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MANAGEMENT OF *TRIALEURODES VAPORARIORUM* (WESTWOOD) IN TOMATO CROPS

Alina SURDULESCU[1], Raluca VIZITIU[1], Alexandra PRODAN[1], Alexandra ȘANDRU[1], MONICA BUTNARIU[1], Ramona ȘTEF[1]

[1]University of Life Sciences King Mihai I from Timisoara, Romania
Corresponding author: ramonastef@usvt.ro; monica_butnariu@usvt.ro

Abstract. *The greenhouse whitefly (Trialeurodes vaporariorum) is a pest with a wide range of host plants, rapid development, high reproductive capacity and multiple overlapping generations. These biological characteristics are enhanced through the insect's ability to secrete a waxy substance that makes the control of this species very challenging. The aim of the study was to evaluate the efficacy of chemical and biological products in reducing the population of Trialeurodes vaporariorum in tomato crops. The influence of deltametrin, flupyradifuron, Isoclast TM active, potassium salt of fatty acides treatments and spirotetramat was assessed under protected environment(greenhouse). The study protocol included six randomized variants in three replications. The aggressiveness of the target species on tomato plants was evaluated following EPPO guidelines 1/36(3). The efficacy of the products against hemipteran population was assessed at 3 days after treatment (DAT), 7 DAT and 14 DAT. The results recorded during the study showed that the aggressiveness and population levels exerted by adult and nymph stages were highest in untreated control variant. Satisfactory results were recorded in the plots treated with delthamethrin. The biological product Isoclast TM active expressed a lower efficacy against Trialeurodes vaporariorum population compared with other treatments. The systemic insecticides like Sivanto Prime and Movento 100 SC showed the highest efficacy in controlling the population at 7 DAT. Contact and ingestion insecticides control was satisfactory controlling the population within the first 72 hours.*

Keywords*: Trialeurodes vaporariorum, Solanum lycopersicum, control, efficacy,*

INTRODUCTION

The yield of *Solanum lycompersicum* is reduced by several pathogens and pests, among which the greenhouse fly *Trialeurodes vaporariorum* is a common pest (COTUNA et al., 2022, NEACȘU et al., 2019, CĂRĂBEȚ et al., 2009, CĂRĂBEȚ et al., 2023).

The species *Trialeurodes vaporariorum* belongs to the order Hemiptera, family Aleyrodidae, originating from North America. Currently it is a cosmopolitan species found in Africa, Europe, Asia, North America, Oceania, South America. In Europe, the greenhouse whitefly has been reported in 33 countries, including Romania. *Trialeurodes vaporariorum* isn't a native to Romania, the first report dates back to 1949 (BYRNE et al., 1990). This pest is of significance economic importance, ranking high among harmful hemipterans. Is highly polyphagous and the number of host plants it attacks continues to increases. In 2001 Zabel reported 240 host plants (ZABEL et al., 2001), in 2020 Zahra declared 500 species (ZAHRA et al., 2020), and by 2024, 859 of species from 469 genera and 121 family were documented (CABI, 2024; DEARLOVE et al., 2024). The damage caused by this pest can be observed in agricultural and horticultural crops (vegetables and fruits), ornamental plants and even wild flora (ALBORNOZ, 2023), cultivated both in open field and controlled environments.

In Romania, the highest damages occur in tomato crops, eggplant, cucumbers in greenhouse and field as well, pepper and bean cultivated in greenhouse. This species causes both direct and indirect damage: by extracting sap from plants, reducing their vitality and productivity or indirect by secreting a substance called "honeydew" which promotes the fungal growth, disrupting physiological processes (STENBERG, 2017). Moreover, greenhouse whitefly adults

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act as a virus vectors transmitting them to tomato plants such as beet pseudo yellow virus (BPYV), tomato chlorosis virus (ToCV), tomato yellow leaf curl virus (TYLCV), bean mosaic virus (BGMV) and tomato infectious chlorosis virus (TICV), losses can reach up to 50%. Literature data indicate that the annual losses caused by this pest exceed 1 billion dollars globally (KIM et al., 2023). Given the above, it is essential to maintain this pest population below the economic damage threshold (PED = 3-5 adults/leaf or 5-10/eggs-larvae/leaf) through application of effective integrated pest management systems (OMER et al., 1993).

