Persian J. Acarol., 2025, Vol. 14, No. 1, pp. 173–184.
https://doi.org/10.22073/pja.v14i1.86083
Journal homepage: http://www.biotaxa.org/pja

Article

Prey location by the predatory mites *Neoseiulus californicus* and *Phytoseiulus persimilis* (Acari: Phytoseiidae) under exposure to chlorfenapyr and acequinocyl

Navid Sehat-Niaki[1], Azadeh Zahedi Golpayegani[1*], Ehssan Torabi[1*], Alireza Saboori[1, 2] and Behnam Amiri-Besheli[3]

1. *Department of Plant Protection, Faculty of Agriculture, College of Agriculture and Natural Resources, University of Tehran, Iran; E-mails: Navidsehat93@ut.ac.ir, zahedig@ut.ac.ir, eh_torabi@ut.ac.ir, saboori@ut.ac.ir*
2. *Department of Plant Protection, Faculty of Agriculture, Aydin Adnan Menderes University, Aydin, Türkiye*
3. *Department of Plant Protection, Sari Agricultural Sciences and Natural Resources University, Sari, Iran; E-mail: B.amiri@sanru.ac.ir*

[*] Corresponding authors

ABSTRACT

Biological control is widely regarded as a sustainable and eco-friendly approach to pest management. However, the use of acaricides may occasionally be required as a supplementary measure. This study investigated the effect of two acaricides, chlorfenapyr and acequinocyl on the olfactory response of the predatory mites, *Neoseiulus californicus* (McGregor) and *Phytoseiulus persimilis* Athias-Henriot (Acari: Phytoseiidae). In olfactory assays, mites were exposed to acaricide-treated or control discs and then introduced into a Y-tube olfactometer to evaluate their response to odor sources (healthy vs. spider mite-infested leaves). G-test was employed for data analysis. The results showed that predatory mites treated with different concentrations of acaricides moved randomly between Y-tube arms, while control mites and those in the acequinocyl field concentration treatment showed a significant preference for the arm containing spider mite odor, indicating that no disruption in odor tracking occurred. With increasing acaricide concentration, the number of mites that hesitated to choose between the two arms of the Y-tube increased. Furthermore, the average time taken for mites to select, and reach the odor source increased in treatments with higher concentrations, indicating that higher pesticide levels impair the mites' ability to detect and respond to prey odors. These findings highlight the disruptive effects of pesticides on predatory mites' olfactory pathways, which could compromise their role in biological control. To preserve their effectiveness, careful selection and use of pesticides are essential. Moreover, incorporating olfactory response studies into pesticide selectivity evaluations can further support integrated pest management programs.

KEYWORDS: Acaricide, bioassay, biological control, olfactory response, predatory mite.

PAPER INFO.: Received: 19.08.2024, Accepted by: *O. Joharchi*, 06.10.2024, Published: 15.01.2025

INTRODUCTION

Tetranychus urticae Koch (Acari: Tetranychidae), commonly referred to as the two-spotted spider mite, poses a substantial threat to a wide array of agricultural and ornamental plants on a global scale (Migeon and Dorkeld 2010). This pest is distinguished by its rapid colony expansion and brief life cycle (Dermauw *et al.* 2013). With a broad host range, *T. urticae* damages plants by consuming

How to cite: Sehat-Niaki, N., Zahedi Golpayegani, A., Torabi, E., Saboori, A. & Amiri-Besheli, B. (2025) Prey location by the predatory mites *Neoseiulus californicus* and *Phytoseiulus persimilis* (Acari: Phytoseiidae) under exposure to chlorfenapyr and acequinocyl. *Persian Journal of Acarology*, 14(1): 173–184.

plant sap and destroying plant cells (Huffaker *et al.* 1970). Chemical acaricides have been extensively employed to manage this pest (Van Leeuwen *et al*. 2010). However, a significant obstacle in pest management is the rapid evolution of acaricide resistance (Van Pottelberge *et al.* 2008). As a result, researchers are investigating alternative control methods, with biological control agents showing considerable promise.

Phytoseiid predatory mites are crucial elements in biological control within integrated pest management (IPM) programs due to their high reproductive rates, efficient food-seeking behaviors, ability to persist on plants with low prey densities, and adaptability to diverse habitats (McMurtry and Croft 1997). *Neoseiulus californicus* (McGregor) (Acari: Phytoseiidae), a generalist predator (Pratt 1998), preys on various sources, including the two-spotted spider mite, exhibiting higher growth rates when feeding on this specific pest (Rhodes and Liburd 2009). *Phytoseiulus persimilis* Athias-Henriot (Acari: Phytoseiidae), a specialist predator of tetranychid mites, is the most extensively used biological control agent for managing two-spotted spider mites, especially in greenhouse settings (Van Lenteren and Woets 1988).

To ensure food security for a growing global population, agricultural production relies heavily on pest control measures (Tudi *et al*. 2021). While pesticides offer effective pest control, their indiscriminate nature poses significant environmental risks (Popp *et al*. 2012). Since most pesticides have a broad spectrum of activity, they also eliminate non-target and beneficial species (Croft 1990). Research indicates that even selective pesticides can adversely affect natural enemies (Řezáč *et al.* 2010). Pesticides may exert lethal effects, causing organism mortality, or sublethal effects, altering other biological characteristics (Řezáč *et al.* 2010; Papachristos and Milonas 2010). These adverse effects can compromise the efficacy of natural enemies, negatively impacting life cycle and demographic parameters, impairing orientation and foraging behavior, and consequently, reducing predatory capacity (Poletti *et al*. 2007; Nadimi *et al*. 2011; Hamedi *et al.* 2011). Thus, understanding the lethal and sublethal impacts on key predators is essential before integrating any pesticide into a pest management system.

