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Repellent, Insecticidal, and Oviposition Inhibitory Effects of *Nicotiana tabacum*, *Nicotiana rustica,* and *Nepeta cataria* on the *Trialeurodes vaporariorum*

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ABSTRACT

Trialeurodes vaporarium (Westwood) is one of the important pests of ornamental, greenhouse, field, and vegetable plants worldwide. Because of the acute effects of chemical pesticides, it is necessary to investigate low-risk alternatives for the control of this pest. In this study, the insecticidal, repellent, and oviposition-inhibiting effects of ethanolic extracts of *Nicotiana tabacum*, *Nicotiana rustica,* and *Nepeta cataria* on adult *Trialeurodes vaporarium* were calculated at three concentrations (1000, 2000, and 5000 ppm) and after three times (12, 24, and 48 hours) in a factorial completely randomized design with four replications. The findings showed that the percentage of mortality increased with increasing concentration and exposure duration to the extracts. The LC_{50} values of *Nicotiana rustica*, *Nicotiana tabacum*, and *Nepeta cataria* extracts were 10704, 11996, and 13989 ppm, respectively. The highest and lowest percentage of mortality was reported in *Nicotiana rustica* extract at a concentration of 5000 ppm and after 48 hours with 95% mortality and *Nepeta cataria* extract at a concentration of 1000 ppm and after 12 hours with 28.24% mortality, respectively. The effect of the extracts on egg-laying inhibition showed that as time passed and the effect of the extracts decreased, the number of eggs laid increased slowly. The results of the repellent tests showed that *Nicotiana tabacum* extract had the highest repellent effect of 90% after 48 hours and *Nepeta cataria* extract had the lowest repellent effect of 22.42% after 12 hours. Overall, the findings of the study indicated that these extracts had desirable effects and could be used as safe compounds in the integrated management program for this pest.

Keywords: *Trialeurodes vaporariorum*, Greenhouse, Ethanolic extracts, Integrated management program.

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INTRODUCTION

Trialeurodes vaporarium (Westwood, 1856) (Homoptera: Aleyrodidae), is a polyphagous pest with great economic importance, high generation number, wide distribution, and global distribution, and is found in most greenhouses, under cover crops, fields, and gardens on many agricultural, horticultural, ornamental and ornamental plants. This pest is very polyphagous (multiple-eating) and feeds on the sap of more than 250 genera and about 600 plant species worldwide with its stinging-sucking mouthparts [1]. The adults and nymphs of this pest feed on the sap of the host plant, but the nymphs feed more intensively and cause more damage. The feeding site on the leaves turns pale, gradually turns yellow, and falls prematurely. In damaged plants, general growth is very slow and the plant becomes weak. This pest completely covers the surface of the plant by secreting honeydew, so that a soot cake grows on the honeydew and the amount of photosynthesis in the plant is reduced. The plants are weakened due to a lack of normal respiration, which reduces the quantity, quality, and marketability of the product. In addition, this pest also causes the transmission of some important plant viruses [2-4].

This pest was first reported in 1856 by Westwood in England and then observed in the United States in 1870, but its origin is in the tropics. Over the past few decades, with the development of greenhouse crops, the prevalence and expansion of the whitefly population as one of the important economic pests has been increasing day by day [5]. Various factors, including a wide host range, multigenerational nature, high reproductive rate, establishment of different stages of this pest on the underside of the leaf, lack of feeding in the puparium stage, abundant honeydew formation on the leaf surface, and resistance to most common chemical pesticides, have led to insufficient effectiveness of pesticides, resulting in excessive use and higher concentrations of pesticides and increased damage to this pest [6]. There are many plant hosts for this pest, the most important of which are field and vegetable plants such as tobacco, tomato, cucumber, eggplant, pepper, and cotton [7-9].

