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Botanical insecticides for pest management in tomato grown in cultivation facilities

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Abstract. *An alternative to synthetic insecticides is the use of naturally occurring products, such as botanical products with insecticidal properties. Biological testing of the botanical products Krisant EC 750 ml/ha and Neem Azal T/S 0.3% was performed at the Maritza Vegetable Crops Research Institute - Plovdiv to determine their effectiveness against potato aphid (Macrosiphum euphorbiae Thomas, 1878), thrips (Thrips tabaci Lindemanla, 1889; Frankliniella occidentalis Pergande, 1895), greenhouse whitefly (Trialeurodes vaporariorum Westwood, 1856), cotton bollworm (Helicoverpa armigera Hübner, 1808), tomato leaf miner (Tuta absoluta Meyrick, 1917) and two-spotted spider mite (Tetranychus urticae Koch, 1836). These species are some of the most common economically important pests in growing tomatoes in greenhouses. The phytopesticides Neem Azal T/S and Krisant EC were applied alone and in combination. The tested plant protection products showed very good biological activity against these pests and relatively higher effectiveness over 78% shows the combined treatment.*

Keywords: phytopesticides, effectiveness, pyrethrin, azadirachtin, greenhouses

Introduction

Modern trends in organic farming require the search for alternative methods of pest control. In recent years, efforts have been focused on the use of natural plant protection products such as botanical insecticides. Many plants have insecticidal properties due to the natural alkaloids, esters, glycosides, etc. (Regnault-Roger and Philogène, 2008).

In dealing with pest management, organic farmers are challenged with the same insect pests confronting conventional farmers, however, they must rely first on a system-based use of biological, cultural, mechanical and physical practices to reduce or avoid pests' problems. When these practices fail to control pests, they need to apply biological plant protection products to their organic crops. Three major categories of insecticides widely used in organic production include products formulated with spinosad, pyrethrin and neem derivatives. These active ingredients are contained in about one third of the insecticidal products allowed for organic use (Dively et al., 2020).

Pyrethrins are extracted from dried flowers and seeds of the pyrethrum plant (*Chrysanthemum cinerariaefolium* Vis.) (*Asteraceae*). Many years, pyrethrum has been used safely and effectively as a pesticide worldwide. The flowers of this plant, which contain a mixture of fragrant esters called pyrethrins, have extremely unusual insecticidal properties. Unique in their ability to control most pests while not posing a threat to the environment, pyrethrins have been of great interest to many scientists (Casida and Quistad, 1995).

Organic formulations have the same mode of action as the conventional pyrethroid insecticides, functioning as a sodium channel modulator by disrupting the impulses along the axons of neurons, resulting in paralysis and death of the insect (Casida, 1980). Pyrethrins have broad spectrum of activity on many insects, causing a quick knockdown effect as a contact and stomach poison, but breaks down rapidly in sunlight (Isman, 2006; Jababu et al., 2016).

Products from the leaves and seeds of the Neem tree, *Azadirachta indica* A. Juss (*Meliaceae*), have been used for centuries for medical and pesticidal purposes and are currently available in various organic formulations of oils, soaps and extracts containing mainly the compound azadirachtin. In chemical composition they are limonoids and have specific antifeedant and deterrent action. Neem-based products have a very broad range of behavioral

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and physiological effects on many groups of insect pests, acting as an antifeedant, insect growth regulator, repellent, sterilant and inhibitor of oviposition (Mordue and Nisbet, 2000; Isman, 2006; Hiiesaar et al., 2009). Depending on the formulation and application method, neem constituents can also be absorbed through plant roots and leaves, providing some level of systemic activity on certain insect pests (Seljasen and Meadow, 2006).

Botanical products are promising. They affect only the target pests and are effective in very small quantities, degrade quickly and provide a safe living environment and are free of residues in food. When they are included in integrated pest control programs, the botanical pesticides can significantly reduce the use of conventional pesticides as they can be used in rotation or in combination with other insecticides. Thus, it is possible to reduce the overall use of chemical insecticides and slow down the development of resistance in pest populations (Khater, 2012; Lengai et al., 2020; Toan et al., 2021).

The most widely distributed and used commercial botanical pesticides include pyrethrum and neem products (Grzywacz et al., 2014). Plant pesticides are the subject of numerous laboratory tests (Morgan, 2009). Nevertheless, there are very few studies that present results of their practical use and there is a great lack of comparisons of the biological effectiveness of several products on different pest species.