Chlorfenapyr, marketed under the trade name Conqueror®, is a systemic and contact insecticide -acaricide, effective against various pests, including tarsonemid mites, tetranychid mites, and whiteflies (Raghavendra *et al.* 2011; Zhao *et al.* 2017). This pesticide, a part of the pyrrole chemical group, disrupts the proton gradient necessary for oxidative phosphorylation (Dekeyser 2005). It is recommended for managing pests resistant to organophosphates, carbamates, and pyrethroids (Sheppard and Joyce 1998; Zhao *et al*. 2017). Acequinocyl, available as Kanemite®, is a naphthoquinone analog formulated as a suspension concentrate (SC) and classified as a reduced-risk pesticide by the United States Environmental Protection Agency (EPA). It inhibits mitochondrial respiration and is recommended for controlling phytophagous mites (Yorulmaz Salman *et al*. 2015).

In the context of predatory mite foraging behavior, plants under herbivore attack emit volatile compounds that alert predatory mites to their presence, called herbivore-induced volatiles (HIPVs), which provide essential chemical cues for prey location (Dicke and Sabelis 1988). Phytoseiid mites possess sensitive chemoreceptors on their palps and first legs, enabling them to detect very low concentrations of these olfactory signals (Jagers op Akkerhuis *et al.* 1985). Consequently, these predators rely on host plants' chemical and tactile stimuli for effective prey searching. However, despite the critical role of predatory mites in pest control, the potential impacts of acaricides on the orientation behavior of predatory mites remain underexplored, making it crucial to understand how these chemicals alter predator-prey interactions and potentially influence biological control efficiency.

Given the importance of this issue, this study aims to investigate whether acaricides influence the olfactory response of predatory mites to herbivore-induced volatiles. Olfactory assays were conducted on *N. californicus* and *P. persimilis*, following their exposure to differen concentrations of two acaricides, to evaluate potential changes in their ability to detect and respond to prey odors.

The findings of this experiment can provide valuable insights into the potential behavioral adaptations of predatory mites under chemical stress, contributing to the development of more sustainable pest management strategies.

MATERIALS AND METHODS

*Rearing of two-spotted spider mite (*T. urticae*)*

Common bean plants [*Phaseolus vulgaris* L. (Fabaceae) var. Red Alamouti] were grown in plastic pots in a greenhouse (soil: perlite; 50:50%) under controlled conditions (25 ± 5 °C, 16L:8D photoperiod, 65 ± 5% RH) at the Department of Plant Protection, Faculty of Agriculture, University of Tehran, Karaj, Iran. Plants were irrigated daily with tap water and fertilized every other day with a NPK (20 × 20 × 20). Two-spotted spider mites, *T. urticae* (green form; food source for the predatory mites) were reared on bean plants. Fresh bean plants were regularly added to the rearing system.

Rearing of the predatory mites

The predatory mites, *P. persimilis*, and *N. californicus*, were reared on masses of detached bean leaves, infested with *T. urticae*, placed upside down on a plastic sheet on a water-saturated sponge. The plastic sheet was surrounded by napkin tapes which were put into the water from the otherwise that the predatory mites could drink water. Fresh *T. urticae*-infested leaves and fresh corn pollen (*Zea mays* L.) were added to the rearing system and the old predator-free leaves were removed regularly (Overmeer 1985). The cultures were kept in separate growth chambers under controlled conditions (25 ± 1 °C, 16L:8D photoperiod, 65 ± 5% RH) in the Acarology laboratory at Jalal Afshar Zoological Museum, Department of Plant Protection, Faculty of Agriculture, University of Tehran, Karaj, Iran.

Chemical properties and dosage used

Acequinocyl (3-Dodecyl-1,4-dioxo-1,4-dihydro-2-naphthalenyl acetate), available as Kanemite® (suspension concentrate 15%, Agro-Kanesho Co.), and Chlorfenapyr (4-bromo-2-(4-chlorophenyl)-1-ethoxymethyl-5-trifluoromethyl-1H-pyrrole-3-carbonitrile), available as Conqueror® (suspension concentrate 36%, Saraye Sepand Pars Co.), were employed in this study. The toxicity of these pesticides on the predatory mites *P. persimilis* and *N. californicus* was assessed using the leaf disc dipping method as described by Helle and Overmeer (1985). Details of the complete bioassay procedure and determination of effective concentration ranges can be found in Sehat-Niaki *et al.* (2025). In this study, four pesticide concentrations, including the field-recommended rate, LC_{10}, LC_{30}, and LC_{50}, were selected based on the results reported in the referenced study as detailed in Table 1.

Table 1. Pesticides concentrations (g/L) used in the experiment.

Species	Pesticide	LC_{10}	LC_{30}	LC_{50}	Field
P. persimilis	Chlorfenapyr	0.311	0.429	0.536	0.4
	Acequinocyl	1.677	2.558	3.428	1.0
N. californicus	Chlorfenapyr	0.696	0.953	1.186	0.4
	Acequinocyl	3.332	4.711	5.987	1.0

Olfactory response of predatory mites to odor sources

The experiment was conducted in a two-choice olfactometer bioassay at the behavioral acarology laboratory, Jalal Afshar Zoological Museum, Department of Plant Protection, Faculty of

Agriculture, University of Tehran, using the method described by Sabelis and Van der Baan (1983). The olfactometer consisted of a Y-shaped glass tube with a Y-shaped metal wire fixed in the middle of the glass tube to guide the mites. The base of the tube was connected to an air pump that directed airflow from the arms of the tube to the base. Airflow through both arms of the Y-tube was calibrated with a digital flow meter with needle valves between the air outlet from the chambers containing the odor sources and the olfactometer arms to ensure equal airflow rates in both arms. Glass chambers containing the odor sources were connected to the end of each of arms by a transparent hose. The chambers were used for the following odor sources: (a) bean leaves infested with two-spotted spider mites, (b) bean leaves without two-spotted spider mites. Predators were starved for 2.5 hours before the experiment. Black Polyvinyl chloride (PVC) discs (3 cm diameter, 1 mm thickness) were immersed in 40 ml of different acaricide concentrations or distilled water (control) for 5 seconds and then air-dried for 2 hours at 27 °C and 70% RH. The predatory mites were then transferred to the treated and untreated discs for 30 minutes without food. A starved predatory mite (treated or untreated) was placed at the base of the Y-tube and allowed to walk upwind along the wire inside the tube to choose one of the two odor sources in the Y-shaped tube. Both sources were prepared with identical leaves. The olfactometer assay was performed at 24–27 °C and 60–80% RH and was replicated three times. Females were observed for a maximum of five minutes. When mites did not reach the end of one of the arms within five minutes, no choice was recorded and was not considered in the analysis. Each replicate of the experiment was continued until 20 female predatory mites responded to an odor source. After testing five mites, the position of the odor source was changed to avoid uncontrollable asymmetry in the experiment. The mean time of odor source selection in the olfactometer after exposure to acaricide or distilled water (control) was also measured. The efficacy of this method has been validated through greenhouse bioassays (Janssen 1999).

