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Study on the effectiveness of chemical and biological agents to control tomato leaf miner (*Tuta absoluta* Meyrick, 1917)

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Abstract. *In growing four tomato varieties in greenhouses, the effect of a conventional and integrated scheme for control of tomato leaf miner (Tuta absoluta Meyrick, 1917) was studied. Six consecutive treatments were performed at ten-day intervals. The conventional scheme includes the following products: Confidor Energy OD 0.08%, Ampligo 150 ZC 400 ml/ha, Coragen 20 SC 200 ml/ha, Exalt 25 SC 2400 ml/ha, Voliam Targo 063 SC 800 ml/ha and Voliam Targo 063 SC 800 ml/ha. In the integrated scheme the following products for plant protection are used - Confidor Energy OD 0.08%, Sineis 480 SC 250 ml/ha, Sineis 480 SC 250 ml/ha, Voliam Targo 063 SC 800 ml/ha, Neem Azal T/S 0.3% and Neem Azal T/S 0.3%. The effectiveness of the plant protection products against the tomato leaf miner, the degree of pest attack of the different varieties and the tomato productivity were studied in this experiment. It was established that in the conventional and in the integrated treatment scheme, the highest efficiency was shown by the product Voliam Targo 063 SC, applied in a dose of 800 ml/ha on the seventh day after spraying. The percentage of damaged plants was the lowest in the variety Clarosa F_1 (4.00%), with the application of the conventional plant protection scheme. The results were similar in the integrated scheme – 6.00%, while in the control the degree of infestation reached 18.00%. The percentage of damaged fruits in both treatment schemes was 6.00%, significantly lower than in the control (24.00%). The highest tomato productivity was observed with the application of the conventional plant protection scheme in Manusa F_1 variety.*

Keywords: biological and chemical products, effectiveness, integrated pest management, tomato, *Tuta absoluta*

Introduction

Tomato leaf miner (*Tuta absoluta* Meyrick, 1917) (Lepidoptera: Gelechiidae) is a serious invasive pest and the damage caused by this pest has a negative effect on the tomato production in the world. It damages the leaves, but especially great is the damage on the fruits. Production loss can reach 80-100% (Illakwahhi and Srivastava, 2017). Control of this pest is a difficult task due to the latent lifestyle of caterpillars in mines, high reproductive potential, polyvoltine development and resistance to many of the insecticides used (Sequera et al., 2000; Lietti et al., 2005; Jallow et al., 2018). The successful control of *T. absoluta* requires the development of integrated plant protection systems which include a set of measures: crop rotations, use of pheromone traps, placement of insect nets, application of bioagents and bioproducts, treatment with insecticides (OEPP/EPPO Bulletin, 2005; Benvenga et al., 2007; Faria et al., 2008; Huber and Drobny, 2010; Goda et al., 2015).

The most commonly used practice to control *T. absoluta* is the use of chemical products. Studies are ongoing to determine the efficacy of plant protection products with a view to establishing a successful plant protection strategy for the control of the tomato leaf miner, with the aim of avoiding the risk of resistance in populations as much as possible (Lietti et al., 2005; Bielza, 2010; Braham and Hajji, 2012; Yankova and Ganeva, 2013; Yankova at all., 2014; Yankova and Markova, 2020).

Collavino and Giménez (2008) reported that products with a.i. imidacloprid could be applied for control of tomato leaf miner. Preliminary studies show that products with a. i. spinosad and indoxacarb are effective against the pest caterpillars (Sapkal et al., 2018; Dilip and Srinivasan., 2019; Sandeep et al., 2020; Sandeep et al., 2021), and insecticides based on deltamethrin and methomyl can be used to control adults, although the latter have a negative side effect on natural enemies and pollinators (Potting et al., 2010).

The phytopesticidal properties of plant products have a number of advantages that make them preferred in modern agriculture. They do not pose a threat to the environment or human health. This group includes the products with the active ingredient azadirachtin, extracted from the grains and the

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vegetative mass of Neem tree (*Azadirachta indica* A. Juss). Gonçalves-Gervásio and Vendramim (2007) investigated the systemic and translaminar movement in plants of aqueous Neem seed extract (*A. indica*) and its effects on moths in the laboratory. The results show that regardless of the method of application, the extract causes caterpillar mortality from 48% to 100%.