The aim of the study is to determine the biological activity of the phytopesticides Krisant EC 750 ml/ha and Neem Azal T/S 0.3% applied alone and in combination against some economically important pests in growing tomato in greenhouses.

Material and methods

The experiments were conducted during the period 2020-2021 at the „Maritsa" Vegetable Crops Research Institute - Plovdiv. Standard entomological methods have been applied to establish the effectiveness of two botanical plant protection products against some economically important pests in tomato variety Pink Rock F1 grown in greenhouses.

Test pests: potato aphid (*Macrosiphum euphorbiae* Thomas, 1878), thrips (*Thrips tabaci* Lindemanla, 1889; *Frankliniella occidentalis* Pergande, 1895), greenhouse whitefly (*Trialeurodes vaporariorum* Westwood, 1856), cotton bollworm (*Helicoverpa armigera* Hübner, 1808), tomato leaf miner (*Tuta absoluta* Meyrick, 1917) and two-spotted spider mite (*Tetranychus urticae* Koch, 1836). Test plant protection products:

Krisant EC 750 ml/ha - insecticide based on natural pyrethrins of plant origin. Product of the company Sipcam Iberia (Spain).

Neem Azal T/S 0.3% – phytopesticide from the Indian Neem-tree (*Meliaceae: Azadirachta indica* A. Juss.), produced by Trifolio – M GmbH, Germany, active ingredient 1% azadirachtin A + 0.5% azadirachtin B, C, D and 2.5% Neem-substance.

Plants naturally infested by pests have been treated. The number of live specimens on pre-marked plants and leaves before and at intervals (days) after treatment was recorded. Effectiveness (E%) was calculated by the formula of Henderson-Tilton (1955) and Abbott (1925) for greenhouse whitefly larvae:

$$E\% = \left(1 - \frac{TaxCb}{TbxCa}\right).100$$

E – effectiveness (%); *Ta* - number of live individuals in the variant after treatment; *Tb* - number of live individuals in the variant before treatment; *Ca* - number of live individuals in the control after treatment; *Cb* - number of live individuals in the control before treatment.

$$E\% = \left(\frac{Pv - Pk}{100 - Pk}\right).100$$

E – effectiveness (%); *Pv* - mortality % in the variant; *Pk* - mortality % in the control.

The determination of the effectiveness of the tested plant protection products was in a single treatment. Control - untreated plants. A comparative analysis of the results obtained by the method of Duncan's multiple range test (1955) was made.

Results and discussion

According to the results obtained in the experiments performed on Pink Rock F_1 tomato variety grown in greenhouses, it is obvious that the product Krisant EC at a dose of 750 ml/ha has a very good initial effectiveness against aphids - 81.44% on the 3rd day after treatment. At the end of the reports on the 14th day after treatment, the effectiveness significantly decreased - 56.69%. This is probably due to the good contact action of the product Krisant EC, which belongs to the group of pyrethrins. The phytopesticide Neem Azal T/S in a concentration of 0.3% shows good effectiveness against potato aphid (*Macrosiphum euphorbiae* Thomas, 1878) on the 5th day after treatment - 81.20%. The results obtained by us for the good aphicidal activity of the products Krisant EC and Neem Azal T/S confirm those obtained in previous studies (Yankova and Markova, 2016; Yankova and Markova, 2019). The combination of products Krisant EC 750 ml/ha + Neem Azal T/S 0.3% has the best biological activity against this pest, the effectiveness reaches a maximum value of 88.14% on the 5th day after treatment. In this variant, good initial activity was observed (86.88% on the 3rd day after treatment) and relatively good efficacy was maintained 14 days after treatment (68.70%), which is significantly higher than in individual treatment with Krisant EC and Neem Azal T/S (Table 1).

Table 1. Effectiveness of the botanical insecticides Krisant EC and Neem Azal T/S towards some economically important pests in tomato grown in greenhouses

