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EFFICACY OF BIO-INSECTICIDES AGAINST THRIPS (THYSANOPTERA: THRIPIDAE) AS A PEST OF *PELARGONIUM* CROPS IN A COMMERCIAL GREENHOUSE IN WESTERN ROMANIA

Ana-Maria VÎRTEIU, Marius BOLDEA, Ramona ȘTEF, Florin PRUNAR, Silvia PRUNAR, Ioana GROZEA

University of Life Science “King Mihai I” from Timisoara, 119 Calea Aradului, Timişoara, Romania

Corresponding author emails: anamariavarteiu@usvt.ro, ioanagrozea@usvt.ro

Abstract

The economic importance of thrips in the last ten years, in terms of both direct (often quality) and indirect (via viruses and phytoplasmas) damage to protected flower crops, in particular pelargoniums, has in most cases necessitated the adaptation of integrated management practices. A rich thrip fauna, with Frankliniella occidentalis, Frankliniella intonsa, Thrips tabaci, Thrips major being the most abundant species, was revealed by the analysis of the data collected from the greenhouse in Dudeștii Noi (Timiș County). Feeding pattern analysis revealed the consistent presence of very high levels of polyphagous species. In order to maintain a high quality of Pelargomium plants for rapid commercialisation, treatments were carried out in 2023 and the efficacy of bio-insecticides to control thrips species was evaluated. The results showed that the chemical products had the highest efficacy, namely Exalt with the active ingredient spinetoram and among the biological products used, Laser 240 SC (spinosad as active ingredient) had the highest efficacy. The least effective products used to control thrips were those based on diatom powder and neem oil.

Key words*: bio - insecticides, thrips, pelargonium, greenhouses, western Romania.*

INTRODUCTION

With about 280 species, the genus *Pelargonium* is the second largest genus in the family *Geraniaceae*. Most of the species are widely used as ornamental and medicinal plants (Van der Walt, 1984; Blerot et al., 2016; Celi et al., 2024).

There are many reasons why this plant is so popular, but here are just some: it is extremely easy to grow, which makes it ideal for the novice gardener; it flowers for a very long time, from spring to autumn; it comes in a rainbow of hues, from pink and red to white, orange, purple and a host of bicoloured, patterned and unusual varieties; it is available in scented, upright, climbing and many other varieties; it is versatile and can be combined with many other plants (Yu et al., 2016; Negro et al., 2021; Karagüzel et al., 2024). Due to its premium status, it plays a vital role for many players in the European floral industry, from growers to retailers and many others along the supply chain (EU to fund Pelargonium promotional campaign, 2024. Retrieved from https://www.floraldaily.com/.../)

In Romania (Toma et al., 2012; 2021; Mihuț, 2021), as in most other European countries (Faust et al., 2016; Havardi-Burger et al., 2020), the pelargonium is one of the most popular flowers, used for planting in pots or in the ground, in protected areas or in ornamental gardens (Gabriel, 2015; Moldovan et al., 2023). Thrips are one of the main insects affecting the quality of flowers, in this case pelargomium flowers, both in the garden and in greenhouses (Lewis, 1997; Atakan, 2019; Jandricic et al., 2024). Therefore, knowledge of the population densities, temporal and spatial distribution of these species in different cultivars of pelargonium is essential for the selection of the most effective control strategies.

The number of thrips species varies greatly on a global scale: Lewis (1997) estimated 8000 thrips species, of which 5500 are pests; Tang et al. (2023), estimated 7700; and Mound (2002), cited by Pizzol et al. (2014), estimated 10,000; one thing common to all authors in the literature is that only about 1% of all recently recorded species are considered pests (Morse & Hoodle 2006; Zvaríková et al., 2020).