The control of *Trialeurodes vaporariorum* population is a major challenge due its characteristics such high reproductive rates, high fertility rate, short life cycle, overlapping generations, secretion of waxy substances, preference for the underside of leaves, a wide range of hosts, its global distribution, adaptability to various environmental conditions and resistance development towards certain chemical substances (ZHANG et al., 2017). *Trialeurodes vaporariorum* management involves parasitic and predatory arthropods, biopesticides based in microorganisms like viruses, bacteria fungi and protozoa (BUTU et al., 2021, WRAIGHT et al.,2017, LACEY et al., 2015, VÎRTEIU et al., 2015) and pesticides (ALBORNOZ et al., 2023).

The most common method used against *Trialeurodes vaporariorum* are pesticides but their success depends on multiple applications and use of different active ingredients. While pyrethroids, carbamates and organophosphates have effectively controlled whiteflies, their repeated use disrupted natural biological control systems, conducting to pest resurgence due to resistance development (ZAHRA et al., 2020, OMER et al., 1993) as well as resistance to neonicotinoids and other new insecticides (KARATOLOS et al., 2010; WHALON et al., 2012). These insecticides caused negative effects on human health and other invertebrates (PISA et al., 2015, CIMINO et al., 2017). In now days chemical insecticides such as neonicotinoids, organophosphates and nicotine-based products are used (ZAHRA et al., 2020).

This study was conducted in respect of efficacy assessment of chemical and biological products against species *Trialeurodes vaporariorum* in *Solanum lycopersicum* cultivated under controlled conditions in greenhouse.

MATERIAL AND METHODS

The chemical and biological products testing were performed in greenhouse cultivated tomato (*Solanum lycopersicum*) (Figure 1) located in Belint (Timis county). The temperature and relative humidity in the greenhouse were controlled (24-28ºC and relative humidity of 60-70%).

Experimental design

The trial was set up using randomized blocks with three replicates for each treatment. Each plot consists in 10 tomato plants, 45 cm between plants and 80 cm between rows. The hybrid Precos F1 with indeterminate growth was used.

Applied treatments

Five test items were applied against witheflies, including three chemical and two biological products. The trial included six variants, five treated and untreated control (Table 1).

The test items were:

No. crt.	Comercial product	Active ingridient	Dose
1.	Decis Expert 100 EC	100 g/l deltamethrin	75 ml / ha
2.	Sivanto Prime 200SL	200 g/l flupyradifurone	0,56 l/ha
3.	Closer	sulfoxaflor (isoclast TM active120 g/l (11,3%))	0,16 L/ha
4.	Flipper	479,8 g/l potassiom salt of fatty acids C7-C18	16 l/ha
5.	Movento 100 SC	100 g/l spirotetramat	0.75 l/h

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Figure 1. The greenhouse where the trial was conducted targeting control of *Trialeurodes vaporariorum*

The insecticides were applied in growth stage of the first floral bud emergence, BBCH 51. Applications were performed during the morning using a manual sprayer to minimize the evaporation.

Efficacy assessment

The population in experimental plots was determined through witheflies counting on the day of the application (April 10, 2024)

The evaluation was performed according to EPPO guidelines P 1/36(3), by counting alive forms of adults and nymphs at 3 days after treatment (DAT), 7 DAT and 14 DAT. Through randomized assessment of 5 plants each plot.

The efficacy was calculated using Abbotts formula: Efficacy after Abbott %= $(c_a-c_t/c_a)*100$ - Where c_a infestation percentage in untreated control, c_t infestation percentage in treated plots. The results were statistically analized ANOVA and test Tukey.

RESULTS AND DISCUSSIONS

The biological and chemical treatments were applied after a first assessment, which aimed to determine the population level of *Trialeurodes vaporariorum* in the tomato crop.

Table 1.

Analysis of results with the Tukey test regarding the aggressiveness of the species *Trialeurodes vaporariorum* in the *Solanum lycopersicum* culture (3 DAT)

