affected predatory mites more severely than phytophagous mites (Castagnoli *et al*. 2005) [9]. The observed differences may be related to species-specific sensitivity, life-history traits such as larviparity and thelytoky in *T. californicus* (Da Silva *et al*. 2014) [10], and experimental conditions.

Overall, the present findings align with previous research indicating that Congest provides rapid and strong acaricidal and reproductive control, while chitosan offers moderate, slower-acting effects with potential environmental advantages. In agreement with recent reviews (Abenaim and Conti 2023) [3], chitosan may be best utilized as a complementary or rotational tool within integrated mite management programs to reduce reliance on conventional acaricides, delay resistance development, and improve environmental safety.

Conclusion

The present study demonstrates that congest is a highly potent acaricide against immature and adult stages of *E. orientalis* and *T. californicus*, showing strong toxicity, pronounced reproductive inhibition, and excellent semi-field efficacy, particularly after extended exposure. Chitosan exhibited lower toxicity but showed consistent time- and concentration-dependent improvements in mortality and reproductive suppression. Collectively, the results support Congest as the primary option for effective mite suppression, while chitosan may be integrated as a complementary component in integrated mite management programs where reduced-risk or environmentally friendlier inputs are desired.

Author contributions: Design and conduct experiments: R.H.M., A.R.A.; Analyses of data: R.H.M., A.R.A.; writing - review and editing: R.A.E. All authors have read and agreed to the published version of the manuscript.

Funding: The author(s) received no financial support for the research, authorship, and/or publication of this article.

Availability of data and materials: Data are available upon request from the authors.

Ethics approval and consent to participate: No human participants were involved in any studies conducted by the authors for this article.

Consent for publication: NA.

Competing interests: The authors declare no conflict of interest.

Enerative AI statement: NA.

References

1. Abdelmaksoud E, Elrefai S, Mahmoud K, Mohammed S. The effectiveness of some pesticides in the control of thrips and red spider mites on strawberry plants. Arab Univ J Agric Sci,2020:28(1):329-335. doi:10.21608/ajs.2020.23382.1163.
2. Abdou DAM, Elbokl MM, Elmageed AE, Habashy MG. Lethal and sublethal effects of mixed pesticides on Tetranychus urticae Koch and its predator Phytoseiulus persimilis. Arab J Plant Prot,2023:41(1):40-47. doi:10.22268/AJPP-41.1.040047.
3. Abenaim L, Conti B. Chitosan as a control tool for insect pest management: A review. Insects,2023:14(12):949. doi:10.3390/insects14120949.