The *Thripidae* family are the most serious thrips pests of ornamental plants (Funderburk, 2007; Mirab-Balou et al., 2015; Atakan, 2023). Due to ongoing taxonomic revisions and new species discoveries, it is difficult to determine the exact number of thrips species in Europe. However, over 300 species of thrips are estimated to occur in Europe (*Thrips*, Order: *Thysanoptera*, 2024. Retrieved from https://www.amentsoc.org/insects/.../), of which 91 species were recorded in Romania according to Knechtel (1951). By 2002, however, Vasiliu-Oromulu reported that the number had exceeded 150, indicating significant progress in taxonomic research and identifying species over the decades. This increase is likely to be due to: improvements in sampling methods - better traps and identification techniques; changes in habitat and climate - which may have affected thrips diversity; introduction of new species - possibly through trade and horticulture (Marullo et al., 2021). Little is known about the population dynamics and management of *Thripidae* in greenhouse grown pelargoniums in Romania. Nevertheless, in the last 15 years of research, a significant number of thrips species have been mentioned in ornamental plants according to Bărbuceanu & Vasiliu-Oromulu (2012) and Vîrteiu et al. (2015; 2022): *Frankliniella intonsa* (Hinds), *Frankliniella occidentalis* (Pergande), *Frankliniella schultzei* (Trybom), *Frankliniella fusca* (Hinds), *Frankliniella fasciatus* (Linnaeus), *Heliothrips haemorrhoidalis* (Bouché), and *Thrips tabaci* (Lindeman).

Frankliniella (*Thripidae*), one of the most widespread genus of thrips, attacks the inflated buds and open flowers of all types of ornamental plants, causing necrosis, cell collapse, deformation, discolouration, necrotic spots with a silvery sheen (Childers & Achor, 1991; Childers, 1997; Shipp et al., 2000), thus reducing the ornamental value of these plants.

The cosmopolitan species *Frankliniella occidentalis* (Pergande) (*Thysanoptera: Thripidae*) has the greatest economic impact on pelargoniums, but species density-damage relationships vary.

The aim of this work was to evaluate the efficacy of biopesticides in controlling thrips species in indoor pelargoniums to maintain high ornamental value for marketing in 2023.

MATERIALS AND METHODS

Survey

The research was carried out under greenhouse conditions in Dudești Noi, located in the north-central part of the Timiș County (45° 50'16" N, 21° 06'02" E, 99 m above sea level), with an area of 5,039.5 ha, mainly used for agricultural purposes (3550.7 ha) and for growing vegetables and flowers in greenhouses (8.63 ha). The greenhouse consists of an air-inflated, double-layered polyethylene structure with an area of 300 square m, where pelargonium are grown on tabletops in small, individual pots, covering a total of 90 m^2.

Plant material and indoor bioassays

The efficacy of bioinsecticide applications approved by the Ministry of Agriculture and Rural Development - Romania was evaluated for thrips control in pelargonium crops in western Romania during spring 2023. The evaluated bioinsecticides are listed in Table 1.

Table 1. Bioinsecticides evaluated for thrips management in *Pelargomium* crops in greeanhouse, Dudești Noi, 2023

Trade nume	Active ingredients	Manufacturer	Rates applied/ 5 m^2
Laser™ 240 SC	*spinosad*	Corteva Agriscience	4.5 ml
Neemex	Neem Oil (*Azadiracht a indica*)	B.H.S. Bio Innovation	9.0 ml
Diatom trips	Diatomaceo us earth	B.H. Homevo	45 g
Azor	potassium soap	Quelagrow Iberica	18 ml
Exalt	spinetoram	Corteva Agriscience	18 ml

The plants used in the experiment were obtained from seeds. Sowing was performed on January 10, 2023. Immediately after sowing, spray watering with Previcur Energy was performed and the substrate was covered with plastic film (stretch) until emergence. After 8 days, when young seedlings emerged, another watering was performed, also with Previcur Energy fungicide.

Transplanting into individual pots was carried out when the plants had 1-2 true leaves.