Pheromone traps are used not only to monitor but also to reduce population density. They reduce the number of the pest and limit damage to plants and fruits, especially in cultivation facilities (Vacas et al., 2011; Cocco et al., 2012, 2013; Yankova et al., 2017). Mohamedova et al. (2016) tested the attractive action of pheromone traps with different doses of pheromone.

Widespread resistance to insecticides is a major problem in agriculture, as is resistance in *T. absoluta* populations in tomatoes to some insecticides. In addition, growing public concern about pesticide safety and possible environmental damage has led to an increase in the focus on pest control products. Integrated Pest Management (IPM) has become one of the main limiting factors. The protection of human health, the environment, ecosystems and biodiversity has recently been considered important elements in the application of agricultural practices. It is done in a sustainable way through a combination of biological, cultural, mechanical, physical and chemical instruments in a way that minimizes economic, health and environmental risks (Romeh, 2019).

The aim of the study was to establish the effectiveness of a conventional and integrated plant protection scheme against the tomato leaf miner (*Tuta absoluta* Meyrick, 1917) in the cultivation of tomatoes in greenhouses.

Material and methods

The study was conducted in 2019-2020 at the "Maritsa" Vegetable Crops Research Institute, Plovdiv and greenhouses "Polymerstroy" - Plovdiv.

Plant test: For the experiment the following tomato varieties were used: Pink Rock F_1; Manusa F_1; Clarosa F_1 and Myrsini F_1.

Tomato leaf miner (Tuta absoluta Meyrick, 1917): Four readings on the caterpillars (L1-L4) of the tomato leaf miner were performed: *First* - before treatment, *Second* - 3 days after treatment, *Third* - 7 days after treatment, *Fourth* - 10 days after treatment. The effectiveness (%) was calculated by the Henderson-Tilton (1955) formula.

Method of counting: Before treating each replication, plants and leaves infested by the tomato leaf miner (*T. absoluta*) were pre-marked, noting the number of living specimens. Live caterpillars were reported on the 3rd, 7th and 10th day after treatment. Control - untreated plants. Each treatment included 4 repetitions. The total area of the experiment was 300 m^2.

Test plant protection products

First treatment scheme (conventional) - Confidor Energy OD 0.08% (a.i. imidacloprid+deltamethrin); Ampligo 150 ZC 400 ml/ha (a.i. lambda cyhalothrin+chlorantraniliprol); Coragen 20 SC 200 ml/ha (a.i. chlorantraniliprole); Exalt 25 SC 2400 ml/ha (a.i. spinetoram); Voliam Targo 063 SC 800 ml/ha (a.i. abamectin+chlorantraniliprole), Voliam Targo 063 SC 800 ml/ha (six consecutive treatments at intervals of 10 days).

Second treatment scheme (integrated) - Confidor Energy OD 0.08%; Sineis 480 SC 250 ml/ha (a.i. Spinosad); Sineis 480 SC 250 ml/ha; Voliam Targo 063 SC 800 ml/ha; Neem Azal T/S 0.3% (a.i. azadirachtin); Neem Azal T/S 0.3% (six consecutive treatments every 10 days).

Pheromone traps

The sex pheromones of the tomato leaf miner - E-3, Z-8 and Z-11-tetradecatrienyl acetate were synthesized in the Laboratory for synthesis and application of pheromones at the Federal State Budgetary Organization All-Russian Plant Quarantine Center (FGBU VNIIKR). The experiments were conducted in greenhouses with indeterminate tomato varieties on an area of 150 m^2 according to a methodology developed by FGBU VNIIKR. The reporting duration was 30 days. Dispensers containing 0.5 mg of pheromone have been submitted for joint research. The traps were placed in the greenhouse at a rate of 1 trap/20 m^2 after establishing the beginning of the flight of the tomato leaf miner, determined by signal pheromone traps with a sticky bottom type "Delta" (Russell IPM). During the study period, the dispensers and adhesive bottoms in the traps were not replaced.

At the end of the period, the infestation by the tomato leaf miner was established with pheromones (integrated production) and in the one without pheromones (conventional production). The following indicators are reported: percentage of damaged plants (5 repetitions of 10 checkered-situated plants), average number of mines/leaf (5 repetitions of 10 randomly selected leaves), and percentage of damaged fruits (5 repetitions of 10 randomly selected fruits).

