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Short Communication

Greenhouse evaluation of flonicamid efficacy against green peach aphid (*Myzus persicae*) and western flower thrips (*Frankliniella occidentalis*) at different population densities

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Abstract

The green peach aphid (*Myzus persicae* Sulzer) and the western flower thrips (*Franklinella occidentalis* Pergande) are major pests in pepper greenhouses. One of the strategies for their effective control is the use of insecticides with novel modes of action and a short pre-harvest interval. In this study, we evaluated the efficacy of the insecticide flonicamid (WG 50%) on different population densities of *M. persicae* and *F. occidentalis* in bell pepper greenhouses in Isfahan Province (Iran). The experiments were conducted as a randomized complete block design at the highest registered application rate of the insecticide (125 mg ai l^{-1}). The results showed that flonicamid effectively controlled *M. persicae* populations, achieving greater than 80% mortality at various population densities up to 14 days after treatment. Also, no significant difference was observed between low and high population densities of this pest. In contrast, flonicamid showed good efficacy only against low densities of F. occidentalis (79% mortality at 14 days post-treatment). For high thrips densities, the efficacy declined to 63, 59, and 47% on days 3, 7, and 14 post-treatment, respectively, showing significant differences compared to low population densities at all time intervals. These findings suggest that flonicamid is a highly effective and safe insecticide for managing *M. persicae* at any population density and *F. occidentalis* at low densities in pepper greenhouses.

Keywords: Bell pepper, greenhouse pests, insecticide, mortality, spraying

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گزارش کوتاه انگلیسی

ارزیابی گلخانه‌ای کارایی حشره‌کش فلونیکامید در تراکم‌های جمعیتی مختلف شته سبز هلو (*Myzus persicae*) و تریپس غربی گل (*Frankliniella occidentalis*)

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چکیده

شته سبز هلو (*Myzus persicae* Sulzer) و تریپس غربی گل (*Franklinella occidentalis* Pergande) از آفات بسیار مهم گلخانه‌های فلفل می‌باشند. یکی از راهکارهای کنترل موفقیت‌آمیز آن‌ها استفاده از حشره‌کش‌هایی با نحوه‌ی اثر جدید با دوره‌ی کارنس پایین می‌باشد. از این‌رو، در پژوهش حاضر کارایی حشره‌کش فلونیکامید (WG 50%) روی تراکم‌های مختلف جمعیت شته سبز هلو، *M. persicae* و تریپس غربی گل *F. occidentalis* در گلخانه‌های فلفل دلمه‌ای استان اصفهان (ایران) مورد بررسی قرار گرفت. آزمایش‌ها در قالب طرح بلوک‌های کامل تصادفی با بالاترین میزان مصرف ثبت شده از این حشره‌کش (١٢٥ mg ai l^{-1}) انجام شد. نتایج نشان داد فلونیکامید به خوبی باعث کنترل جمعیت شته سبز هلو شد و تا ١٤ روز پس از تیمار درصد تلفات در تراکم‌های جمعیتی مختلف بالای ٨٠ درصد بود. همچنین، هیچ تفاوت معنی‌داری در بین کنترل جمعیت با تراکم‌های پایین و بالای این آفت مشاهده نشد. در مقابل، فلونیکامید تنها در کنترل جمعیت با تراکم پایین تریپس غربی گل کنترل خوبی را از خود نشان داد (٧٩ درصد، ١٤ روز پس از تیمار). در تراکم جمعیتی بالای تریپس در روزهای سوم، هفتم و چهاردهم پس از تیمار میزان کارایی به ترتیب به حدود ٦٣، ٥٩ و ٤٧ درصد کاهش یافت که در تمامی فواصل زمانی تفاوت معنی‌داری با تراکم پایین جمعیت تریپس داشت. بنابر نتایج بدست آمده، فلونیکامید می‌تواند به عنوان یک حشره‌کش بسیار موثر و ایمن در تراکم‌های جمعیتی مختلف شته سبز هلو و تراکم‌های جمعیتی پایین تریپس غربی گل در گلخانه‌های فلفل مورد استفاده قرار گیرد.