Treatment 1	Treatment 2	Mean diff.	p-adj	lower	Upper
Control	Deltamethrin	-45	0^{***}	56.20	-33.80
Control	Flupyradifurone	-56.67	0^{***}	62.86	-40.47
Control	Potassium salts	-26.67	0^{***}	37.86	-15.47
Control	Isoclast TM	-40	0^{***}	51.19	-28.80
Control	Spirotetramat	-51.67	0^{***}	62.86	-40.47
Deltamethrin	Isoclast	5	0.67^{-}	-6.20	16.20
Deltamethrin	Flupyradifurone	-11.67	0.04^{**}	-22.86	-0.47
Deltamethrin	Spirotetramat	-6.67	0.40^{-}	17.86	4.53
Deltamethrin	Potassium salts	-18.33	0.002^{**}	7.14	29.53
Flupyradifurone	Isoclast TM active	16.67	0.0032^{**}	5.47	27.86
Flupyradifurone	Spirotetramat	5	0.67^{-}	-6.20	16.20
Flupyradifurone	Potassium salts	30	0^{***}	18.80	41.20
Isoclast	Spirotetramat	11.67	0.04^{*}	0.47	22.86
Isoclast	Potassium salts	-13.33	0.017^{**}	--2.14	24.53
Spirotetramat	Potassium salts	25	0.001^{***}	13.80	36.20

F-Statistic: 77.40, p-Value: 1.04, P-value and confidence intervals (confidence intervals corrected using the Tukey method)> * p<0.05

After the application of phytosanitary products, three days after application, the assessment of the aggressiveness of the greenhouse whitefly on the tomato hybrid, Precos F1, was made (Table 1 and Figure 2).

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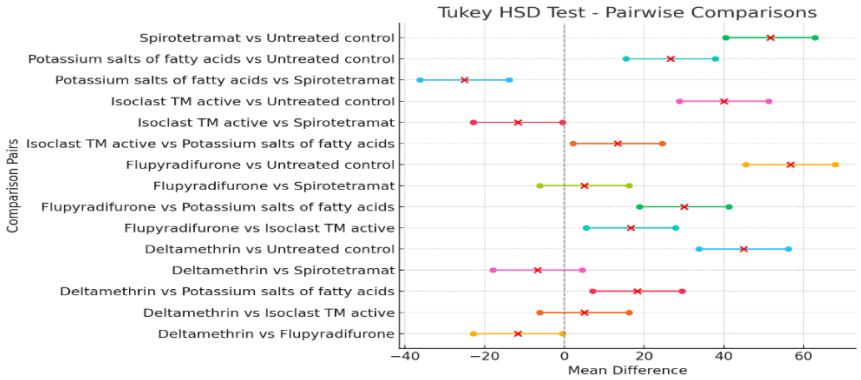

Figure 2. Representation of the average differences in tomato plant aggressiveness between treated variants (3 DAT)

At 72 hours after the application of the treatments, the least attacked plants were found in the variants treated with flupyradifurone and spirotetramat (Table 2).

Table 2

Reduction of aggressiveness of the *Trialeurodes vaporariorum* species in treated variants compared to the control

Treatment	Reduction in infestation I (%)	Reduction in infestation II (%)	Reduction in infestation III (%)	Mean
Deltamethrin	75	66.67	71.43	71.03
Flupyradifurone	83.33	91.67	92.86	89.29
Potassium salts	50	33.33	42.86	42.06
Isoclast TM	58.33	66.67	64.29	63.10
Spirotetramat	83.33	83.33	78.57	81.74
Control	0	0	0	0

The frequency of plants attacked by *Trialeurodes vaporariorum* was reduced by 42.06 – 89.29%. The substances Isoclast TM and potassium salts reduced the aggressiveness of the midge, in the protected tomato crop, by 42.06 – 63.10% compared to that manifested in the untreated variant (Table 2 and Figure 3).

The most protected tomato plants, from the attack of *Trialeurodes vaporariorum* species, were those treated with flupiradifuron (89.29%).

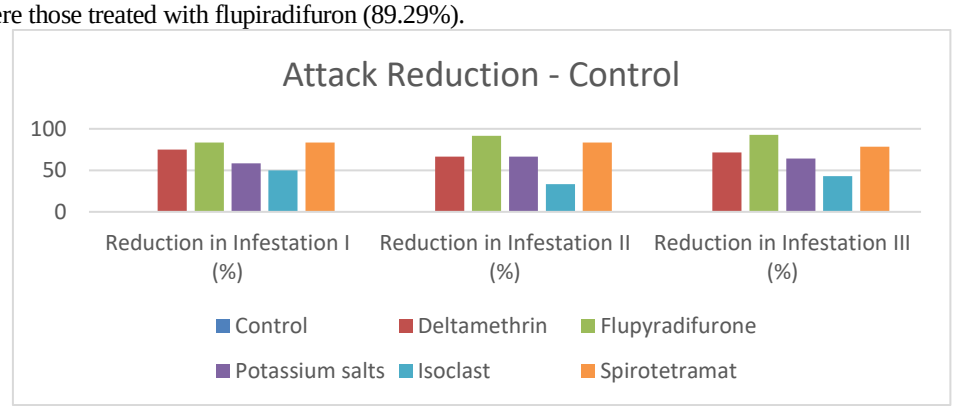

Figure 3. Attack reduction in the treated variants compared to the control (3 DAT)