Data analysis

The number of female mites selecting odor sources in the olfactometer bioassay was analyzed using goodness-of-fit tests at a 95% confidence level in Excel 2019, including a test for heterogeneity between replicates. The mean time required for female mites to choose an odor source after exposure to the acaricide (or control) was evaluated through univariate analysis. Statistically significant differences between treatments were identified using Tukey's Honest Significant Difference (HSD) post-hoc test, conducted in SPSS version 27.

RESULTS

Olfactory bioassays

The number of mites that chose each odor-laden arm in the Y-tube olfactometer, along with the corresponding G-test results, are detailed in Tables 2 and 3. When predatory mites were treated with different concentrations of pesticides, they moved randomly between the two arms of the Y-tube olfactometer, showing no significant difference in the number of choices for either arm. Notably, the results were consistent for both predatory mite species, indicating that both were susceptible to the tested pesticides. Figure 1 shows that a significant difference in the number of mites selecting either arm of the olfactometer was observed only in the control and field concentration treatments of acequinocyl, suggesting that the orientation behavior of these mites remained unaffected under these conditions. However, in other treatments, as the concentration increased, the difference in the selection of the two arms decreased to a non-significant level. This implies that the mites randomly chose one of the two arms, indicating an impairment in odor discrimination. Figure 2 also illustrates the time taken by predatory mites to select an odor source in the Y-tube, showing that with increasing pesticide concentration, the time spent on selecting and walking in the experimental arena significantly increased.

Table 2. Olfactory response of *Neoseiulus californicus* treated with different concentrations of chlorfenapyr and acequinocyl to olfactory sources in the Y-shaped olfactometer tube containing healthy bean leaves and leaves infested with two-spotted spider mites. Results were evaluated by the G-test (Ch: chlorfenapyr; Ac: acequinocyl).

Treatment	Choice Response				Replicated goodness of fit			*P*-value
	No. [a]	Infested	Uninfested	None [b]	*Gh*	*Gp*	*Gt*	
Control	60	44	16	15	2.34	7.49	9.84	0.0061
Ch-Farm	60	40	20	19	1.06	2.71	3.78	0.0994
Ch-LC_{10}	60	35	25	23	0.13	0.10	0.24	0.7444
Ch-LC_{30}	60	31	29	27	0.53	0.50	1.04	0.4755
Ch-LC_{50}	60	27	33	37	0.40	3.05	3.45	0.0805
Control	60	45	15	15	0.53	9.10	9.63	0.0025
Ac-Farm	60	42	18	17	0.47	4.78	5.26	0.0286
Ac-LC_{10}	60	40	20	19	0.15	2.71	2.86	0.0994
Ac-LC_{30}	60	32	28	23	0.93	0.20	1.14	0.6495
Ac-LC_{50}	60	29	31	31	0.13	1.51	1.64	0.2184

[a] The total number of mites tested for each treatment. It corresponds to the sum of mites that chose either the infested or uninfested leaves.
[b] The number of mites that did not make a choice between infested and uninfested leaves and were therefore excluded from the analysis.