کلید واژه‌ها: آفات گلخانه‌ای، تلفات، حشره‌کش، سمپاشی، فلفل دلمه‌ای

دبیر تخصصی: دکتر معصومه ضیائی

Introduction

Flonicamid is a systemic insecticide with contact-stomach activity, belonging to the pyridine carboxamide group. The insecticide is a selective feeding inhibitor and targets sucking pests including aphids, whiteflies, and thrips. Its mode of action involves affecting the chordotonal organs of susceptible insects, leading to feeding cessation and eventual death by starvation. Flonicamid exhibits favorable toxicological, environmental, and ecotoxicological profiles, making it an effective insecticide in resistance management and integrated pest management programs (Morita et al., 2014; Spalthoff et al., 2022; Mahdavi et al., 2025). Due to its short pre-harvest interval (one day) on greenhouse crops such as cucumbers and strawberries, flonicamid was registered in Iran in 2013 as an effective insecticide for controlling greenhouse pests, especially aphids and thrips (PPO, 2025).

The green peach aphid, *Myzus persicae* (Sulzer) (Hemiptera, Aphididae), is the most economically important aphid pest worldwide. Its direct damage results from feeding on plant sap, while indirect damage is caused by honeydew production and growth of sooty mold on leaves, as well as by the transmission of plant viruses (Blackman and Eastop, 2007). Another highly destructive greenhouse pest is the western flower thrips (WFT), *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). Since the late 1970s, this pest has spread from its native habitat in western North America to become a major global plant pest (Shipp et al., 2000). Factors such as their broad host range, extensive distribution, high reproductive rate, and short life cycle have made these two species as serious pests (Cloyd, 2009; Bass et al., 2014). The indiscriminate and excessive use of chemical pesticides for controlling these pests has led to significant environmental problems and the development of resistance to multiple insecticide classes (Bass et al., 2014; Graily-Moradi et al., 2021). These factors have become a major barrier to effective chemical control using conventional insecticides currently available. Therefore, the use of alternative insecticides with novel modes of action that are effective against resistant strains while exhibiting favorable toxicological and environmental properties is very important (Cloyd, 2009). Various studies have evaluated the efficacy of flonicamid against different pests, including the cotton aphid (*Aphis gossypii* Glover) (Shafaghi et al., 2022), the green peach aphid (Sabra et al., 2025), the greenbug (*Schizaphis graminum* Rondani) (Gul et al., 2023), and the western flower thrips (Radosevich & Cloyd, 2020; Renkema et al., 2020).

Given the expansion of greenhouse cultivation (especially pepper varieties) and the export of these products to Iran's neighboring countries, the use of low-risk pesticides with short pre-harvest intervals has become increasingly important. Over the past decade, flonicamid use in Iranian greenhouses has risen significantly due to its one-day pre-harvest interval and minimal risk to natural enemies (Shafaghi et al., 2022). Therefore, the present study aimed to evaluate the efficacy of flonicamid against different population densities of two important pests, green peach aphid and WFT, in bell pepper greenhouse systems.

Materials and Methods

Greenhouses

This research was conducted in four soil-based bell pepper greenhouses (Nirvin variety) located in Isfahan Province, Iran. The experiment followed a randomized complete block design with four locations as blocks during June and July 2022. All treatments were randomly assigned within each location, with ten replicates per

treatment at each site. The specifications of the greenhouses are presented in Table 1.

Table 1. Information on the investigated pepper greenhouses.

County	Site	Coordinates	AMSL[1]	Greenhouse Area (m^2)
Tiran and Karvan	Mirabad village	35°52'40" N, 51°04'09" E	2029	3000
Tiran and Karvan	Suran village	32°48'19" N, 50°55'20" E	2061	5000
Falavarjan	Baharan city	32°31'12" N, 51°32'07" E	1618	2000
Tiran and Karvan	Ab-e Garm village	32°48'16" N, 50°51'20" E	2139	3000

[1] Above Mean Sea Level

The first greenhouse (Mirabad village) had a high population density of WFT (average 23-33 thrips per plant on flowers), and the second greenhouse (Suran village) had a low density of WFT (average 6-12 thrips per plant on flowers). The third greenhouse (Baharan city) had a low density of green peach aphid (average 31-58 aphids per plant on leaves), while the fourth greenhouse (Ab-e Garm village) had a high density of *M. persicae* (average 89-134 aphids per plant on leaves). Infestations occurred naturally in the greenhouses and no artificial inoculation was performed. Also, no cages were used to isolate infested plants from other greenhouse plants. Due to the patchy distribution of pests within greenhouses, treatment blocks were established exclusively in infested areas.