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The second evaluation was carried out at 7 DAT, the results regarding the frequency of plants attacked by *Trialeurodes vaporariorum* were subjected to statistical analysis which showed that there were significant differences between the treated plots (Table 3). Comparisons performed using the Tukey test show the existence of significant, moderate and even lack of differences.

Table 3

Analysis of the results with the Tukey test regarding the aggressiveness of *Trialeurodes vaporariorum* species in *Solanum lycopersicum* culture (7 DAT)

Deltamethrin	Flupyradifurone	-16.67	0.021**	-31.12	-2.21
Deltamethrin	Isoclast TM active	5	0.85-	-9.45	19.45
Deltamethrin	Potassium salts	16.67	0.021**	2.21	31.12
Deltamethrin	Spirotetramat	-11.67	0.14-	-26.12	2.79
Deltamethrin	Untreated control	58.33	0***	43.88	72.79
Flupyradifurone	Isoclast TM active	21.67	0.0031**	7.21	36.12
Flupyradifurone	Potassium salts	33.33	0.0001***	18.8	47.79
Flupyradifurone	Spirotetramat	5	0.85	-9.45	19.45
Flupyradifurone	Untreated control	75	0***	60.55	89.45
Isoclast TM active	Potassium salts	11.67	0.14-	2.79	26.12
Isoclast TM active	Spirotetramat	-16.67	0.021**	31.12	-2.21
Isoclast TM active	Untreated control	53.33	0***	38.88	67.79
Potassium salts	Spirotetramat	-28.33	0.0003***	42.79	13.88
Potassium salts	Untreated control	41.67	0***	27.21	56.12
Spirotetramat	Untreated control	70	0	55.55	84.45

F-Statistic: 79.37, p-Value: 9.02, P-value and confidence intervals (confidence intervals corrected using the Tukey method)> * p<0.05

The number of plants attacked by *Trialeurodes vaporariorum* in the plots treated with deltamethrin did not differ from the one recorded in the variant treated with Flupyradifurone (Table 3, Figure 4), being insignificant.

Tomato plants treated with the products: Decis Expert 100 EC (deltamethrin), Sivanto Prime 200SL (flupyradifurone), Flipper (potassium salts), Closer (isoclast TM active) and Movento 100 SC (spirotetramat) reduced the attack of the *Trialeurodes vaporariorum* species by 41.67-75% compared to the untreated control (Figure 5).

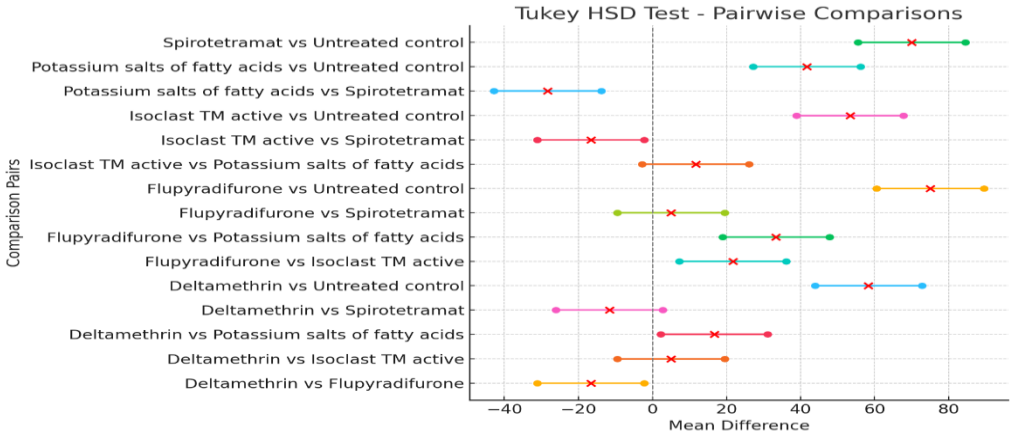

Figure 4. Representation of the average differences in aggressiveness of tomato plants between the treated variants (7 DAT)