The continuous use of chemical pesticides has created strong selective pressure on the whitefly population, causing resistance, accelerated population growth, and increased fecundity of this pest [10]. The high toxicity of common pesticides for humans, environmental pollution, and the emergence of pest resistance to chemical pesticides have led to many efforts in recent years to introduce low-risk compounds to control plant pests [11]. In the meantime, some plant extracts and essential oils, known as herbal pesticides, have shown good performance as alternatives to chemical pesticides to reduce the adverse effects of chemical compounds [12-14]. The use of plant compounds as pesticides of plant origin is one of the environmentally friendly methods and is an important component of integrated pest management (IPM) for sustainable agriculture and the production of healthy products [15, 16]. Plants have evolved an efficient defense system against most pests, so some plants have become rich sources of compounds with biocidal properties. For example, compounds with repellent, anti-nutritional, growth and reproductive inhibition, anti-ovicidal, ovicidal, and metabolic effects on insect behavior and biology can be mentioned [17-19].

Very limited studies have been conducted on the insecticidal, repellent, and anti-ovicidal effects of some plant extracts and essential oils on *Trialeurodes vaporariorum*. For example, in 2010, the contact repellent and anti-ovicidal effects of essential oils of *Corymbia citriodora* Hook, *Pogostemon cablin* Blanco, and *Thymus vulgaris* L. were investigated [20]. The repellent and spawning inhibitory effects of aqueous ethanolic and Estonian extracts of several plant extracts against *Trialeurodes vaporariorum* were investigated. The results showed that the Estonian extracts had no repellent or repellent effects. The aqueous and ethanolic extracts of *Raphannus raphanistrum* L. and *Ambrosia artemisifolia* L. had the highest repellent effects with 76% and 72%, respectively, and their repellent effects gradually decreased over time. The ethanolic extract of *Piper auritam* Kunth had the highest repellent effect with 66%. The highest spawning inhibitory effects were related to the aqueous extract of *R. raphanistrum* with 76% and *P. auritum* with 72%, respectively [21].

The general attention and approach to the use of plant compounds for pest control led to the implementation of the current study to evaluate the insecticidal, repellent, and oviposition-inhibiting effects of ethanolic extracts of *Nicotiana tabacum*, *Nicotiana rustica,* and *Nepeta cataria* on adult *Trialeurodes vaporarium*.

MATERIALS AND METHODS

Collection of the studied plants

After collection, the leaves of *Nicotiana tabacum*, *Nicotiana rustica*, and *Nepeta cataria* plants were first washed superficially and then disinfected with 2% sodium hypochlorite for 5 minutes and then washed three times with distilled water and dried in the shade, away from sunlight and with proper ventilation. Then, the samples were directly powdered in the laboratory and then completely powdered using an electric grinder and passed through a mesh sieve.

Preparation of plant ethanol extract

To prepare the extract, extraction by soaking method was used and ethanol was used as an organic solvent. 100 grams of each plant powder was soaked with 500 ml of 30% ethanol. After stirring under the hood for one hour, the body of the containers was covered with aluminum foil to prevent direct light radiation. The mixture of plant powder and solvent was placed in a shaker at a speed of 100 rpm for 48 hours. The prepared extract was separated from the plant pulp using filter paper and in the next step, it was distilled by a rotary distillation device evaporator at 40 °C and a speed of 100 rpm, then this concentrated extract was placed in an oven at 40 °C to completely remove the remaining solvent and the extracts. The extracts prepared in dark-colored glass jars on which the plant name and extraction date were recorded were stored in a refrigerator at 4 °C until use. These extracts were considered pure extracts and were diluted with distilled water to perform the tests for each extract and used.