Insecticide

The commercial formulation of flonicamid (Stepeki® WG 50%) was prepared from Saray Sepand Pars Company (Tehran, Iran) and applied at the highest registered application rate of 25 g per 100 L of water (125 mg ai l^{-1}) (PPO, 2025). The insecticide was uniformly sprayed across all rows of bell pepper plants in the greenhouse using a 200-L trolley-type sprayer equipped with a single-nozzle lance. A water-only treatment served as the control.

Sampling

For sampling of *M. persicae*, ten plants were randomly selected and five leaves were collected from the upper half of each plant. The samples were individually placed in ventilated containers (11×10×4 cm) and transferred to the laboratory for counting. The number of live insects per sample was recorded using a stereomicroscope (×20 magnification). Differentiation between life stages was not considered; thus, all stages (nymphs and apterous adults) were counted collectively (Golmohammadi et al., 2020).

For sampling of WFT, ten plants were randomly selected, and three flowers from each plant were evaluated. A white A4 sheet was placed beneath each pepper flower, and thrips were dislodged by tapping the flower five times. The number of thrips shed onto the paper was then counted. The economic injury threshold for this pest under greenhouse conditions is defined as 3 to 7.5 thrips per flower (Shipp et al., 2000). Sampling and counting of insects were performed one day before spraying and on days 3, 7, and 14 post-treatment.

Statistical analysis

Mortality percentage for each treatment was estimated using the Henderson-Tilton formula (1955) as follows:

$$\text{Insecticide efficacy\%} = \left(1 - \frac{T_a}{C_a} \times \frac{C_b}{T_b}\right) 100$$

Where T_a and T_b represent the number of live insects on treated plants after and before spraying; C_a and C_b represent number of live insects on control plants after and before spraying, respectively. The data were analyzed using IBM-SPSS v.22.0 software (IBM Corp., 2013*)*. Normality was assessed using the Kolmogorov-Smirnov test, and the mean mortality percentage was calculated for each treatment. Statistical comparisons were conducted using One-way ANOVA (to evaluate insecticide efficacy across sampling days) and t-test (to compare low-density vs. high-density treatments). The means were compared with Tukey's test at the 5% level.

Results and Discussion

The mean percent efficacy of flonicamid on days 3, 7, and 14 post-spraying for both low and high densities of *M. persicae* is presented in Table 2. No significant difference in insecticidal efficacy was observed between the two aphid densities. Additionally, none of the post-treatment sampling days exhibited significant differences. Throughout all post-spraying days for both pest densities, flonicamid demonstrated consistent and acceptable efficacy in controlling *M. persicae.*

Similarly, other studies have also reported the effective and sustained control of flonicamid against the aphid *Aphis gossypii* at 3, 7, and 14 days after treatment (without significant differences) (Golmohammadi et al., 2020; Shafaghi et al., 2022). Morita et al. (2007) demonstrated that flonicamid was highly effective against aphids regardless of species, life stages (nymphs and adults), and morphs (winged and wingless). The insecticide rapidly inhibits feeding behavior within 30 minutes of application without inducing overt toxic symptoms such as convulsions**.** This anti-feeding activity persists irreversibly until mortality occurs (Morita et al., 2007; Golmohammadi et al., 2020). Numerous studies have documented flonicamid's effectiveness against *M. persicae* in both laboratory and greenhouse conditions (Sabra et al., 2025; Markad et al., 2025). Resistance risk assessments for *M. persicae* have yielded satisfactory results for flonicamid (Arthur et al., 2022; Kirkland et al., 2024), but this does not mean that resistance will not develop in the future. Notably, *M. persicae* possesses high reproductive potential, a broad host range, short generation cycles, and the ability to fly (winged form), which enhances its capacity to resist chemical insecticides (Bass et al., 2014; Arthur et al., 2022). Therefore, despite its effective efficacy and a different mode of action compared to previous insecticide groups, resistance management programs should not be ignored and this chemical compound should not be used indiscriminately.