In order to obtain a vigorous crop, with a high aesthetic and ornamental value, respectively a high commercial value, a series of fertilizers were applied from transplanting to flowering as follows: - Algaren Twin, MagicP Star at transplanting; - King Life 12 - 48 - 8 + Mg, Calfomyth, Drin, Foliacon 22 and King Life 30 - 10 - 10 + Mg at 10, respectively 20 days after the transplanting; - King Life 20 - 20 - 20 and Calfomyth at bud burst; King Life 8 - 5 - 40 + Mg, Algaren Twin and Calfomyth at flowering.
The varieties used in the experiment were as follows *Pelargonium peltatum* x *zonale* 'Anthony' and *Pelargonium peltatum* 'Blue Wonder'.
There were 6 treatments in the trial: 4 bioinsecticides x 1 chemical insecticide plus untreated control (see Table 1), arranged in a randomised complete block design with 3 replications (18 plots in total). Treatment applications began when thrips densities reached 20 adults/trap and the application date was 13 July 2023. The bioassays were evaluated at 24, 72 hours and 7 and 14 days. All insecticide treatments were applied using a pressurized backpack sprayer. A 1.2 m long boom fitted with four twin-flat fan nozzles (Peis HM 4301, Spraying Systems) was used at a walking speed of 1.2 m/s calibrated to deliver 6-8 l/min.

Thrips sampling and identification

The surveys were carried out from the early spring (February) to the summer (July) of 2023, with sampling taking place at intervals between 7 and 10 days. Double-sided sticky traps of different colours (blue and yellow) were used to collect thrips individuals from each pelargomium variety.
The sampling methods are in line with those used by Vîrteiu et al., 2018; Muntean & Grozea, 2021; Vîrteiu et al., 2021; 2022. Thus, double-sided sticky traps / plot (two/colour) were used, placed at 0.5 m apart, in the middle of each plot. A plot has a perimeter of 5 m^2 and consists of 120 pelargonium plants (Figure 1).
Each month the traps were replaced and taken to the laboratory for preparation and identification.
Slide-mounted adult thrips were identified by using the keys given by zur Strassen (2003); Mound & Marullo (1996); Mound & Kibby (1998).

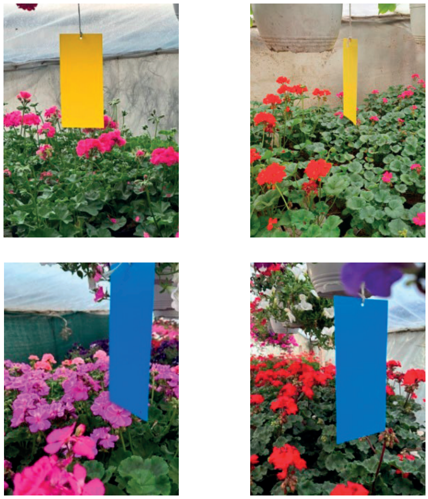

Figure 1. Double-sided sticky traps that were used in the experiment

Statistical analysis

Statistical analyses were performed in R- 4.4.2 for Windows (83 megabyte, 64 bit). R is available as Free Software under the terms of the Free Software Foundation's GNU General Public License in source code form. Average values, standard deviations, coefficients of variation were calculated and the Tukey HSD and Duncan's multiple range tests were applied to determine significant differences between plots. The Henderson - Tilton test was used to calculate the efficacy coefficient for reducing the thrips population.

$$E\% = \left(1 - \frac{n \text{ in Co before treatment} * n \text{ in T after treatment}}{n \text{ in Co after treatment} * n \text{ in T before treatment}}\right) * 100$$

where:
n = thrips population,
T = treated,
Co = control

RESULTS AND DISCUSSIONS

The economic importance of thrips in the past ten years, both in terms of direct, mostly qualitative (Trdan et al., 2008) and indirect, through viroid and phytoplasma transmission (Mound, 1997; Jenser et al., 2003) losses on ornamentals in protected areas, especially on pelargoniums, has necessitated continuous adaptation of IMPs in the majority of cases. This, combined with the need to adapt to an ever-changing phytopharmaceutical market, with the constant withdrawal of some pesticide active ingredients, encouraged us to look for alternative solutions to control thrips in pelargonium crops.