Host insect rearing (Trialeurodes vaporarium)

Whitefly rearing was carried out under controlled conditions in an insect breeding room with a temperature of 25 ± 2 °C, a photoperiod of 16 hours of light and 8 hours of darkness, and a relative humidity of 65 ± 5%. For this purpose, pots containing tobacco plants were transferred to wooden cages with dimensions of 80 × 80 × 120 cm, the walls of which were covered with a 10-mesh net. An appropriate number of whiteflies from the tobacco field infected with this pest were collected using a suction aspirator and transferred to the laboratory for identification and breeding. Then, using reliable sources and an identification key, they were identified by an expert and were diagnosed as *Trialeurodes vaporarium*. Then, 100 of these whiteflies were transferred to each cage. To lay eggs and create the next generations of this pest, adult insects were collected by an aspirator and transferred to pots containing fresh plants, thus providing an appropriate density of whiteflies for subsequent experiments.

Investigation of the insecticidal effect of extracts on Trialeurodes vaporarium adults

Experiments on the contact toxicity effect of extracts on greenhouse whitefly adults were carried out under laboratory conditions. In each experiment, 3 different concentrations (1000, 2000, and 5000 ppm) of each of the plant extracts used were used in 4 replicates. After conducting preliminary experiments, 3 different concentrations of each extract were determined. To conduct the experiments, equal-sized pieces of tobacco leaves were dipped in different concentrations of plant extracts (1000, 2000, and 5000 ppm) using a sampler and after drying on a 1% agar gel surface, they were placed separately in Petri dishes with a diameter of 9 cm and a height of 1 cm. Then, 20 whole whiteflies were transferred to each Petri dish. In the control treatment, only solvent (ethanol) was used. To create ventilation, a round hole with a diameter of 1 cm was made on the lid of each Petri dish and covered with a net to prevent smoke toxicity. The number of dead insects was counted and recorded after 12, 24, and 48 hours and the percentage of lethality was calculated according to the Abbott, 1925 formula. All experiments were carried out in a germinator with a temperature of 25 ± 2 °C, a relative humidity of 65 ± 5%, and a photoperiod of 16 hours of light and 8 hours of darkness [22]. The criterion for identifying dead insects was the absence of reaction in the legs and body of the pest when stimulated by a brush [23].

Investigation of the repellent effect of extracts on Trialeurodes vaporarium adults

The repellent test was performed using the method of Liu and Ho [24]. Thus, in Petri dishes with a diameter of 9 cm and a height of 1 cm, a filter paper with a diameter of 9 cm was divided into two halves. Then, each half of the filter paper was soaked in one ml of a solution of each of the plant extracts with three concentrations of 1000, 2000, and 5000 ppm, and the other half as control was soaked in one ml of solvent (ethanol) and exposed to air for one hour in the room to dry. Then, the two halves of the filter paper were glued together from the bottom with adhesive tape from the cut part and placed inside the Petri dish. Two leaf discs (one treated with the extract and the other with the control) were placed on both sides of a circular piece of moist filter paper 6 cm apart in a Petri dish 9 cm in diameter and 1 cm in height. Also, to eliminate the fumigation effect of the extracts, a circular 2 cm diameter screen was placed on the lid of each Petri dish. Then, 20 adult whiteflies were selected from the greenhouse and placed in the center of the filter paper in each Petri dish. Then, the Petri dishes were kept in a germinator at a temperature of 25 ± 2 °C, a relative humidity of 65 ± 5%, and a photoperiod of 16 hours of light and 8 hours of darkness. After 12, 24, and 48 hours, the number of adult insects on the control and treatment sides were counted and the repellent index was calculated.

Tests to determine the degree of egg-laying inhibition

The effect of ethanolic extracts on the degree of egg-laying inhibition of the greenhouse whitefly was studied on the adult insect of this pest. After immersing filter paper for 10 seconds in concentrations of 1000, 2000, and 5000 ppm of plant extracts and the control treatment with ethanol solvent, the filter papers were then transferred to test containers with a height of 18 cm and a diameter of 8 cm. After 30 minutes and evaporation of the solvent, 20 adult female insects were placed into Petri dishes with a diameter of 9 cm and containing tobacco leaf discs with a diameter of 8 cm. The females were placed on the underside of the leaf discs in the treated and control Petri dishes for 24 hours at a temperature of 25 ± 2 °C and a relative humidity of 65 ± 5%. After this period, every 24 hours for 5 consecutive days, these females were placed on new leaves and the number of eggs laid by them on the underside of the leaves was counted and recorded during this period.