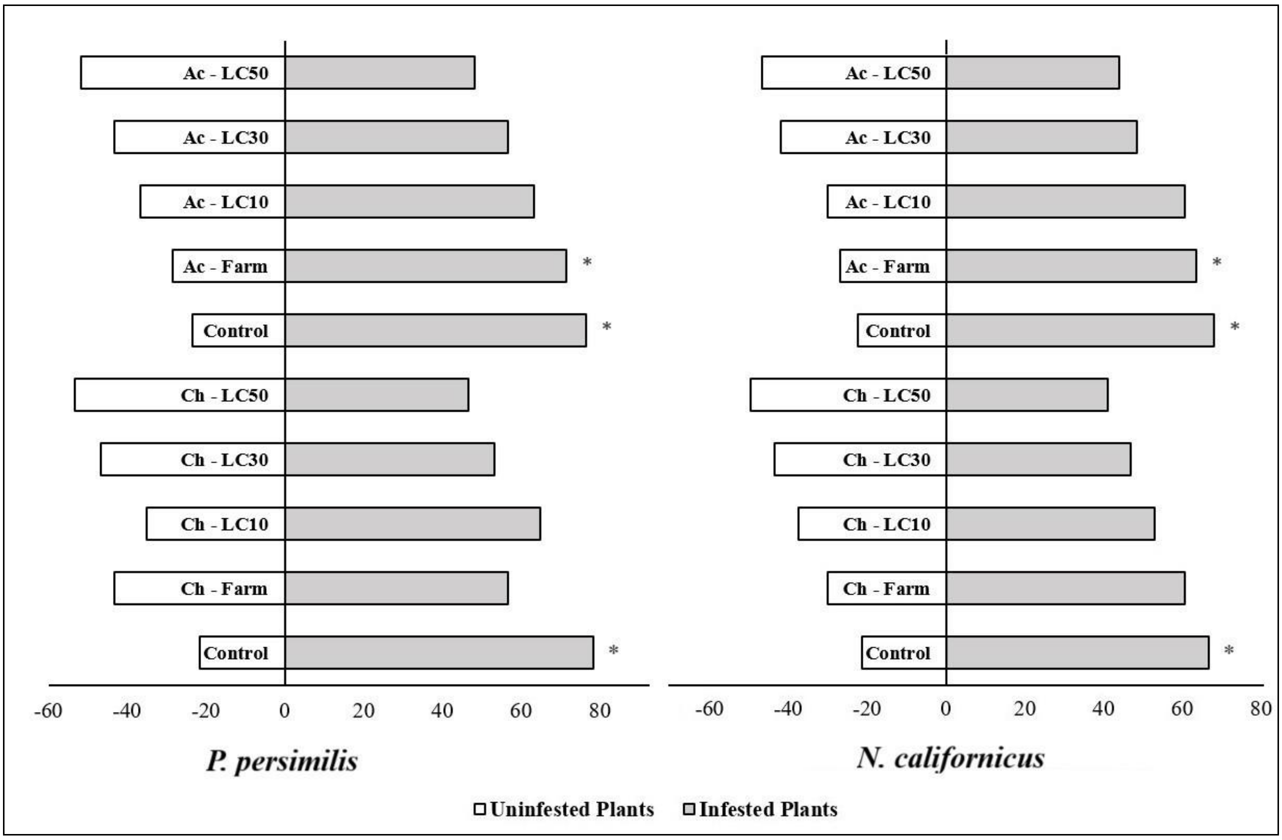

Figure 1. Olfactory response of the predatory mites *Neoseiulus californicus* and *Phytoseiulus persimilis* treated with different concentrations of chlorfenapyr and acequinocyl to odor sources in a Y-tube olfactometer bioassay comprising healthy bean leaves vs. bean leaves infested with two-spotted spider mites. Results were evaluated by the goodness-of-fit test. Asterisks indicate significant differences ($P < 0.05$) between individuals that choose one of the two odor sources in each treatment.

Table 3. Olfactory response of *Phytoseiulus persimilis* treated with different concentrations of chlorfenapyr and acequinocyl to olfactory sources in the Y-shaped olfactometer tube containing healthy bean leaves and infested leaves with two-spotted spider mites. Results were evaluated by the G-test (Ch: chlorfenapyr; Ac: acequinocyl).

Treatment	Choice Response				Replicated goodness of fit			*P*-value
	No. [a]	Infested	Uninfested	None [b]	*Gh*	*Gp*	*Gt*	
Control	60	46	14	14	0.19	12.85	13.05	0.0003
Ch-Farm	60	34	26	22	0.13	0.04	0.14	0.9481
Ch-LC_{10}	60	39	21	20	0.44	1.90	2.24	0.1674
Ch-LC_{30}	60	32	28	25	0.22	2.66	2.89	0.1025
Ch-LC_{50}	60	28	32	33	0.13	2.21	2.35	0.1364
Control	60	46	14	14	0.18	10.88	11.07	0.0009
Ac-Farm	60	43	17	17	1.18	6.05	7.33	0.0138
Ac-LC_{10}	60	38	22	20	0.58	1.24	1.82	0.2649
Ac-LC_{30}	60	34	26	21	0.54	0.04	0.54	0.9481
Ac-LC_{50}	60	31	29	30	0.13	0.50	0.64	0.4755

[a] Total number of mites tested for each treatment. It corresponds to the sum of mites that chose either the infested or uninfested leaves.
[b] Number of mites that did not make a choice between infested and uninfested leaves and were therefore excluded from the analysis.

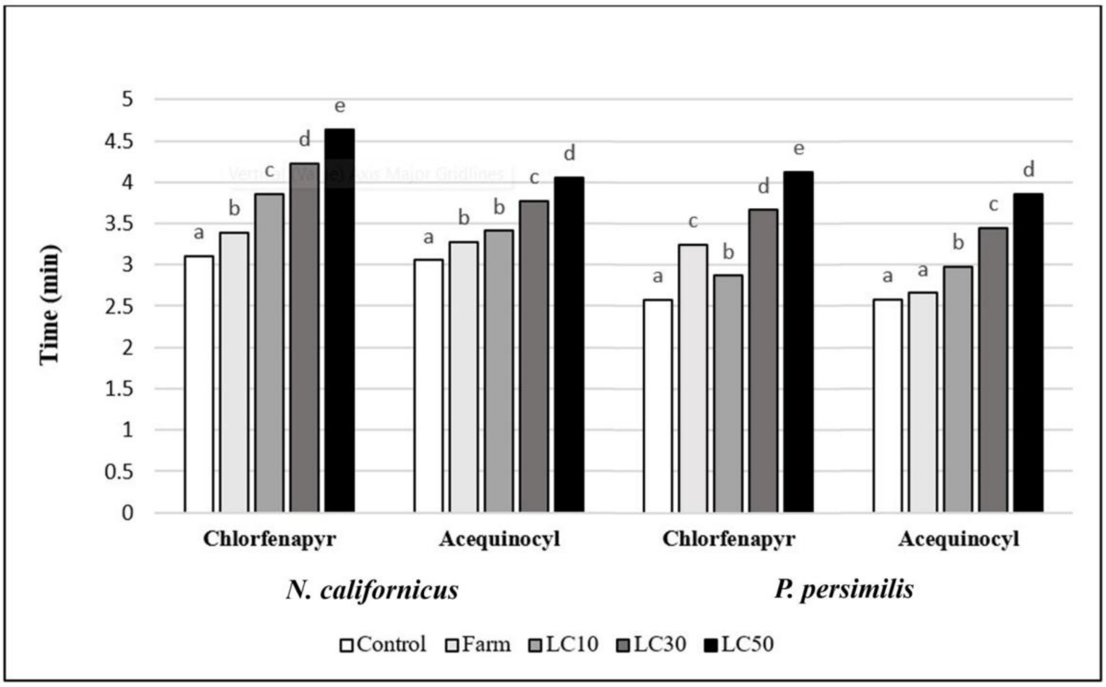

Figure 2. Average time to source choice in a Y-tube olfactometer by the predatory mites, *Neoseiulus californicus* and *Phytoseiulus persimilis* exposed to different concentrations of chlorfenapyr and acequinocyl. Results were analyzed using univariate analysis, followed by Tukey's HSD post-hoc test to determine statistically significant differences between treatments.