The occurrence of thrips was observed from 8 February to 13 May 2023 on all the pelargonium varieties (Table 2). Data analysis revealed a rich thripsofauna in Dudeștii Noi greenhouse, consisting of a total of 635 individuals of five thrips species, namely: *Frankliniella occidentalis, Frankliniella intonsa, Thrips tabaci and Thrips major.*

Table 2. Abundance of thrips on colored sticky traps on 2 *Pelargonium* varieties from February to May 2023 at Dudești Noi (Timiș County), Romania

Observation date	**Abundance of thrips (number/ sticky trap/varieties)/**									
	Frankliniella occidentalis		***Frankliniella intonsa***		***Thrips tabaci***		***Thrips major***		***Other thrips species***	
	*A	**BW ****	*A	**BW ****	*A	**BW ****	*A	**BW ****	*A	**BW ****
08-Feb	8^{ab}	0^{a}	5^{a}	0^{a}	11^{a}	3^{a}	0^{a}	0^{a}	1^{a}	0^{a}
23-Feb	13^{ab}	2^{a}	5^{a}	1^{a}	8^{a}	9^{a}	0^{a}	1^{a}	0^{a}	1^{a}
10-Mar	17^{ab}	11^{a}	17^{a}	0^{a}	7^{a}	11^{a}	0^{a}	0^{a}	4^{a}	0^{a}
27-Mar	8^{ab}	11^{a}	9^{a}	12^{a}	1^{a}	7^{a}	2^{a}	1^{a}	2^{a}	0^{a}
11-Apr	39^{ab}	17^{a}	10^{a}	17^{a}	19^{a}	21^{a}	2^{a}	5^{a}	6^{a}	4^{a}
29-Apr	44^{ab}	21^{a}	8^{a}	11^{a}	31^{a}	35^{a}	5^{a}	2^{a}	2^{a}	4^{a}
13-May	59^{ab}	19^{a}	6^{a}	7^{a}	44^{a}	8^{a}	0^{a}	0^{a}	1^{a}	0^{a}

*A - Anthony variety; BW** - Blue Wonder variety; Values in columns followed by the same letter(s) are not significantly different to each other according to Tukey HSD tests at $p \leq 0.05$.

Frankliniella occidentalis was by far the most abundant species with 188 specimens collected and an average of 26.85 specimens per trap for the Anthony variety, while *Thrips tabaci* was the second most abundant species (n= 121; $\bar{x}$= 17.29). The most abundant species on the Blue Wonder variety was *Thrips tabaci* with 94 specimens collected and an average of 13.43 specimens per trap. The least collected species was *Thrips major*, with an average of 1.29 specimens per trap for both species studied. In the case of *Frankliniella intonsa*, we can highlight the very high abundance in the pelargonium flower in comparison with the other 3 species of thrips, which preferred to feed on the terminal flower buds and less on the flowers.

Covaci et al. (2012) considered *F. occidentalis* as the main pest of ornamental greenhouse crops in the north-western part of Romania. This species is particularly attracted to inflorescences (van Dijken et al. 1995), and pelargoniums are plants that continue to flower year-round; these are some of the most important conditions that provide a constant food source, leading to an exponential increase in the populations of this species.

ANOVA test for differences in abundance between thrips species ($F = 7.07$; $df = 9$; $p = 0.027 < 0.05$) confirms significant differences between number of thrips species/pelargonium variety collected during monitoring period (Table 3).