Statistical analysis

This research was conducted as a factorial experiment in a completely randomized design with three factors and four replications. The first factor was plant extract at three levels, the second factor was the concentration at three levels, and the third factor was time at three levels. The data were analyzed by SAS 9.0 software and the LSD (least significant difference) test was utilized to compare the means at the 1% probability level.

RESULTS AND DISCUSSION

Toxicity effect of different concentrations of plant extracts on Trialeurodes vaporarium adult

The results of the analysis of variance of the impact of plant extracts on the percentage of the lethality of *Trialeurodes vaporarium* at different times of the experiment showed that the effect of plant extracts, concentration, time, the interaction effect of extract × concentration, extract × time, concentration × time, and extract × concentration × time had significant differences at the probability level of one percent (P ≤ 0.01) **(Table 1)**. The average percentage of the lethality of adult insects *Trialeurodes vaporarium* due to the application of different concentrations of plant extracts after each of the studied times showed a significant difference, and their mean comparison is presented in **Table 2**. The highest and lowest percentage of the lethality of the extracts after 12 hours were related to *Nicotiana rustica* extract with a concentration of 5000 ppm at 62.01% and *Nepeta cataria* extract with a concentration of 1000 ppm at 28.24%, respectively. The highest and lowest percentages of the lethality of the extracts after 24 hours were respectively related to *Nicotiana rustica* extract with a concentration of 5000 ppm at 79.22% and *Nepeta cataria* extract with a concentration of 1000 ppm at 33.47%. The highest and lowest percentages of the lethality of the extracts after 48 hours were respectively related to *Nicotiana rustica* extract with a concentration of 5000 ppm at 95% and *Nepeta cataria* extract with a concentration of 1000 ppm at 40.05%. In general, in the present study, the highest lethality was observed in the ethanolic extract of *Nicotiana rustica*, which had 95% lethality at a concentration of 5000 ppm after 48 hours. The lowest lethality was observed in the ethanolic extract of *Nepeta cataria* with a concentration of 1000 ppm after 12 hours at 28.24%. Based on the findings of the current study, the lethality of the extracts was highest at the highest concentration (5000 ppm) and the longest time (48 hours). In all three plant extracts studied, the rate of adult insect mortality increased with increasing extract concentration **(Table 2)**.

Table 1. Analysis of variance of the effect of plant extracts on the percentage of adult insect mortality of *Trialeurodes vaporarium* at different times of the experiment.

S. O. V	df	Mean Squares
Concentrations	2	1387.26**
Extract	2	8690.01**
Extract × Concentration	4	142.09**
Time	2	9904.26**

Concentration × Time	4	152.57**
Extract × Time	4	709.59**
Extract × Concentration × Time	8	30.99**
Error	81	2.06
CV (%)	-	3.57

**: Significant at 1% probability level.

Table 2. Comparison of the average effect of plant extracts on the percentage of adult insect mortality of *Trialeurodes vaporarium* at various times of the experiment.

Treatments	Concentration (PPM)	% Mortality in hours (Time)		
		12 h	24 h	48h
Nicotiana rustica	5000	62.01de	79.22c	95a
Nicotiana tabacum	5000	55.65ef	73.32e	89.8b
Nepeta cataria	5000	51.5h	67.05d	80.16cd
Nicotiana rustica	2000	48.69fg	61. 3def	70.46ef
Nicotiana tabacum	2000	47.45g	51.87efg	59.03e
Nepeta cataria	2000	42.38gh	48.54fg	52.6efgh
Nicotiana rustica	1000	37. 7i	45.32ghi	50.32f
Nicotiana tabacum	1000	34. 84ij	40.98h	46.43ghi
Nepeta cataria	1000	28.24j	33.47ijk	40.05hi

Means followed by the same letter in each column are not significantly different at a 1% probability level based on the LSD (Least Significant difference).