DISCUSSION

Biological control, as a sustainable and environmentally friendly method for pest management, has gained significant traction among both farmers and researchers (Nchu 2024). However, its success can be affected by various factors, including plant species, planting density, environmental conditions, and the deployment strategy of the released predators (Jarosik 1990; Opit *et al*. 2009;

Tiftikçi *et al*. 2022). In some cases, the use of biological control alone is not sufficient to completely prevent pest damage and loss (Solomon *et al.* 2000). In such cases, there is a need for complementary methods such as pesticides. The use of pesticides, while helpful in controlling pest populations, can have negative effects on the orientation behavior of predatory mites. Disruption of the olfactory response of predatory mites caused by sublethal concentrations of acaricides can have significant ecological consequences in the field. Since phytoseiid mites rely heavily on odors to locate their prey, they will not be able to identify prey in the presence of acaricides, which consequently reduces the effectiveness of biological control (Desneux *et al*. 2007). Therefore, it is crucial to select acaricides that exert minimal or no negative effects on predatory mites (Croft 1990).

Based on the bioassay data reported by Sehat-Niaki *et al.* (2025) and summarized in Table 1, chlorfenapyr is substantially more toxic to both predatory mite species compared to acequinocyl, with approximately five times greater potency. The higher LC_{50} value of acequinocyl, which exceeds the estimated field concentration, underscores its relatively lower toxicity and suggests it poses minimal risk to these beneficial mites. This is also reflected in our olfactometer experiment results. As shown in Figure 1, when not exposed to acaricides, mites significantly preferred the arm containing the two-spotted spider mite odor. However, when treated with acaricides, they moved randomly between the two arms of the Y-tube, and there was no significant difference in the number of choices between the two arms. Additionally, the time taken for mites to choose and walk on the arms increased significantly with increasing acaricide concentrations (Fig. 2). Only in the acequinocyl field concentration treatment was a significant difference observed, and it was not different from the control, suggesting that acequinocyl does not disrupt the orientation behavior of the predatory mite at low concentrations.

In treatments with higher acaricide concentrations, we observed that a greater number of mites hesitated in their choice between the two arms of the Y-tube, as the mites took longer to make a choice compared to the control and a large number of them did not reach the end of either arm within the five-minute observation period, ultimately being classified as 'undecided'. The fact that some mites traveled halfway down the arm indicates that the pesticides do not eliminate the ability to detect prey, but they do reduce the ability to follow the prey's scent. The exact mechanisms underlying the changes in olfactory response are still unclear, and further experiments are needed to elucidate the underlying causes. Possible reasons for this include: Pesticides may disrupt the nervous system and olfactory sensilla of mites, reducing their ability to detect prey odors (Lima *et al*. 2015), or may reduce the activity of mites, limiting their energy in locating prey. Acaricides can affect the muscle function of mites, leading to weakness and reduced mobility. They also may alter the behavior of mites, directing them towards unnatural stimuli (Lima *et al*. 2012).

Previous studies have also shown the negative effects of other pesticides on the searching and olfactory behaviors of predatory mites. Teodoro *et al.* (2008) found that exposure to fenbutatin oxide residues impaired the olfactory response of the predatory mite *Iphiseiodes zuluagai* Denmark & Muma (Acari: Phytoseiidae), as these mites no longer showed attraction to pest-infested or damaged plants. Similarly, the study by Lima *et al*. (2015) investigated how abamectin, azadirachtin, and fenpyroximate influenced the predatory behavior of *Neoseiulus baraki* (Athias-Henriot). When unexposed to pesticides, this mite displayed a preference for fruits infested with *Aceria guerreronis*. In contrast, pesticide exposure led to a diminished ability to differentiate between infested and non-infested fruits. Additionally, when exposed to abamectin, the predatory mite spent more time resting and traveled longer distances before selecting a source of odor. These findings indicate that pesticides disrupt the ability of *N. baraki* to efficiently locate and select prey habitats. In another study by Desneux *et al.* (2004), the effect of five pesticide compounds (lambda-cyhalothrin, chlorpyrifos, pirimicarb, and triazamate) on the response to plant host odors in the predatory wasp *Aphidus ervi* (Haliday) (Hym.: Brconidae) was investigated. The concentrations were selected from sublethal doses to LD_{50} and, for some products, to LD_{70}. The results showed that none of the doses of lambda-cyhalothrin, chlorpyrifos, and pirimicarb had any effect on the responses of *A. ervi* to the odor of a plant infested with the aphid *Myzus persicae* on oilseed rape. Only mites exposed to triazamate showed a significantly reduced tendency to move toward the aphid-infested plant. This suggests that triazamate may negatively affect the mites' sense of smell or their ability to follow the odor of the plant host. Zhang *et al*. (2014) found that sublethal concentrations of deltamethrin (LC_{10} and LC_{20}) disrupted the orientation behavior of the predatory bug *Cyrtorhinus lividipennis* Reuter (Het.: Miridae). However, sublethal concentrations of triazophos (LC_{10} and LC_{20}), chlorantraniliprole, and pymetrozine (at the recommended field rate) did not affect the olfactory response of the surviving predators. Yang *et al.* (2021) investigated the effects of spirotetramat on the parasitoid wasp *Encarsia formosa* Gahan (Hym.: Aphelinidae). Their findings revealed that low concentrations (LC_{10}) of this pesticide enhanced the wasp's ability to locate and parasitize whiteflies. Conversely, higher concentrations (LC_{50}) impaired these abilities. These results underscore the importance of determining optimal pesticide concentrations in agricultural settings.