4. Abbott WS. A method of computing the effectiveness of an insecticide. J Econ Entomol,1925:18(2):265-267.
5. Alakhdar HH. Efficacy of chitosan nano-particles against two tetranychid mites and two associated predaceous mites (Acari: Tetranychidae: Phytoseiidae). Egypt Sci J Pestic,2020:6(1):8-13.
6. Al Dhafar ZM, Abdel Razik MAA, Osman MA, Sweelam ME. Efficacy of selected pesticides on citrus brown mite, *Eutetranychus orientalis* (Acari: Tetranychidae) and the side effects on three predatory mites under citrus orchard conditions. Braz J Biol,2024:84:e282436. doi:10.1590/1519-6984.282436.
7. Amer AI, Kassem EMK, Afifi HA. Efficacy of the predatory mite Amblyseius swirskii (Acari: Phytoseiidae) and selected acaricides in controlling phytophagous mites on eggplant under field conditions. Egypt J Plant Prot Res Inst,2025:8(3):306-318.
8. Bakr EM. A new software for measuring leaf area, and area damaged by Tetranychus urticae Koch. J Appl Entomol,2005:129(3):173-175. doi:10.1111/j.1439-0418.2005.00948.
9. Castagnoli M, Liguori M, Simoni S, Duso C. Toxicity of some insecticides to Tetranychus urticae, Neoseiulus californicus and *Tydeus californicus*. BioControl,2005:50(4):611-622. doi:10.1007/s10526-004-8121-7.
10. Da Silva GL, Da Cunha US, Ferla NJ. Life cycle of *Tydeus californicus* (Acari: Tydeidae) on leaves of Inga marginata with and without pollen of Typha angustifolia under laboratory conditions. Int J Acarol,2014:40(7):509-512. doi:10.1080/01647954.2014.953999.
11. Elhalawany AS. Influence of some host plants and temperature on biological aspects of the citrus brown mite, *Eutetranychus orientalis* (Klein) (Acari: Actinedida: Tetranychidae). Ann Agric Sci Moshtohor,2019:57(3):745-754. doi:10.21608/assjm.2019.98137.
12. Elhalawany AS, Abou-Zaid AM, Amer AI. Laboratory bioassay for the efficacy of coriander and rosemary extracted essential oils on the citrus brown mite, *Eutetranychus orientalis* (Actinidida: Tetranychidae). Acarines,2019:13:15-20. doi:10.21608/AJESA.2019.164149.
13. Elhalawany AS, Ahmad N, Ali S. Pathogenicity of two entomopathogenic fungi and toxicity, oviposition deterrent, and repellency of two essential oils on *Eutetranychus orientalis*. Acarines,2022:16(1):1-7. doi:10.21608/ajesa.2022.291541.
14. Finney DJ. Probit analysis. 3rd ed. London: Cambridge University Press, 1971.
15. Henderson CF, Tilton EW. Tests with acaricides against the brown wheat mite. J Econ Entomol,1955:48(2):157-161.
16. Kandil MA, Eweis EA, Mobarak SA, Abbas NMT. Effects of chitosan and emamectin benzoate on the reproductive system of Eobania vermiculata (Muller) land snails. Egypt J Biol Pest Control,2020:30(1):21. doi:10.1186/s41938-020-00224-1.
17. Krantz GW, Walter DE. A manual of acarology. 3rd ed. Oregon: Oregon State University Book Stores, 2009.
18. Mahmoud RH, Abdel-Khalik AR, Kassem EMK. Efficacy of diatomaceous earth and sulfur on some mites (Acari) under laboratory and semi-field conditions. Persian J Acarol,2024:13(4):829-839. doi:10.22073/pja.v13i4.85611.
19. Rabea EI, Badawy ME, Rogge TM, Stevens CV, Smagghe G, Hofte M, *et al*. Insecticidal and fungicidal activity of newly synthesized chitosan derivatives. Pest Manag Sci,2005:61:951-960.
20. SAS Institute. SAS statistics and graphics guide, release 9.1.3. Cary (NC): SAS Institute, 2003.
21. Shalaby M, Nasr H, Mostafa I, Ibrahim NA. Comparison between the effect of nano chitosan and fabcomic insecticide against Tetranychus urticae (Acari: Tetranychidae). Egypt Acad J Biol Sci F Toxicol Pest Control,2019:11(3):125-128. doi:10.21608/eajbsf.2019.66481.
22. Sparks TC, Nauen R. IRAC: Mode of action classification and insecticide resistance management. Pest Biochem Physiol,2015:121:122-128. doi:10.1016/j.pestbp.2014.11.014.
23. Vela JM, Wong E, Jaques JA, Ledesma C, Boyero JR. Mite diversity (Acari: Tetranychidae, Tydeidae, Iolinidae, Phytoseiidae) and within-tree distribution in citrus orchards in southern Spain, with special reference to *Eutetranychus orientalis*. Exp Appl Acarol,2017:73(2):191-207. doi:10.1007/s10493-017-0180-4.
24. Zaher MA. Survey and ecological studies on phytophagous, predaceous and soil mites in Egypt. I: Phytophagous mites in Egypt (Nile valley and Delta). PI 480 Programme, USA Project No. EG-ARS-30, Grant No. FG-Eg-228, 1984, 228.