Table 2. Mean control efficiency percentage (± SE) of flonicamid against low (31-58 individuals/plant) and high (89-134 individuals/plant) densities of *Myzus persicae* in bell pepper greenhouses of Baharan city and Ab-e Garm village.

Aphid population	Efficacy% (days after treatment)			Statistics		
	3	7	14	*F*	df	*P*
Low density	92.38±2.16Aa[1]	88.00±3.63Aa	83.80±1.63Aa	2.690	2, 27	=0.86
High density	87.01±1.95Aa	91.56±2.37Aa	84.10±2.48Aa	2.720	2, 27	=0.84
t	-1.845	0.822	0.101			
P	=0.082	=0.424	=0.921			

[1] Means with the same upper-case letters in each column are not significantly different at 5% level (using t-test), means with the same lower-case letters in each row are not significantly different (Tukey's test, $P<0.05$)

Table 3 presents the insecticide efficacy percentage for controlling *F. occidentalis* on different sampling days. In contrast to *M. persicae*, a significant difference was observed in the efficacy of flonicamid between low and high pest densities. The efficacy percentage was significantly higher at low pest density than at high density across all post-treatment days. At low pest density, no significant differences in efficacy were detected between sampling days after treatment. However, at high pest density, significant variations were observed. The efficacy at high pest density declined to 44.47% by day 14 post-treatment, which was significantly lower than the values recorded on day 3 (62.56%) and day 7 (58.69%). Similarly, Srivastava et al. (2014) reported moderate efficacy of flonicamid (98 g a.i./ha) against WFT on pepper plants. However, its impact on natural enemies (*Orius insidiosus* Say) was lower compared to broad-spectrum and effective insecticides such as acetamiprid (84 g a.i./ha). Other studies estimated the efficacy of flonicamid against adult *F. occidentalis* to be in the range of 50–80%, which was lower than that of spinosad (>95%) and chlorfenapyr (>67%) (Radosevich & Cloyd, 2020).

Most available insecticides primarily target nymphs or adults, with minimal efficacy against eggs or pupae. Consequently, pest control programs require repeated applications to eliminate life stages unaffected by previous treatments (e.g., nymphs emerging from eggs or adults emerging from pupae). This issue becomes particularly critical when generational overlap is common (Cloyd, 2009). Flonicamid, while highly effective against adults and nymphs, shows reduced activity against eggs and pupae (Abbas et al., 2022). This difference in efficacy may explain the observed variability in its performance against high populations of *M. persicae* and *F. occidentalis* in the present study; since the aphid population consisted of nymphs and adults, the thrips population included all life stages. Additional factors contributing to flonicamid's lower efficacy against high densities of WFT compared to *M. persicae* include differences in feeding behavior, mobility, and microhabitat preferences on pepper plants. *Frankliniella occidentalis* displays cryptic behavior and high mobility, traits exacerbated at higher pest densities, which reduce exposure to contact insecticides.

Table 3. Mean control efficiency percentage (± SE) of flonicamid against low (6-12 individuals/plant) and high (23-33 individuals/plant) densities of *Frankliniella occidentalis* in bell pepper greenhouses of Mirabad and Suran villages.

Thrips population	Efficacy% (days after treatment)			Statistics		
	3	7	14	*F*	df	*P*
Low density	85.95±3.43 Aa[1]	89.13±3.29 Aa	79.12±3.01 Aa	2.478	2, 27	=0.103
High density	62.56±3.06 Ba	58.69±3.70 Ba	47.44±2.24 Bb	6.599	2, 27	<0.005
t	-5.089	-6.149	-8.441			
P	<0.0001	<0.0001	<0.0001			

[1] Means with the same upper-case letters in each column are not significantly different at 5% level (using t-test), means with the same lower-case letters in each row are not significantly different (Tukey's test, $P<0.05$)

The results of the present study align with similar research findings, indicating that the key to managing WFT with insecticides is to initiate pest control programs when insect populations are at "low" levels. This strategy avoids simultaneous exposure to different life

stages of the insect during the crop production cycle. When WFT populations reach "high" levels, frequent insecticide applications at shorter intervals may become necessary, which can lead to the emergence and development of resistance. In contrast, flonicamid has shown successful control of *M. Persicae* at different population densities and can be used as an effective insecticide in integrated management programs for this pest.

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