The findings of this research, along with other studies, underscore the importance of cautious selection and use of pesticides to preserve the effectiveness of biological control and support natural enemies of pests. Pesticides can disrupt the olfactory and neural pathways of predatory mites, compromising their prey-locating ability and consequently, their effectiveness in pest control. Therefore, olfactory response studies examining pesticide impacts on predatory mites' decision-making should be prioritized as an important parameter in evaluating pesticide selectivity. By considering this parameter, pesticides with minimal adverse effects on natural enemies can be selected and used appropriately in pest management programs. This is especially crucial given the vital role of predatory mites in biological pest control and maintaining ecological balance in agricultural systems. Proper pesticide selection not only supports these natural enemies but also contributes significantly to environmental health and sustainable agriculture. Future research should focus on exploring the olfactory mechanisms and other internal processes that influence the behavior of predatory mites when exposed to acaricides, aiming to develop more targeted and eco-friendly pest management strategies. Such efforts will optimize pest control practices, balancing efficacy and environmental safety to ensure the long-term viability of integrated pest management systems.

ACKNOWLEDGMENT

The research was financially supported by the University of Tehran under Grant number 73149051.6.21 which is greatly appreciated.

REFERENCES

Croft, B.A. (1990) *Arthropod biological control agents and pesticides*. John Wiley and Sons Inc, New York, 723 pp.

Dekeyser, M.A. (2005) Acaricide mode of action. *Pest Management Science*, 61: 103–110. DOI: 10.1002/ps.994

Dermauw, W., Wybouw, N., Rombauts, S., Menten, B., Vontas, J., Grbić, M., Clark, R.M., Feyereisen, R. & Van Leeuwen, T. (2013) A link between host plant adaptation and pesticide resistance in the polyphagous spider mite *Tetranychus urticae*. *Proceedings of the National Academy of Sciences*, 110(2): E113–E122. DOI: 10.1073/pnas.1213214110

Desneux, N., Decourtye, A. & Delpuech, J.-M. (2007) The sublethal effects of pesticides on beneficial arthropods. *Annual Review of Entomology*, 52(1): 81–106. DOI: 10.1146/annurev.ento.52.110405.091440

Desneux, N., Rafalimanana, H. & Kaiser, L. (2004) Dose-response relationship in lethal and behavioural effects of different insecticides on the parasitic wasp *Aphidius ervi*. *Chemosphere*, 54(5): 619–627. DOI: 10.1016/j.chemosphere.2003.09.007

Dicke, M. & Sabelis, M.W. (1988) How plants obtain predatory mites as bodyguards. *Netherlands Journal of Zoology*, 38: 148–165.

Hamedi, N., Fathipour, Y. & Saber, M. (2010) Sublethal effects of abamectin on the biological performance of the predatory mite, *Phytoseius plumifer* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, 53: 29–40. DOI: 10.1007/s10493-010-9382-8

Helle, W. & Overmeer, W.P.J. (1985) Toxicological test methods. *In*: Helle, W. & Sabelis, M.W. (Eds.), *Spider mites: Their biology, natural enemies and control*. Vol. 1A, Elsevier, Amsterdam, Oxford, New York, Tokio, pp. 391–395.

Huffaker, C.B., van de Vrie, M. & McMurtry, J.A. (1970) Ecology of tetranychid mites and their natural enemies: A review: II. Tetranychid populations and their possible control by predators. *Hilgardia*, 40(11): 391–458. DOI: 10.3733/hilg.v40n11p331

Jagers op Akkerhuis, G., Sabelis, M.W. & Tjallingii, W.F. (1985) Ultrastructure of chemoreceptors on the pedipalps and first tarsi of *Phytoseiulus persimilis*. *Experimental & Applied Acarology*, 1: 235–251. DOI: 10.1007/bf01198521

Janssen, A. (1999) Plants with spider-mite prey attract more predatory mites than clean plants under greenhouse conditions. *Entomologia Experimentalis et Applicata*, 90(2): 191–198. DOI: 10.1046/j.1570-7458.1999.00438.x

Jarosik, V. (1990) *Phytoseiulus persimilis* and its prey on glasshouse cucumbers and peppers: key factors related to biological control efficiency. *Acta Entomologica Bohemoslovaca*, 87(6): 414–430.

Lima, D.B., Melo, J.W.S., Gondim, M.G.C., Jr., Guedes, R.N.C., Oliveira, J.E.M. & Pallini, A. (2015) Acaricide-impaired functional predation response of the phytoseiid mite *Neoseiulus baraki* to the coconut mite *Aceria guerreronis*. *Ecotoxicology*, 24(5): 1124–1130. DOI: 10.1007/s10646-015-1459-z

Lima, D.B., Melo, J.W.S., Guedes, R.N.C., Siqueira, H.A.A., Pallini, A. & Gondim, M.G.C., Jr. (2012) Survival and behavioural response to acaricides of the coconut mite predator *Neoseiulus baraki*. *Experimental and Applied Acarology*, 60: 381–393. DOI: 10.1007/s10493-012-9644-8

McMurtry, J.A. & Croft, B.A. (1997) Life-styles of phytoseiid mites and their roles in biological control. *Annual Review of Entomology*, 42(1): 291–321. DOI: 10.1146/annurev.ento.42.1.291

Migeon, A., Nouguier, E. & Dorkeld, F. (2010) Spider Mites Web: A comprehensive database for the Tetranychidae. *In*: Sabelis, M.W. & Bruin, J. (Eds.), *Trends in Acarology*. Springer, Dordrecht, pp. 557–560. DOI: 10.1007/978-90-481-9837-5_96

Nadimi, A., Kamali, K., Arbabi, M. & Abdoli, F. (2011) Study on persistence tests of miticides abamectin and fenproximate to predatory mite *Phytoseiulus persimilis* (Acarina: Phytoseiidae). *African Journal of Agricultural Research*, 6(2): 338–342.