One of the most important indicators used to compare the insecticidal activity of essential oils and plant extracts is the concentration that causes 50% mortality in the pest. *Nicotiana rustica* extract had higher contact toxicity against adult *Trialeurodes vaporariorum* compared to other extracts studied. The highest toxicity was related to *Nicotiana rustica* extract with LC_{50} of 10704 ppm and the lowest toxicity was related to *Nepeta cataria* extract with LC_{50} of 13989 ppm. A comparison of the 95% confidence limits of the LC_{50} values showed that there was a significant difference between the LCs calculated for these three extracts **(Table 3)**.

Table 3. Calculated LC_{50} values of the contact toxicity effect of plant extracts on adult *Trialeurodes vaporariorum*.

Plant extracts	LC50 (PPM)	Assurance limits (95%)	X^2	df	Slope ± SE
Nicotiana rustica	10704	1.48–3.22	2.37	3	1.78 ± 0.63
Nicotiana tabacum	11996	3.48–6.55	3.51	3	2.92 ± 0.38
Nepeta cataria	13989	3.73 – 6.89	4.42	3	3.78 ± 0.69

The 95% confidence interval was determined based on the method of Robertson and Preisler (1992).

Repellent effect of different concentrations of plant extracts on Trialeurodes vaporariorum adults

The results of the repellency test showed that all the extracts studied at different concentrations had a repellent effect on *Trialeurodes vaporariorum* adults, but their repellency rates were different from each other. The highest and lowest repellency rates were observed in *Nicotiana tabacum* extract after 48 hours at 90% and *Nepeta cataria* extract after 12 hours at 22.42%. A Chi-square (X^2) test was performed for all three extracts between the numbers of insects attracted to the treatment and the control after 48 hours separately. **Table 4** shows the percentage of repellency of methanolic extracts of mountain thyme and oregano on greenhouse whitefly adults. The percentage of repellency increased with increasing extract concentration and exposure duration to the extract. *Nicotiana tabacum* extract had significantly high repellent power and at the highest concentration (5000 ppm) after 48 hours, it had the highest repellent rate (90%), indicating the high potential of this extract for use as a repellent compound against this pest. The lowest repellent effect was related to *Nepeta cataria* extract, which at the lowest concentration (1000 ppm) after 12 hours, had only a 22.42% repellent effect. Comparison of the repellent effect of plant extracts at different sampling times showed that these extracts were statistically significantly different from each other at the probability level of one percent (P ≤ 0.01).

Table 4. Percent repellent effect of plant extracts used on adults of *Trialeurodes vaporariorum*.

Plant extracts	Concentration (PPM)	Repellency (%)			X^2	P–value
		12 h	24 h	48 h		
Nicotiana tabacum	1000	48.12[i]	59.8[h]	70.03[cd]	15.02	0.17
	2000	60.08[efg]	79.13[bcd]	86.19[abc]	19.27	0.008
	5000	70.01[cde]	80.91[b]	90[a]	20.87	0.000
Nicotiana rustica	1000	41.33[j]	53.12[hij]	62.13[ef]	12.77	0.51
	2000	56.02[hi]	69.43[cdef]	79.1[bc]	18.41	0.009
	5000	65.13[c]	76.13[c]	87.01[ab]	19.08	0.003
Nepeta cataria	1000	22.42[mno]	25.08[m]	28.18[lm]	0.95	0.09
	2000	25.26[mn]	29.07[l]	30.27[klm]	3.51	0.75
	5000	28.14[lm]	30.58[kl]	33.25[k]	5.59	0.31

Means followed by the same letter in each column are not significantly different at a 1% probability level.