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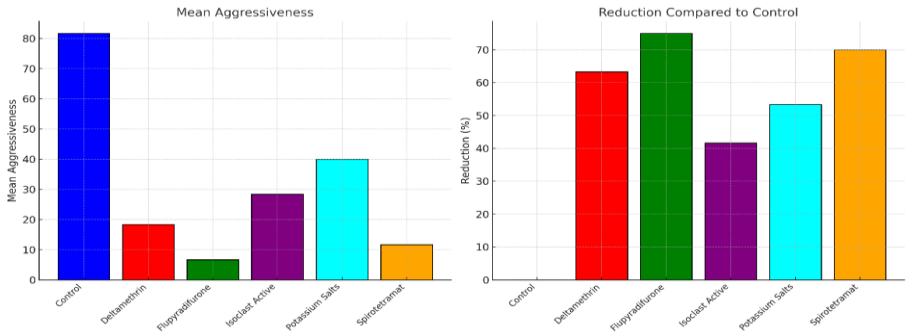

Figure 5. The percentages recorded in the treated variants regarding the reduction of greenhouse whitefly attack compared to the control (%)

The post hoc t-pairs test (with adjusted p values) showed that the aggressiveness on tomato plants, produced by the greenhouse whitefly, was very significantly lower, in the variants treated with Flupyradifurone, Deltamethrin, Spirotetramat compared to the control (Table 4 and Figure 6) The number of plants attacked by *Trialeurodes vaporariorum*, in the plots treated with deltamethrin, did not show statistical differences compared to the affected plants in the plots treated with the other three chemical treatments. Aggressiveness in plots treated with deltamethrin was lower compared to that in plots treated with the biological product Flipper (p-0.021), the statistical differences being moderately significant.

The plants from the plots treated with flupyradifurone were protected against greenhouse whitefly attack, very significantly and moderately significantly compared to those in the plots treated with potassium salts (p-0.0001) and isoclast TM active (p-0.0031).

The control provided by flupyradifurone and spirotetramat, to tomato plants, did not differ statistically (p-0.85). The Closer insecticide, although new generation, did not satisfactorily protect tomato plants against greenhouse whitefly attack, compared to the protection offered by Flipper (the biological product), the Tukey test suggests a lack of statistical differences (p-0.14).

Table 4

Results interpreted with the Tukey HSD test regarding the effect of treatments in reducing the aggressiveness of the *Trialeurodes vaporariorum* species in tomato crops at 14 DAT

Treatment 1	Treatment 2	Mean diff.	p-adj	lower	Upper
Control	Potassium salts	-68.33	0,021**	31.12	19.45
Deltamethrin	Isoclast TM active	5	0.85	-9.45	11.44
Deltamethrin	Flupyradifurone	-16.67	0.89	-14.77	28.11
Deltamethrin	Spirotetramat	-11.67	0.14	-26.12	2.78
Deltamethrin	Potassium salts	-6.67	0.021**	2.21	31.12
Deltamethrin	Untreated control	58.33	0***	43.88	72.79
Flupyradifurone	Isoclast TM active	21.67	0.0031**	7.21	36.12
Flupyradifurone	Spirotetramat	5	0.85	-9.45	19.45
Flupyradifurone	Potassium salts	33.33	0.0001***	18.87	47.78
Flupyradifurone	Untreated control	75	0***	60.55	89.45
Isoclast TM active	Potassium salts	11.67	0.14	-2.79	26.12
Isoclast TM active	Spirotetramat	-16.67	0.021**	31.12	-2.21
Isoclast TM active	Untreated control	53.33	0***	38.88	67.79
Potassium salts	Spirotetramat	28.33	0.0003***	-42.79	-13.88
Potassium salts	Untreated control	41.67	0***	27.21	56.12
Spirotetramat	Untreated control	70	0***	- 55.55	-84.45