Nchu, F. (2024) Sustainable biological control of pests: The way forward. *Applied Sciences*, 14(7): 2669. DOI: 10.3390/app14072669

Opit, G.P., Perret, J., Holt, K., Nechols, J.R., Margolies, D.C. & Williams, K.A. (2009) Comparing chemical and biological control strategies for twospotted spider mites (Acari: Tetranychidae) in commercial greenhouse production of bedding plants. *Journal of Economic Entomology*, 102 (1): 336–346. DOI: 10.1603/029.102.0144

Overmeer, W.P.J. (1985) Rearing and handling. *In*: Sabelis, M.W. (Ed.), *Spider mites, their biology, natural enemies and control*. Vol. 1A, Elsevier Science, Amsterdam, the Netherlands, pp. 161–170.

Papachristos, D.P. & Milonas, P.G. (2008) Adverse effects of soil applied insecticides on the predatory coccinellid *Hippodamia undecimnotata* (Coleoptera: Coccinellidae). *Biological Control*, 47(1): 77–81. DOI: 10.1016/j.biocontrol.2008.06.009

Poletti, M., Maia, A.H.N. & Omoto, C. (2007) Toxicity of neonicotinoid insecticides to *Neoseiulus californicus* and *Phytoseiulus macropilis* (Acari: Phytoseiidae) and their impact on functional response to *Tetranychus urticae* (Acari: Tetranychidae). *Biological Control*, 40: 30–36. DOI: 10.1016/j.biocontrol.2006.09.001

Popp, J., Pető, K. & Nagy, J. (2012) Pesticide productivity and food security. A review. *Agronomy for Sustainable Development*, 33(1): 243–255. DOI: 10.1007/s13593-012-0105-x

Pratt, P.D., Monetti, L.N. & Croft, B.A. (1998) Within- and between-plant dispersal and distributions of *Neoseiulus californicus* and *N. fallacis* (Acari: Phytoseiidae) simulated bean and apple plant systems. *Environmental Entomology*, 27(1): 148–153. DOI: 10.1093/ee/27.1.148

Raghavendra, K., Barik, T.K., Sharma, P., Bhatt, R.M., Srivastava, H.C., Sreehari, U. & Dash, A.P. (2011) Chlorfenapyr: a new insecticide with novel mode of action can control pyrethroid resistant malaria vectors. *Malaria Journal*, 10: 16. DOI: 10.1186/1475-2875-10-16

Řezáč, M., Pekár, S. & Stará, J. (2010) The negative effect of some selective insecticides on the functional response of a potential biological control agent, the spider *Philodromus cespitum*. *BioControl*, 55(4): 503–510. DOI: 10.1007/s10526-010-9272-3

Rhodes, E.M. & Liburd, O.E. (2009) Predatory mite, *Neoseiulus californicus* (McGregor) (Arachnida: Acari: Phytoseiidae). *EDIS*, 2005(13): EENY-359. DOI: 10.32473/edis-in639-2005

Sehat-Niaki, N., Zahedi Golpayegani, A., Torabi, E., Saboori, A. & Amiri-Besheli, B. (2025) Behavioral and acaricidal effects of the chlorfenapyr and acequinocyl on the predatory mites, *Neoseiulus californicus* and *Phytoseiulus persimilis* (Acari: Phytoseiidae). *Experimental and Applied Acarology* (In press).

Sabelis, M.W. & van de Baan, H.E. (1983) Location of distant spider mite colonies by phytoseiid predators: demonstration of specific kairomones emitted by *Tetranychus urticae* and *Panonychus ulmi*. *Entomologia Experimentalis et Applicata*, 33(3): 303–314. DOI: 10.1111/j.1570-7458.1983.tb03273.x

Sheppard, C.D. & Joyce, J.A. (1998) Increased susceptibility of pyrethroid-resistant horn flies (Diptera: Muscidae) to Chlorfenapyr. *Journal of Economic Entomology*, 91(2): 398–400. DOI: 10.1093/jee/91.2.398

Solomon, M.G., Cross, J.V., Fitzgerald, J.D., Campbell, C.A.M., Jolly, R.L., Olszak, R.W., Niemczyk, E. & Vogt, H. (2000) Biocontrol of pests of apples and pears in northern and central Europe - 3. Predators. *Biocontrol Science and Technology*, 10(2): 91–128. DOI: 10.1080/09583150029260

Teodoro, A.V., Pallini, A. & Oliveira, C. (2008) Sub-lethal effects of fenbutatin oxide on prey location by the predatory mite *Iphiseiodes zuluagai* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, 47(4): 293–299. DOI: 10.1007/s10493-008-9219-x

Tiftikçi, P., Kök, Ş. & Kasap, İ. (2022) The effect of host plant on the biological control efficacy of the predatory mite, *Phytoseiulus persimilis* Athias-Henriot against two-spotted spider mites, *Tetranychus urticae* Koch on field-grown vegetables. *Crop Protection*, 158: 106012. DOI: 10.1016/j.cropro.2022.106012

Tudi, M., Daniel Ruan, H., Wang, L., Lyu, J., Sadler, R., Connell, D., Chu, C. & Phung, D.T. (2021) Agriculture development, pesticide application and its impact on the environment. *International Journal of Environmental Research and Public Health*, 18(3): 1112. DOI: 10.3390/ijerph18031112

Van Leeuwen, T., Vontas, J., Tsagkarakou, A., Dermauw, W. & Tirry, L. (2010) Acaricide resistance mechanisms in the two-spotted spider mite *Tetranychus urticae* and other important Acari: A review. *Insect Biochemistry and Molecular Biology*, 40(8): 563–572. DOI: 10.1016/j.ibmb.2010.05.008

Van Lenteren, J.C. & Woets, J. (1988) Biological and integrated pest control in greenhouses. *Annual Review of Entomology*, 33(1): 239–269. DOI: 10.1146/annurev.en.33.010188.001323