Variant	Effectiveness (%)	Days after treatment					
		1	3	5	7	10	14
Aphids							
Krisant EC 750 ml/ha	**MIN**	56.67	65.00	70.22	64.93	48.16	45.89
	MAX	82.22	91.11	89.90	82.22	76.19	72.41
	Average	69.30 a	**81.44** bc	78.69 c	72.30 c	63.66 c	56.69 c
	SD	12.26	11.37	8.19	7.63	11.82	12.76
Neem Azal T/S 0.3%	**MIN**	42.40	64.19	66.63	70.67	46.24	49.49
	MAX	73.33	85.33	88.27	84.00	73.33	64.80
	Average	56.37 c	77.99 c	**81.20** bc	74.34 bc	64.27 c	59.24 c
	SD	12.96	9.56	9.84	6.45	12.41	6.77
Krisant EC 750 ml/ha + Neem Azal T/S 0.3%	**MIN**	64.20	74.56	77.20	73.82	68.23	62.12
	MAX	82.35	91.85	93.58	91.53	87.39	78.09
	Average	71.44 a	86.88 a	**88.14** a	80.28 a	76.43 a	68.70 a
	SD	8.48	8.25	7.44	8.14	7.99	6.96
Thrips							
Krisant EC 750 ml/ha	**MIN**	53.06	67.19	72.58	67.86	50.00	43.42
	MAX	100.00	100.00	100.00	100.00	80.56	62.50
	Average	68.98 a	82.08 ab	**85.60** ab	79.84 ab	63.13 c	52.05 c
	SD	21.07	15.27	11.77	14.48	12.78	7.91
Neem Azal T/S 0.3%	**MIN**	46.64	67.19	67.52	63.27	33.33	33.33
	MAX	66.67	100.00	100.00	100.00	80.56	68.18
	Average	53.58 c	77.65 c	**81.53** c	78.45 c	60.59 c	58.06 ab
	SD	8.92	15.36	15.17	16.03	19.77	16.54
Krisant EC 750 ml/ha + Neem Azal T/S 0.3%	**MIN**	58.38	70.88	74.40	67.73	55.56	33.33
	MAX	83.33	100.00	100.00	100.00	100.00	73.33
	Average	69.95 a	85.53 a	**88.84** ab	80.47 ab	74.72 a	61.99 a
	SD	10.42	12.48	13.16	14.50	20.57	19.17
Greenhouse whitefly (adults)							
Krisant EC 750 ml/ha	**MIN**	63.34	73.96	77.34	70.64	49.01	41.67
	MAX	84.72	88.25	92.36	88.00	89.92	89.97
	Average	73.99 a	80.60 a	**83.26** a	77.73 a	69.52 ab	60.74 ab
	SD	11.38	7.50	6.41	7.44	16.88	20.91
Neem Azal T/S 0.3%	**MIN**	50.31	41.67	68.18	25.33	16.67	19.54
	MAX	64.80	85.33	80.75	77.27	70.67	64.80
	Average	56.89 c	65.38 c	**73.97** c	58.48 c	53.53 c	45.90 c
	SD	7.18	18.01	5.22	22.83	25.08	20.11
Krisant EC 750 ml/ha + Neem Azal T/S 0.3%	**MIN**	66.00	75.43	75.21	72.45	69.76	62.12
	MAX	83.82	91.85	91.85	85.88	87.39	78.09
	Average	76.05 a	83.24 a	**84.66** a	78.24 a	75.79 a	68.70 a
	SD	7.86	8.86	7.01	5.95	8.11	6.96

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

Thrips causes both direct damage and is also a carrier of the Tomato Spotted Wilt Virus (TSWV). Control of these pests is difficult due to the high reproductive potential and the rapid emergence of resistance in populations due to intensive insecticide treatments in greenhouses (Gao et al., 2012). The same trend like in aphids is observed in the results reported in the conducted treatments against tomato thrips in greenhouses. The combination Krisant EC 750 ml/ha + Neem Azal T/S 0.3% is with the best effectiveness, as the maximum value of effectiveness is reported on the 5th day after treatment 88.84%, followed by the variants Krisant EC 750 ml/ha - 85.60% and Neem Azal T/S 0.3% - 81.53% (Table 1).

Against the greenhouse whitefly (*Trialeurodes vaporariorum* Westwood, 1856) adults the variant with combined treatment Krisant EC 750 ml/ha + Neem Azal T/S 0.3% - 84.66% on the 5th day after treatment was also with the best effectiveness against adult individuals. In this variant, good effectiveness was reported against the larvae of this pest - 72.02% on the 7th day after treatment. In the other variants, the reported biological activity against the larvae is unsatisfactory (Tables 1 and 2).