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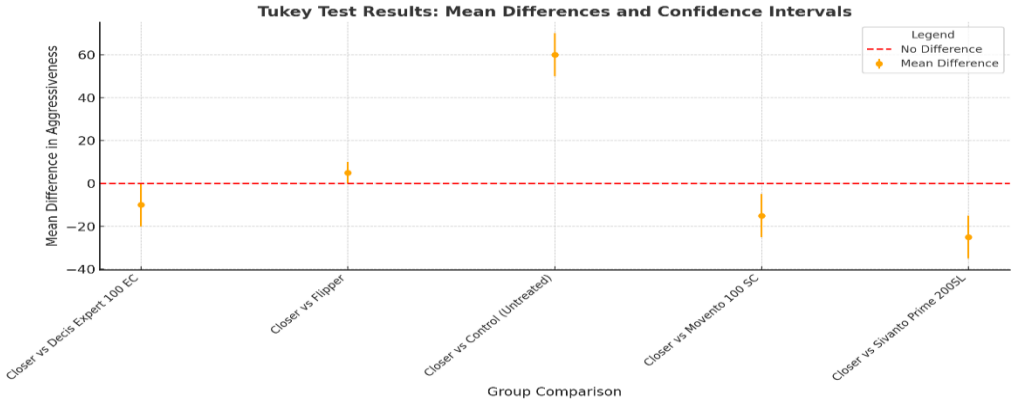

Figure 6. Differences between the mean aggressiveness of the *Trialeurodes vaporariorum* species in the treated variants compared to the untreated control (14 DAT)

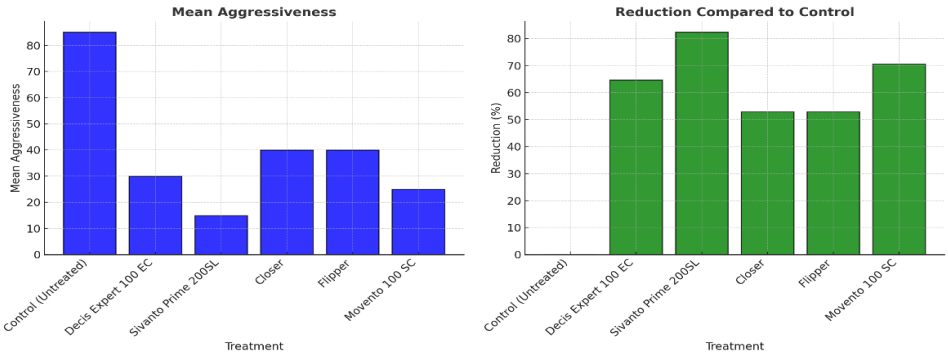

Figure 7. Aggressiveness of the attack of the *Trialeurodes vaporariorum* species from the experimental variants at 14 DAT

The observations made, during the 14 days, highlight that the chemicals flupyradifurone (76.79%) and spirotetramat (73.21%) maintained their superiority in reducing the aggressiveness of the *Trialeurodes vaporariorum* species. The biological product Flipper (44.64%) had the least impact in the control of the greenhouse whitefly in tomato culture (Figure 7).

Figure 8. *Trialeurodes vaporariorum* on the tomato plants of the experimental variants

At 72 hours, after the application of insecticides, it was observed that the population peak of *Trialeurodes vaporariorum* nymphs and adults was recorded in the control plot (35 individuals/5 tomato plants). The reduction in the number of nymphs and adults of *Trialeurodes vaporariorum* was most remarkable in plots treated with Sivanto Prime 200 SL (1.34

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individuals/5 tomato plants) (Figure 9). Movento 100 SC reduced both the density of nymphs and adults, the population level being 3 individuals/5 plants. Both Decis Expert and Closer acted better on the nymph population, having a lower efficacy on adults. Flipper had a reduced effect on the population of *Trialeurodes vaporariorum* compared to the other insecticides.

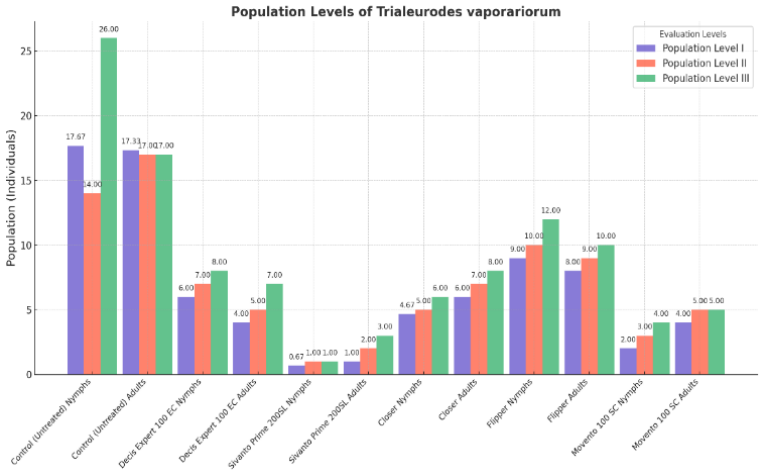

Figure 9. Population level of *Trialeurodes* vaporariorum (3DAY)