Van Pottelberge, S., Van Leeuwen, T., Van Amermaet, K. & Tirry, L. (2008) Induction of cytochrome P450 monooxygenase activity in the two-spotted spider mite *Tetranychus urticae* and its influence on acaricide toxicity. *Pesticide Biochemistry and Physiology*, 91(2): 128–133. DOI: 10.1016/j.pestbp.2008.03.005

Yang, S., Li, M., Shang, H., Liu, Y., Li, X., Jiang, Z., Chen, G. & Zhang, X. (2021) Effect of sublethal spirotetramat on host locating and parasitic behavior of *Encarsia formosa* Gahan. *Pest Management Science*, 78(1): 329–335. DOI: 10.1002/ps.6638

Yorulmaz Salman, S., Aydınlı, F. & Ay, R. (2015) Selection for resistance: Cross-resistance, inheritance, synergists and biochemical mechanisms of resistance to acequinocyl in *Phytoseiulus persimilis* A.H. (Acari: Phytoseiidae). *Crop Protection*, 67: 109–115. DOI: 10.1016/j.cropro.2014.10.001

Zhao, Y., Wang, Q., Wang, Y., Zhang, Z., Wei, Y., Liu, F., Zhou, C. & Mu, W. (2017) Chlorfenapyr, a potent alternative insecticide of phoxim to control *Bradysia odoriphaga* (Diptera: Sciaridae). *Journal of Agricultural and Food Chemistry*, 65(29): 5908–5915. DOI: 10.1021/acs.jafc.7b02098

Zhang, X., Xu, Q., Lu, W. & Liu, F. (2014) Sublethal effects of four synthetic insecticides on the generalist predator *Cyrtorhinus lividipennis*. *Journal of Pest Science*, 88(2): 383–392. DOI: 10.1007/s10340-014-0606-2

اثرهای کلرفناپیر و آسکینوسیل بر مکان‌یابی طعمه توسط کنه‌های شکارگر *Neoseiulus californicus* و *Phytoseiulus persimilis* (Acari: Phytoseiidae)

نوید صحت نیاکی[۱]، آزاده زاهدی گلپایگانی[۲*]، سید احسان ترابی[۳*]، علیرضا صبوری[۴]، بهنام امیری بشلی[۵]

۱. گروه گیاهپزشکی، دانشکدهٔ کشاورزی، دانشگاه تهران، ایران، ایران؛ رایانامه: Navidsehat93@ut.ac.ir، zahedig@ut.ac.ir، eh_torabi@ut.ac.ir، saboori@ut.ac.ir

۲. گروه گیاهپزشکی، دانشکدهٔ کشاورزی، دانشگاه آیدین عدنان مدرس، آیدین، ترکیه

۳. گروه گیاه‌پزشکی، دانشگاه علوم کشاورزی و منابع طبیعی ساری، ساری، ایران؛ رایانامه: B.amiri@sanru.ac.ir

* نویسندگان مسئول

چکیده

مهار زیستی به‌عنوان روشی پایدار و سازگار با محیط زیست برای مدیریت آفات در نظر گرفته می‌شود، اما گاهی استفاده از آفت‌کش‌ها به عنوان روشی مکمل ضروری است. در این مطالعه، تأثیر دو آفت‌کش کلرفناپیر و آسکینوسیل بر پاسخ بویایی هرناهای شکارگر *Neoseiulus californicus* و *Phytoseiulus persimilis* (Acari: Phytoseiidae) بررسی شد. در آزمایش‌های بویایی‌سنجی، هرناها در معرض دیسک‌های تیمار شده با آفت‌کش یا آب (شاهد) قرار گرفتند و سپس در یک لوله بویایی‌سنج Y شکل (دارای دو بازو حاوی برگ‌های سالم لوبیا و دیگری برگ‌های آلوده به هرنای تارتن) برای ارزیابی پاسخ به منابع بو قرار داده شدند. داده‌ها با استفاده از آزمون G-test تجزیه و تحلیل شدند. هرناهای شکارگری که با غلظت‌های مختلف تیمار شده بودند، به‌صورت تصادفی بین دو بازوی Y شکل حرکت کردند، در حالی که هرناهای شاهد تمایل معناداری به بازوی حاوی بوی هرنای تارتن نشان دادند. تنها در دو تیمار شاهد و غلظت مزرعه‌ای آسکینوسیل تفاوت معنی‌داری بین این دو انتخاب مشاهده شد که نشان‌دهنده عدم ایجاد اختلال در فرایند طعمه‌یابی است. با افزایش غلظت آفت‌کش، تعداد هرناهایی که در انتخاب بین دو بازوی Y مردد بودند افزایش یافت. همچنین میانگین زمانی که کنه‌ها برای انتخاب و رسیدن به منبع بو صرف کردند، در تیمارهای با غلظت بیشتر آفت‌کش بیشتر بود، که نشان‌دهنده کند شدن فرایند تصمیم‌گیری آن‌ها است. این مطالعه نشان می‌دهد که آفت‌کش‌ها می‌توانند توانایی کنه‌های شکارگر را در تشخیص و ردیابی بوی طعمه کاهش دهند. این اختلال ممکن است اثربخشی کنترل بیولوژیک را به خطر بیندازد. بنابراین، انتخاب و استفاده از آفت‌کش‌ها باید با دقت و احتیاط انجام شود تا کارایی کنترل زیستی حفظ و دشمنان طبیعی آفات محافظت شوند. همچنین، بررسی‌های مرتبط با پاسخ بویایی باید به عنوان یک فراسنجهٔ مهم در ارزیابی انتخابی بودن آفت‌کش‌ها گنجانده شود تا به بهبود و تقویت برنامه‌های مدیریت تلفیقی آفات کمک کند.

کلمات کلیدی: کنه‌کش، زیست‌سنجی، مهار زیستی، پاسخ بویایی، هرنای شکارگر.

اطلاعات مقاله: تاریخ دریافت: ۱۴۰۳/۵/۲۹، پذیرش توسط: *ا. جوهرچی*، ۱۴۰۳/۷/۱۵، تاریخ چاپ: ۱۴۰۳/۱۰/۲۶