A comparative analysis of the results obtained by the method of Duncan's multiple range test (1955) was made.

Results and discussion

In the conventional treatment scheme, all products included in the study showed very good biological activity against the tomato leaf miner. The highest effectiveness was reported for the product Voliam Targo 063 SC 800 ml/ha on the 7th day after treatment - 90.09%, followed by the products Coragen 20 SC 200 ml/ha - 86.61% on the 10th day after treatment and Exalt 25 SC 2400 ml/ha - 86.07% on the 7th day after treatment (Table 1). The results obtained by us for the good biological activity of the products containing a.i. chlorantraniliprole confirm the results obtained by Fanigliulo et al. (2012).

Table 1. Effectiveness of different treatment schemes against tomato leaf miner (*T. absoluta*) in tomato grown in greenhouses

Treatment/Scheme of treatment	Effectiveness (%)/Days after treatment		
	3-rd	7-th	10-th
First plot (conventional scheme)			
I-st treatment Confidor Energy OD 0.08%	52.63 c	**81.95** c	72.93 c
II-nd treatment Ampligo 150 ZC 400 ml/ha	58.82 bc	**83.33** c	73.68 c
III-rd treatment Coragen 20 SC 200 ml/ha	61.40 ab	85.94 bc	**86.61** a
IV-th treatment Exalt 25 SC 2400ml/ha	68.86 a	**86.07** ab	81.42 ab
V-th treatment Voliam Targo 063 SC 800 ml/ha	61.25 ab	**90.09** a	81.18 ab
VI-th treatment Voliam Targo 063 SC 800 ml/ha	62.50 ab	**8.20** a	79.35 bc
Second plot (integrated scheme)			
I-st treatment Confidor Energy OD 0.08%	58.87 ab	**79.44** bc	77.47 c
II-nd treatment Sineis 480 SC 250 ml/ha	52.94 bc	**83.46** ab	79.24 ab
III-rd treatment Sineis 480 SC 250 ml/ha	52.10 bc	**84.03** ab	79.68 a
IV-th treatment Voliam Targo 063 SC 800 ml/ha	64.58 a	**89.38** a	78.75 bc
V-th treatment Neem Azal T/S 0.3%	47.92 c	75.33 c	**80.26** a
VI-th treatment NeemAzal T/S 0.3%	52.28 bc	77.33 c	**78.41** bc

a, b, c - Duncan's multiple range test ($p<0.05$)

In the integrated treatment scheme the highest effectiveness was recorded in the product Voliam Targo 063 SK 800 ml/ha – 89.38% on the 7th day after treatment. The bioproduct Sineis 480 SC 250 ml/ha also demonstrated very good biological activity - 84.03% on the 7th day after treatment. The phytopesticide Neem Azal T/S 0.3% after two consecutive treatments showed very good effectiveness against the tomato leaf miner, which reached 80.26% on the 10th day of treatment (Table 1). The catch of butterflies of the tomato leaf miner in the plot with an integrated pest control system was monitored. Pheromone traps are placed according to the manufacturer's recommended scheme not only for monitoring but also for reducing the density of adults. Good attractive effect of the traps was observed up to 30 days after placement (Table 2). The results obtained in our reports confirm the ones in our previous studies about the good attractiveness of Russian pheromone traps (0.5 mg pheromone/trap) (Yankova et al., 2017).

The product Voliam Targo 063 SC at a dose of 800 ml/ha shows very good biological activity on the 7th day after treatment, which is kept until 10 days after treatment. This is due to its good systemic action. A similar effect is observed with the phytopesticide Neem Azal T/S 0.3%. It is recommended to carry out two consecutive treatments at intervals of 7-10 days to ensure good effectiveness. Both products Voliam Targo 063 SC and Neem Azal T/S have insecticidal and acaricidal action, short quarantine period, which makes them suitable for treatment during the harvest period at the end of the growing season, when the number of tomato leaf miners and the two-spotted spider mites is high. The product Confidor Energy OD 0.08% has a good contact effect, which provides high effectiveness until the 7th day after treatment. It could be applied at the beginning of the flight of the tomato leaf miner to reduce the density of the pest as soon as it appears.

