AGRICULTURAL SCIENCE AND TECHNOLOGY, VOL. 13, No 4, pp 389-394, 2021
Published by Faculty of Agriculture, Trakia University, Bulgaria
ISSN 1313-8820 (print)
ISSN 1314-412X (online)
http://www.agriscitech.eu
DOI: 10.15547/ast.2021.04.063

Possibilities for integrated control of the cotton bollworm (*Helicoverpa armigera* Hübner, 1808) in the growing tomato in greenhouses

R. Mineva[1]*, V. Yankova[2], N. Valchev[1]

[1]Department of Plant Production, Faculty of Agriculture, Trakia University, 6000 Stara Zagora, Bulgaria
[2]Maritsa Vegetable Crops Research Institute, 32 Brezovsko shose Str., 4003 Plovdiv, Bulgaria

(Manuscript received 20 June 2021; accepted for publication 11 October 2021)

Abstract. *In recent years, there has been a significant increase in the number of cotton bollworm (Helicoverpa armigera Hb., 1808) due to changing climatic conditions, the covert life cycle of caterpillars and the formation of resistance in the populations to some of the commonly used insecticides. Experiments with tomato variety Pink Rock F_1 grown in greenhouses to determine the biological activity of some products for plant protection against cotton bollworm were conducted at the "Maritsa" Vegetable Crops Research Institute - Plovdiv. The bioproducts Rapax, Dipel 2X, Helicovex, Neem Azal T/S and Sineis 480 SC have good effectiveness >77% towards cotton bollworm in the interval 7-14 days after treatment. The tested insecticides Lanate 25 WP, Coragen 20 SC 200 ml/ha, Exalt 25 SC, Voliam Targo 063 SC, Ampligo 150 ZC and Affirm 095 SG show very good biological activity (E>84%) 7-14 days after treatment.*

Keywords: bioproducts, insecticides, *Helicoverpa armigera*, Integrated Pest Management, tomato

Introduction

Tomato is the main greenhouse crop for most countries in the world, as well as for Bulgaria. They are attacked by many pests during the vegetation period. The cotton bollworm (*Helicoverpa armigera* Hübner Lepidoptera: Noctuidae) has become one of the main pests of tomato in recent years (Radonjić and Hrnčić, 2012). Caterpillars cause serious damage, especially to the reproductive organs, although vegetative organs can also be attacked (www.eppo.org). Serious damage has been reported in Europe, especially in the warmer years (Lammers and MacLeod, 2007). Radonjić and Hrnčić (2012) found from 26% to 32% damaged tomato fruits in different years. In severe cases of infestation, more than 80% of fruits are damaged (http://agropedia.iitk.ac.in/content/tomato-fruit-borer). Tomato is one of the crops preferred by the pests. Losses caused by cotton bollworm can reach 50% (Chakraborty et al., 2011).

The control of *H. armigera* is difficult. Studies have been conducted to determine the potential uses of pheromone traps for more accurate determination of the treatment time (Nyambo, 1989; Guerrero et al., 2014; Cherif and Grissa-Lebdi, 2017). In addition to monitoring, pheromone traps can also be used for mass capture, which significantly reduces the density of the pest (Shah et al., 2017).

Excessive use of insecticides contributes to the emergence of resistance in pest populations (Duraimurugan and Regupathy, 2005; Jousen et al., 2012; Hussain et al., 2014). Presence of insecticide resistance has been most widely documented for synthetic pyrethroids, but in some areas *H. armigera* has also developed resistance to other insecticides, i.e. to endosulfan, carbamates and organophosphates (Kranthi et al., 2001; Martin et al., 2003; Lammers and MacLeod, 2007). The increasing problems concerning the resistance means that it is necessary to develop management strategies that are less dependent on chemical insecticides and/or less conducive to the development of sustainability of the control measures used (Karim et al., 2000). Despite the infestation by *H. armigera*, it is still possible for farmers to adopt pest control measures that have less impact on the environment in accordance with the standard principles of the Integrated Pest Management (IPM) philosophy (Pomari-Fernandes et al., 2015).

Bacillus thuringiensis subsp. *kurstaki* suppresses the cotton bollworm population and can be successfully used for control in three consecutive treatments (Broza and Sneh, 1994). *Helicoverpa armigera nucleopolyhedrovirus* (HaNPV) isolates effective against *H. armigera* have been identified in experiments (Jeyarani et al., 2010). *Helicoverpa armigera nucleopolyhedrovirus* is highly pathogenic to the cotton bollworm and can be used to control this pest as a bioinsecticide (Chaeychomsri et al., 2015).