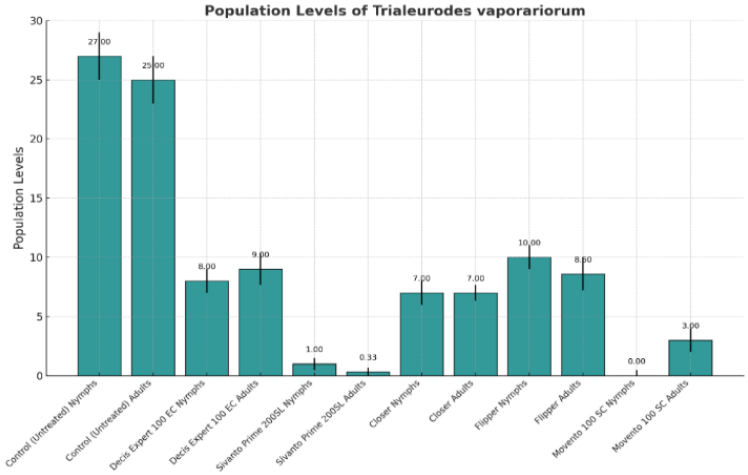

Figure 10. Population level of *Trialeurodes vaporariorum* (7 DAY)

At 7 days after the application of the treatments, the population represented by the nymphal stage was reduced compared to that of the adults, this result being explained by the low mobility of the first-age larvae and the immobility of the other larval stages. The population of *Trialeurodes vaporariorum* increased in the variants treated with Decis Expert, Closer and Flipper, this fact can be explained by the insecticides' mode of action (contact and ingestion). The insecticides Sivanto Prime 200 SL and Movento 100 SC reduced the population of nymphs

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and adults to 0.33 – 1.37 individuals/5 tomato plants, their effectiveness is due to their systemic properties (Figure 10).

The values regarding the population of *Trialeurodes vaporariorum* recorded, at this last assessment, were 2.67 – 31.33 individuals/5 plants. Systemic insecticides maintain their supremacy in reducing the population of *Trialeurodes vaporariorum* even 14 days after the application of the treatments.

At the last assessment (14 DAT) the population of *Trialeurodes vaporariorum* maintained its growth trend recorded at 7 DAT. The number of adults increased compared to the number of nymphs (Figure 11).

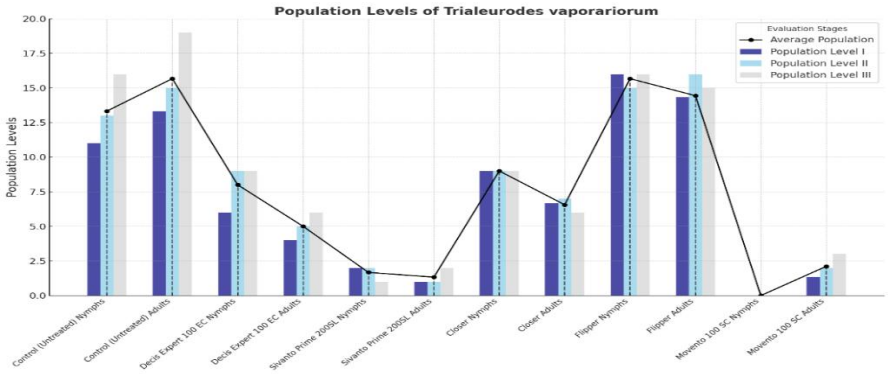

Figure 11. Nivelul populațional de *Trialeurodes vaporariorum* la 14 DAT

CONCLUSIONS

The best results in reducing the population of Trialeurodes vaporariorum were obtained in the variants treated with systemic insecticides, Sivanto Prime and Movento 100 SC.

The effectiveness of the treatments studied decreased with the increase in the time period since application.

The treatments had greater efficacy in reducing the nymph population.

Although the biological product Flipper has not had a significant impact on the population of Trialeurodes vaporariorum in tomato culture, the study indicates that it can be included into integrated control schemes.

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