Table 3. One-way analysis of variance (ANOVA) evaluating the abundance of thrips species in relation to different variables of greenhouse pelargonium crop monitoring

Source	**df**	**F**	***p***	**Sig.**
pelargonium varieties	9	7.07	**0.027**	<0.05
phenological periods	14	4.48	**0.035**	<0.05
feeding regime	9	0.48	0.750	

Bold p-values ($p<0.05$) indicate a significant positive correlation; for $p \geq 0.05$ no significant correlations were observed.

There was a gradual seasonal increase in the number of thrips up to a peak period for each species (Figure 2). Depending on the developmental cycle of each species, preferred feeding sites and vegetative organs, the peak periods of each species were variable.

In this study we provided evidence that the distribution of thrips species in the foliage and inflorescences of pelargonium is not uniform.

There was a close interaction between crop phenological periods and thrips species, with the proportion of thrips species increasing significantly with the flowering period ($F = 4.48$, $df = 14$, $p = 0.035 < 0.05$) (Table 3).

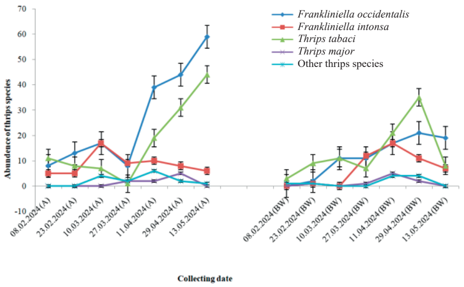

Figure 2. Abundence and seasonal density of thrips species on pelargonium plants (A = Anthony variety; BW = Blue Wonder variety)

In the monitored greenhouse, a higher distribution of thrips species was observed in the inflorescences than in the foliage (Figure 3).

Our general results are in agreement with those of Betanzos et al. (1999) and Palomo et al. (2015), who mentioned that the highest thrips populations were during flowering and in the warmer periods.

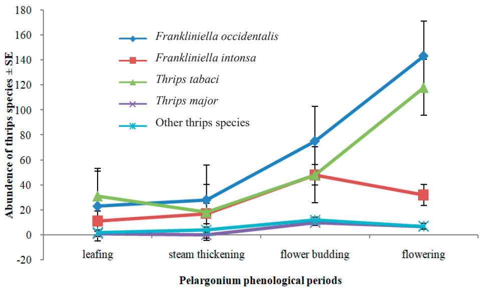

Figure 3. Thrips abundance related to pelargonium phenological periods

Following Healey et al.'s (2017) research, it highlights that in horticultural crops, increases in thrips abundance are linked to crop phenology, with densities increasing as crops mature. Similarities were observed in this study, with population establishment and increased abundance coinciding with successive crop phenological periods: leafing, budding and flowering.

Similar results were obtained by Trdan (2003), who also found that the main factor affecting thrips populations was the plant's phenological stage.

Our results on feeding regime provide experimental evidence for the constant presence of extremely polyphagous species, such as *Frankliniella occidentalis, Frankliniella intonsa* and *Thrips tabaci*. We also observed that pelargoniums strongly facilitated the population growth of *Thrips major*, species with an oligophagous feeding regime, which was particularly rapid from the beginning of budding, whereas the effect of oligophagous species on pelargoniums was not significant ($F = 0.48$, $df = 9$, $p = 0.75$) (Table 3).

Due to the cyclical flowering of pelargonium species, but especially the presence of abundant foliage that provides abundant food throughout the growing season, thrips can have continuous and multiple generations in protected areas (Tomassini & Maini, 1995; Hewitt et al., 2015). The density of these pests is also determined by and closely correlated with the availability of other flowering plants in the study area.

Considering that, in addition to *Pelargonium, Petunia, Dahlia, Gazania*, etc. are the preferred host plants of the pests studied, it is difficult to establish the population dynamics.