Table 2. Effectiveness of the botanical insecticides Krisant EC and Neem Azal T/S towards the larvae (L) of the greenhouse whitefly in tomato grown in greenhouses

Variant	Total number L average per leaf	Population status		Effectiveness (%)
		Average number dead	Death (%)	
1 day after treatment				
Krisant EC 750 ml/ha	45.00	28.00	62.22	62.22
Neem Azal T/S 0.3%	57.00	32.00	56.14	56.14
Krisant EC 750 ml/ha+Neem Azal T/S 0.3%	48.00	31.00	64.58	64.58
Control	42.00	0.00	0.00	-
7 day after treatment				
Krisant EC 750 ml/ha	51.00	33.00	64.70	63.98
Neem Azal T/C 0.3%	60.00	39.00	65.00	64.28
Krisant EC 750 ml/ha+Neem Azal T/S 0.3%	62.00	45.00	72.58	**72.02**
Control	50.00	1.00	2.00	-
14 day after treatment				
Krisant EC 750 ml/ha	58.00	32.00	55.17	55.17
Neem Azal T/C 0.3%	62.00	36.00	58.06	58.06
Krisant EC 750 ml/ha+Neem Azal T/S 0.3%	63.00	38.00	60.32	60.32
Control	52.00	0.00	0.00	-

In recent years, the tomato leaf miner (*Tuta absoluta* Meyrick, 1917) has created serious problems in greenhouse tomato growing. Resistance to used insecticides is often observed in populations, which necessitates the search for alternatives. One approach is the use of botanical insecticides. (Gharekhani and Salek-Ebrahimi, 2014). In our experiments, with the best effectiveness against the larvae of the tomato leaf miner is the variant with combined treatment Krisant EC 750 ml/ha + Neem Azal T/S 0.3% - 84.21% in the interval 7th – 14th day after treatment, followed by Neem Azal T/S 0.3% (82.35% on the 7th day after treatment) and Krisant EC 750 ml/ha (72.22% on the 7th day after treatment). The mixing of the two botanical products combines the contact action of pyrethrum and the systemic action of azadirachtin, in which good biological activity is observed, which persists over 80% for 14 days after treatment (Table 3).

Table 3. Effectiveness of the botanical insecticides Krisant EC and Neem Azal T/S towards the larvae of tomato leaf miner (Tuta absoluta Meyrick, 1917)

Variant	Effectiveness (%)	Days after treatment		
		3	7	14
Krisant EC 750 ml/ha	MIN	40.00	53.87	25.00
	MAX	66.67	100.00	100.00
	Average	55.56 bc	**72.22** c	61.11 c
	SD	12.86	20.54	30.66
Neem Azal T/S 0.3%	MIN	40.00	60.00	60.00
	MAX	66.67	100.00 a	100.00
	Average	52.94 c	**82.35** a	76.47 ab
	SD	11.09	20.74	18.85
Krisant EC 750 ml/ha+Neem Azal T/S 0.3%	MIN	50.00	75.00	73.52
	MAX	83.33	100.00	100.00
	Average	63.16 a	**84.21** a	**84.21** a
	SD	14.20	10.92	11.29

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

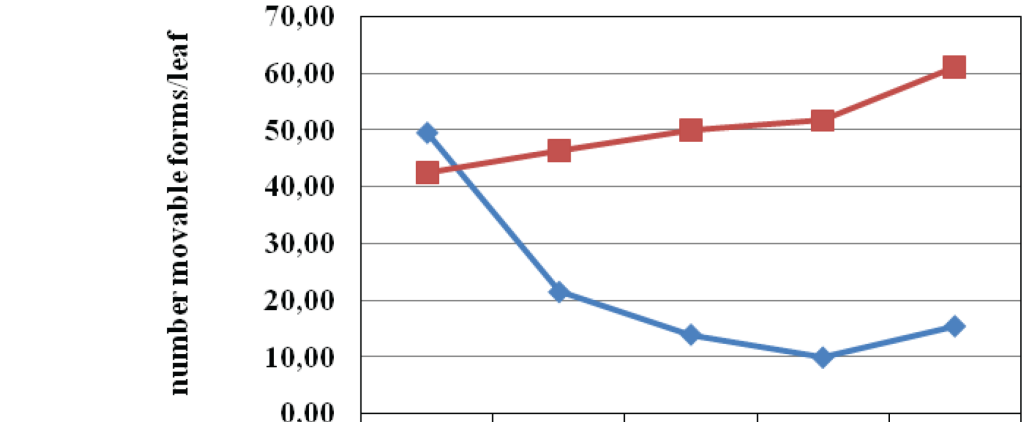
The best effectiveness against the larvae of the cotton bollworm (*Helicoverpa armigera* Hübner, 1808) is the variant Krisant EC 750 ml/ha + Neem Azal T/S 0.3% - 82.86%, followed by Neem Azal T/S 0.3% -78.57% and Krisant EC 750 ml/ha - 62.73% (Table 4).