The effect of different concentrations of plant extracts on the adult insects Trialeurodes vaporariorum on the inhibition of egg production

The results of the test of the percentage of inhibition of egg production of different concentrations of plant extracts on the adult insects *Trialeurodes vaporariorum* showed that the highest inhibition effect was reported in *Nicotiana rustica* extract with a concentration of 5000 ppm at 84.24% and the lowest inhibition effect was reported in catnip extract with a concentration of 1000 ppm at 14.26% **(Table 5)**. The inhibition of egg production increased with increasing concentration.

Table 5. Percentage inhibition of egg production of plant extracts used on the adult insects *Trialeurodes vaporariorum*.

Plant extracts	Concentration (PPM)	% Oviposition inhibitory in times (h)			X^2
		12 h	24 h	48 h	
Nicotiana tabacum	1000	48.08[d]	57.19[d]	68.01[bc]	15.9
	2000	60.05[c]	70.12[b]	78.13[abc]	17.1
	5000	65.12[c]	79.21[ab]	84.24[a]	19.65
Nicotiana rustica	1000	38.16[c]	45.57[de]	58.23[cd]	14.04
	2000	48.17[de]	58.25[cde]	69.93[b]	17.1
	5000	58.18[d]	68.28[bc]	80.03[ab]	18.5
Nepeta cataria	1000	14.26[g]	19.93[fg]	24.01[f]	9.97
	2000	18.0[g]	21.81[f]	28.19[ef]	11.1
	5000	29.03[ef]	30.09[e]	38.86[e]	12.5

Means followed by the same letter in each column are not significantly different at a 1% probability level.

The toxicity study of the extracts in the present study showed that all the plant extracts studied had insecticidal effects on adults of *Trialeurodes vaporariorum*, but their amounts were different from each other. So the toxicity of *Nicotiana tabacum* and *Nicotiana rustica* extracts had the highest amount. The degree of lethality in the extracts studied in the present study was directly related to their concentration. The effect of increasing the concentration of the extract in increasing the insect-killing and repelling effect has been shown in various studies. Among them, the fumigation effect of 53 plant essential oils against different life stages (eggs, nymphs, and adults) of *Trialeurodes vaporariorum* has been investigated. The findings of the experiments revealed that the essential oils of oregano, eucalyptus, cloves, black cumin, and peppermint have the greatest control effect on adults, nymphs, and eggs of this pest, respectively [23].

The concentration required to kill 50% (LC_{50}) of insects exposed to plant compounds depends on various factors, including the pest species, host plant species, and compounds present in them, the sensitivity of the insect, the different growth stages of the insect, the concentration used, the test method, the duration of application, and many other factors [22]. In the current study, *Nicotiana rustica* extract had the lowest lethal dose (LC_{50}) and the highest toxicity. Studies conducted by researchers have shown that plant compounds have extremely high insecticidal and repellent effects on various pests, especially *Trialeurodes vaporariorum*. Among these, the repellent properties of plants from the Asteraceae, Lamiaceae, and Solanaceae families are of interest [25]. The findings of the current study revealed that the repellent properties of the extracts studied did not decrease over time, but rather their repellent percentage increased over time. However, Wagan *et al*. [7] observed that the repellent power of the extracts decreased slightly over time, which was inconsistent with the findings of the current study. In the current study, the filter paper method was used to investigate the repellent properties following other studies [24]. In the study of Al–Mazra and Ateyyat [26], the percentage of lethality increased in both pest species studied with increasing extract concentration and time, which was consistent with the findings of the current study. However, Mendoza-Garcia *et al*. [21] stated that with time, the durability of the essential oils used decreased, which was inconsistent with the findings of the current study.