Flowering ornamentals plants are highly attractive to thrips, allowing rapid population growth (Rhainds et al., 2003, 2005). Thrips feeding activities lead to early flower senescence and leaf abscission (van Dijken et al., 1995), which reduces plant nutrient quality for thrips feeding and reproduction (Nyasani et al., 2013). This suggests that control may need to be timed to coincide with these early stages of growth to reduce the increase in abundance that follows these periods of establishment of thrips populations (Healey et al., 2017).

The results obtained have contributed to the sustainable reduction of thrips populations by identifying the optimum time to apply appropriate thrips control methods. This approach supports an increase in the quality and ornamental value of the plants studied. Data analysis indicates that mid-May is the optimal time to apply treatments, as this is when the highest population levels were recorded for all species analysed.

Due to the very high incidence observed in the samples, and primarily to establish an effective management practice by reducing pest pressure, various botanicals, biological and chemical products were tested in 2023. This approach aims to maintain the high quality of these ornamental flowering plants for commercialization as quickly as possible.

Table 4 shows the response of different insecticides and bio-insecticides on thrips adult population, revealing significant variation in all treatments.

Coefficient of variation (CV %) ranged from 23.65% to 49.34%, indicating relatively low within-treatment variability, suggesting that the data are consistent.

Table 4. Assessing the response of bio-insecticides and chemical insecticides to mean thrips adult populations in pelargonium crops, 2023

Treatments	Mean no. adults/colored sticky traps							
	after 24 hours	E%	after 48 hours	E%	after 7 days	E%	after 14 days	E%
T1 = untreated control	39[a]	-	35[a]	-	41[a]	-	44[a]	-
T2 = Laser 240 SC/ *spinosad*	32[b]	34.69%	11[b]	77.55%	26[b]	46.94%	41[b]	16.33%
T3 = Neemex/ neem oil (*Azadirachta indica*)	40[b]	21.57%	19[b]	62.75%	25[b]	50.98%	47[b]	7.84%
T4 = Diatom trips/ diatomaceous earth	31[c]	20.51%	29[c]	25.64%	33[c]	15.38%	34[c]	12.82%
T5 = Azor/ potassium soap	20[c]	25.93%	15[c]	44.44%	19[c]	29.63%	24[c]	11.11%
T6 = Exalt/spinetoram	17[d]	60.47%	8[d]	81.4%	21[d]	51.16%	27[d]	37.21%
Mean	29.83		19.5		27.5		26.17	
CV%	29.18		49.34		27.19		23.65	
Sig	*		*		*		-	

*Values in columns followed by the same letter(s) are not significantly different to each other according to to Duncan's multiple rangetests at p ≤ 0.05, CV- coefficient of variation, Sig- significance level, *Significant at p < 0.05, E% - efficiency coefficient

Chemical insecticides such as spinetoram were more effective than the bio-insecticides used, but the latter were significantly more effective than untreated controls at all four time points: 24, 48 hours, 7 and 4 days post treatment.

After 24 hours, in the analysis including the untreated control, the insecticides (bio and chemical) significantly affected the mean thrips densities (F =5.76; *df* =11, p =0.037 < 0.05). The efficacy of spinetoram was higher (60.47% reduction) compared to the bio-insecticide, where the highest reduction rate was obtained with spinosad (34.69%). Potassium soap, neem oil and diatomaceous earth showed reductions between 20.51 and 25.93%. A significant difference between the efficacy of the chemical and biological products was observed after 24 hours post treatment.

Direct exposure to the toxicity of chemical and biological insecticides resulted in a significant reduction in adult thrips density 48 h after treatment (F = 16.97; *df* = 11; p = 0.0021 < 0.05). Among the chemical insecticides, spinetoram was found to cause the highest reduction of all thrips species compared to the control, reaching 81.4%. A similar level of efficacy was also shown by the bio-insecticides, both spinosad and neem oil, with a coefficient of efficacy of 77.55% and 62.75%, respectively. Average thrips numbers were reduced to moderate levels by potassium soap and diatomaceous earth.