Table 4. Effectiveness of the botanical insecticides Krisant EC and Neem Azal T/S towards the larvae of cotton bollworm (Helicoverpa armigera Hübner, 1808)

Variant	Effectiveness %	Days after treatment		
		3	7	14
Krisant EC 750 ml/ha	MIN	26.32	27.08	52.60
	MAX	60.00	66.67	73.33
	Average	47.83 c	54.69 c	**62.73 c**
	SD	15.52	18.82	9.13
Neem Azal T/S 0.3%	MIN	49.08	51.40	63.96
	MAX	88.10	88.10	88.89
	Average	64.29 a	72.37 a	**78.57 a**
	SD	16.68	16.73	12.08
Krisant EC 750 ml/ha + Neem Azal T/S 0.3%	MIN	46.67	54.28	75.29
	MAX	88.10	88.10	88.89
	Average	62.29 a	77.26 a	**82.86 a**
	SD	18.05	15.48	6.70

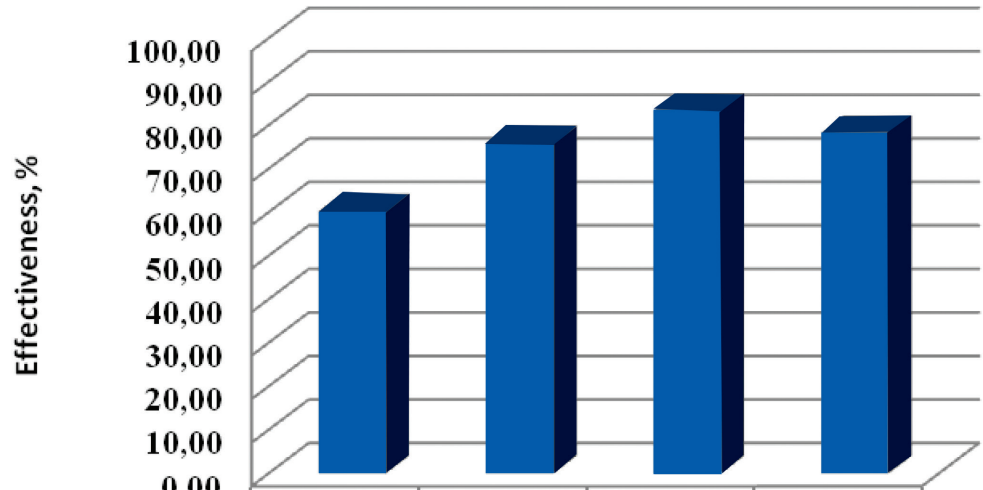
a, b, c … – Duncan's multiple range test ($p < 0.05$)

The botanical product Neem Azal T/S in concentration of 0.3% has both good insecticidal action and it is also a good acaricide. The experiments showed very good biological activity of Neem Azal T/S against the mobile forms of the two-spotted spider mite on the 7th day after treatment - 83.41% (Figures 1 and 2).



days after treatment	before	1	3	7	14
Neem Azal T/S 0,3%	49,50	21,50	14,00	10,00	15,50
Control	42,50	46,50	50,00	51,75	61,25

Fugure 1. Status of the two-spotted spider mite populatiuon after treatment with Neem Azal T/S 0.3%



days after treatment	1	3	7	14
Neem Azal T/S 0,3%	60,30	75,96	83,41	78,27

Figure 2. Effectiveness of the product Neem Azal T/S towards two-spotted spider mite

Most botanical pesticides are used to control insect pests and many studies have been focused mainly on the opportunities they provide (Isman, 2014; Isman and Grieneisen, 2014). Our results confirm the data established by Dively et al. (2020) for a wide range of action against various pests of products from the botanical insecticides group. Their studies also included the two active substances pyrethrum and azadirachtin, as well as the combination between them showing good insecticidal activity. The use of phytopesticides is an alternative to the conventional chemical insecticides to control pests in greenhouse tomato growing.

Conclusion

The botanical products Krisant EC 750 ml/ha, Neem Azal T/S 0.3% and the combination Krisant EC 750 ml/ha + Neem Azal T/S 0.3% have very good effectiveness against

potato aphid, thrips and greenhouse whitefly (adults). The phytopesticide Neem Azal T/S 0.3%, as well as the combination Krisant EC 750 ml/ha + Neem Azal T/S 0.3% are with good biological activity against the tomato leaf miner and the cotton bollworm. The combination Krisant EC 750 ml/ha + Neem Azal T/S 0.3% is with the best effectiveness against the economically important pests included in the study in greenhouse tomato growing. The organic product Neem Azal T/S 0.3% has not only good insecticidal action, but is also a good acaricide.

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