Table 2. Caught butterflies of the tomato leaf miner (*T. absoluta*) in pheromone traps in an integrated scheme for the production of tomato in greenhouses

Pheromone traps	Number of butterflies caught		
	10th day	20th day	30th day
1	29	34	37
2	12	22	28
3	13	19	25
4	2	5	13
5	23	41	47
Total	79	121	150
Average	15.8	24.2	30.0

The biological activity of the plant protection products and the infestation by the pest (percentage of damaged plants, average number of mines per leaf, percentage of damaged fruits) were recorded 10 days after the last variant treatment was determined. The results of the conventional and integrated production are very close, significantly different from the control (Table 3).

Table 3. Damages caused by tomato leaf miner (*T. absoluta*) and productivity of tomato varieties grown in greenhouses at different treatment schemes

Indexes	First plot (conventional scheme)	Second plot (integrated scheme)	Control (non treated)
Tomato variety Pink Rock F_1			
Percentage of damaged plants, %	8.00	10.00	50.00
Average number of mines per leaf	1.50	1.52	4.06
Percentage of damaged fruits, %	12.00	12.00	56.00
Yield, kg/ha	76530	74500	35940
Tomato variety Manusa F_1			
Percentage of damaged plants, %	6.00	8.00	20.00
Average number of mines per leaf	1.32	1.34	2.20
Percentage of damaged fruits, %	10.00	10.00	28.00
Yield, kg/ha	92800	88650	61600
Tomato variety Clarosa F_1			
Percentage of damaged plants, %	4.00	6.00	18.00
Average number of mines per leaf	1.12	1.18	2.06
Percentage of damaged fruits, %	6.00	6.00	24.00
Yield, kg/ha	84370	85110	60240
Tomato variety Myrsini F_1			
Percentage of damaged plants, %	10.00	10.00	52.00
Average number of mines per leaf	1.74	1.76	4.12
Percentage of damaged fruits, %	14.00	14.00	58.00
Yield, kg/ha	79220	76180	38160

The percentage of damaged plants is the lowest in the conventional treatment scheme for the variety Clarosa F1 4.00%, close to this result is the reported value in the integrated scheme – 6.00%, while in the control it reaches 18.00%. The average number of mines per leaf has similar values in the conventional and integrated schemes, 1.12 and 1.18, respectively, lower than the reported value in the control 2.06. The percentage of damaged fruits in the conventional and integrated schemes is 6.00%, significantly lower than that reported in the control 24.00%. This variety has the lowest values of the reported indicators, both in the conventional scheme and in the integrated one. The Clarosa F_1 variety demonstrates a lower infestation by tomato leaf miner (*T. absoluta*) compared to the other tested varieties. The strongest infestation is observed in tomato variety Mirsini F_1, and varieties Pink Rock F_1 and Manusa F_1 are in an intermediate position (Table 3). Appropriate variety selection and successfully applied treatment schemes can ensure well-preserved tomato production.

By applying the conventional pest control scheme, the yields obtained are higher than the integrated one, with the exception of the Clarosa F_1 variety. Using the conventional scheme, the highest yield was obtained in variety Manusa F_1, exceeding the variety Clarosa F_1 by 9.1%, Mirsini F_1 with 14.6% and variety Pink Rock with 17.6%. Although the number of damaged fruits in the Manusa variety is almost twice as high as in the Clarosa F_1 variety, the higher yield is due to the higher fruit weight. The highest productivity was reported again in the Manusa F_1 variety in applying of the integrated control scheme against the tomato leaf miner. The yield is higher by 4-16% compared to other varieties. In both plant protection schemes, compared to the control, the infestation by the pest in terms of yield is most significantly affected in the varieties Pink Rock F_1 and Mirsini F_1.

Conclusion

The tested plant protection products showed very good biological activity against the tomato leaf miner (*Tuta absoluta* Meyrick, 1917). The product Voliam Targo 063 SC demonstrated the highest effectiveness used at a dose of 800 ml/ha on the seventh day after spraying in conventional and integrated treatment schemes. The percentage of damaged plants was the lowest in the variety Clarosa F_1 (8.00%), with the application of the conventional plant protection scheme. The results were similar in the integrated scheme - 10%, while in the control the degree of infestation reached 50%. The percentage of damaged fruits in both treatment schemes was 12.00%, significantly lower than in the control (56.00%). The use of pheromone traps, in addition to monitoring, has an effect on population density and the infestation of fruit by the pest. By applying the conventional scheme pest control, the yields were higher than the integrated, with the highest productivity in the variety Manusa F_1.

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