7 DAT, all bio and chemical insecticides tested significantly reduced thrips infestation compared to the control treatment (F = 9.44, df = 11, p = 0.012 < 0.05). In general, the greatest reduction in thrips population by chemical insecticides was achieved by spinetoram (51.16%), while the best bioinsecticide was neem oil extract (50.98%), followed by spinosad (46.94%).

At 14 DAT, no significant differences (F = 1.70, df = 11, p = 0.220) were observed in the mean number of thrips collected with coloured

sticky traps in pelargonium plants. Efficacy varies between 37.21 and 7.84%, with chemical spinetoram achieving the best results (37.21%), followed by spinosad.
The untreated control exhibited a gradual decrease in thrips populations over time, likely due to natural mortality or environmental factors. Treated groups generally showed an initial increase in mortality within 24-48 hours, with varying levels of persistence up to 14 days.
The highest relative differences compared to the control were observed in spinetoram (Exalt), spinosad (Laser 240 SC) and neem oil (Neemex) treatments, suggesting a strong initial impact on thrips populations.

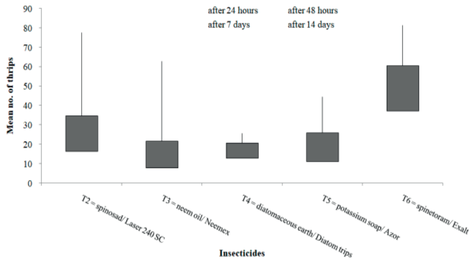

Figure 4. Efficacy of bio and chemical insecticides against thripspopulation, greenhouse pelargonium crops, 2023

The treatments with diatomaceous earth and potassium soap showed a more moderate effect, with reduction coefficients that were closer to those of the control.
These findings indicate that while some treatments significantly reduce thrips populations, further studies with larger sample sizes are required to confirm statistical significance and optimize treatment efficiency.
The results obtained by Lahiri et al. (2024) show us the need to increase the reliance on biopesticides for thrips management, while at the same time highlighting the evidence that plant-based biopesticides can act as valuable rotational products with conventional insecticides for thrips management. In this study, 5 conventional and biological insecticides were tested under greenhouse conditions for their efficacy on thrips populations in pelargoniums. Our observations consistently showed that chemical products showed the highest efficacy under direct contact conditions. These data agree with those of Ataide et al. (2024) who identified 3 conventional and 2 biorational insecticides as most effective against thrips under laboratory conditions. Our study shows that two bioinsecticides, spinosad and neem oil, are most promising for effective thrips control.
In support of our findings, Manideep et al. (2023) showed that spinosad was first in the order of efficacy, reducing 80% of thrips infestations on chrysanthemum plants in the field. Also, Hassan et al. (2024), testing a variety of insecticides in the management of *Thrips tabaci*, certified spinosad with a greater efficacy (94.5%) compared to spinetoram (89.7%). The same authors mention neem oil with 64.1% efficacy, very close to that obtained by us with the same active ingredient (62.75%) 48 hours after application. Monteon-Ojeda et al. (2021) found that three consecutive applications of neem extract were sufficient to reduce *Frankliniella occidentalis* infestation by more than 75%, and spinosad was the best treatment, achieving 90% efficacy with only two applications, positioning it as the best biological option for thrips control. Sahoo & Tripathy (2020), however, recommend using spinosad together with neem oil.

CONCLUSIONS

The overall conclusion of this greenhouse study is that the spinosad-based bioinsecticide can provide reliable protection against thrips species in pelargonium plants, which is of great importance to ornamental growers who continue to struggle with thrips populations that have developed resistance over time to a very wide range of chemicals. Although the performance of neem oil under protected conditions varies, measures can be taken to use this product in parallel with spinosad for the most effective control of thrips in both floricultural and horticultural greenhouses. From a practical point of view and depending on the results obtained, we recommend alternating the spirotoram-based chemical with the single application spinosad/ neem oil combination products.

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