The results of the data obtained from the effect of egg-laying inhibition on the adult insects *Trialeurodes vaporariorum* showed that all the extracts studied in the current study had an egg-laying inhibition effect and there was a significant difference between the different concentrations of the extracts in terms of egg-laying inhibition. The highest rate of egg-laying inhibition was produced by *Nicotiana rustica* extract (85.14%), which is probably due to the presence of spawning inhibitors in it. The positive role of *Nicotiana tabacum* and *Nicotiana rustica* in the current study could be because of the presence of alkaloid compounds, including nicotine. The main alkaloid in *Nicotiana tabacum* and *Nicotiana rustica* is nicotine, and it acts as a very strong insecticide. The role of *Nepeta cataria* extract in killing, repelling, and preventing the spawning of the adult insect *Trialeurodes vaporariorum* is also due to the presence of a large amount of methanol and menthol in it, which are the two compounds that constitute the largest amount of secondary metabolites in *Nepeta cataria* extract and play an important role in the plant's defense against pathogens and act like a strong poison [27].

Overall, the general results of this study revealed that the killing, repelling, and spawning inhibitory effects of the studied extracts increased with increasing concentration and time, which was also observed in the research of other researchers. Most researchers also stated that increasing concentration is an important factor in increasing the toxicity of plant compounds [28-30].

The sensitivity of insect species varies depending on the type of extract and its concentration. The wide variation in chemical compounds present in different populations of a plant is due to geographical, environmental, and genetic factors. The differences in the toxicity of plant extracts depend on the chemical compounds present in them. A compound may potentiate the activity of the extract alone or in combination with other compounds [21]. The constituents of essential oils and plant extracts may vary greatly even within a given plant genus and in different parts of a particular plant species. It is also possible that the essential oil compositions of a particular plant species may vary based on the geographical distribution of the species, the extraction methods of the plant part from which the extraction is made, and the age of the plant part, as well as the presence of chemical races for the plant species [26].

Since *Trialeurodes vaporariorum* causes a lot of damage and farmers frequently use chemical pesticides to control it, the frequent use of pesticides has led to instability in the ecosystem and increased pesticide resistance in pests. Therefore, the need for suitable alternatives to conventional chemical pesticides seems essential. In general, plants are a rich source of natural materials that can be used to develop environmentally safe methods for pest control [31]. According to the results obtained, these plant extracts can be used as biological insecticides because they are safer for humans, the environment, and other organisms, have a reasonable price are biodegradable in the environment, and can be used as a very useful tool in the integrated management of *Trialeurodes vaporariorum*. Due to the volatile nature of the active ingredient of plant extracts and their rapid oxidation, to improve the toxicity efficiency and maintain the insecticidal nature of these compounds, it is necessary to produce formulations from them in future research for use in open environments such as fields.

CONCLUSION

In this study, the insecticidal, repellent, and oviposition-inhibiting effects of ethanolic extracts of *Nicotiana tabacum*, *Nicotiana rustica,* and *Nepeta cataria* on adult *Trialeurodes vaporarium* were calculated at three concentrations (1000, 2000, and 5000 ppm) and after three times (12, 24, and 48 hours) in a factorial completely randomized design with four replications. The findings showed that the percentage of mortality increased with increasing concentration and exposure duration to the extracts. The highest and lowest percentage of mortality was reported in *Nicotiana rustica* extract at a concentration of 5000 ppm and after 48 hours with 95% mortality and *Nepeta cataria* extract at a concentration of 1000 ppm and after 12 hours with 28.24% mortality, respectively. The effect of the extracts on egg-laying inhibition showed that as time passed and the effect of the extracts decreased, the number of eggs laid increased slowly. The results of the repellent tests showed that *Nicotiana tabacum* extract had the highest repellent effect of 90% after 48 hours and *Nepeta cataria* extract had the lowest repellent effect of 22.42% after 12 hours. Overall, the findings of the study revealed that these extracts had desirable effects and could be used as safe compounds in the integrated management program for this pest.

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