*e-mail: r.mineva@abv.bg

The aim of the study is to establish the effectiveness of various biological and chemical plant protection products against cotton bollworm (*Helicoverpa* armigera Hübner, 1808) in the growing tomato in greenhouses with a view to include them in integrated plant protection systems for pest control.

Material and methods

Experiments for determining the biological activity of some plant protection products (Table 1**)** against cotton bollworm (*Helicoverpa armigera* Hübner) in tomato variety Pink Rock F_1 grown in greenhouses were performed at the "Maritsa" Vegetable Crops Research Institute, Plovdiv.

Table 1. Plant protection products tested for effectiveness against cotton bollworm (*H. armigera* Hübner)

Plant protection products	Active ingredient	Dose/ Concentration
Bioproducts		
Rapax	*Bacillus thuringiensis* subsp. *kurstaki* strain EG 2348	1000 ml/ha
Dipel 2X	*Bacillus thuringiensis* var. *kurstaki* strain ABTS	1000 g/ha
Helicovex	*Helicoverpa armigera nucleopolyhedrovirus Hear NVP, DSMZ-BV0003*	200 ml/ha
Neem Azal T/S	azadirachtin	0.3%
Sineis 480 SK	spinosad	300 ml/ha
Chemical insecticides		
Lanate 25 WP	methomyl	1000 g/ha
Coragen 20 SC	chlorantraniliprole	200 ml/ha
Exalt 25 SC	spinetoram	2400 ml/ha
Voliam Targo 063 SC	abamectin+chlorantraniliprole	800 ml/ha
Ampligo 150 ZC	lambda cyhalothrin+chlorantraniliprole	400 ml/ha
Affirm 095 SG	emamectin benzoate	1500 g/ha

Pre-marked plants and fruits infested by cotton bollworm (*H. armigera*) were treated. Four reports were made: *First* - before treatment, *Second* - 3 days after treatment, *Third* - 7 days after treatment, *Fourth* - 14 days after treatment. The experiment is in 4 replications, the readings were performed on 10 fruits per replication, randomly selected from a variant. Control - untreated plants. The effectiveness (%) was calculated by the Henderson-Tilton (1955) formula. The infestation on the fruits (% of damaged fruits) was determined according to variants, 7 days after the treatments. The experiments were conducted in unheated greenhouses under natural infestation by the pest, in four replications.

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

Results and discussion

Successful control on the cotton bollworm (*Helicoverpa armigera* Hübner) requires a complex of activities. IPM occupies an important place in modern vegetable production. In this regard, attempts have been made to determine the biological activity of five bioproducts and six chemical insecticides to control cotton bollworm. The obtained results will give information about the possibilities for their combination in the different technological directions.

Experiments with included biological and chemical plant protection products showed a relatively higher effectiveness (>84%) for chemical insecticides, which confirms the trends observed until now (Table 2). These products also had better initial effect, with an efficiency ranging from 66.67% to 79.52% on the third day after treatment, while organic products showed a slower effect at an effectiveness of 57.62% to 78.48%. With the highest value of effectiveness 90.42% on the 7th day after treatment was the product Coragen 20 SC 200 ml/ha, followed by Lanate 25 WP 1000 g/ha (E=88.10% on the 14th day after treatment) and Exalt 25 SC 2400 ml/ha (E=87.86 on the 14th day after treatment).

The development of resistance in *H. armigera* has forced researchers to look for alternative control measures. Studies have been performed to determine the insecticidal efficacy of formulations of *Azadirachta indica* Juss., nucleopolyhedrovirus (NPV) and new insecticides (chlorantraniliprole) against the 2nd age of cotton bollworm caterpillars collected from different geographical locations (Wakil et al., 2012). The results show that the extract from Neem reduces the attack of tomatoes by *H. armigera* (Houessou et al., 2018). Products based on Neem, applied alone or alternately with *Beauveria bassiana*, are an alternative application for the control of cotton bollworm in tomato cultivation (Mustafiz et al., 2015). In our study the highest efficiency in bioproducts was reported in Sineis 480 SC 300 ml/ha 83.04% on the 7th day after treatment, followed by Dipel 2X 1000 g/ha (E=81.67% on the 7th day after treatment) and Rapax 1000 ml/ha (E=81.43% on the 14th day after treatment). Our results for the good biological activity of spinozad and *Bacillus thuringiensis* confirm the data by Vojoudi et al. (2011) and Bouslama et al. (2020). These products are an alternative and perspective way to limit the infestation. In the bioproduct Neem Azal T/S 0.3%, the lowest efficiency of 77.13% was reported on the 14th day after treatment. Although with lower effectiveness than chemical products, the reported biological activity of the tested organic products is good >77%, which gives a reason for their successful

inclusion in the integrated plant protection schemes for cotton bollworm control (Table 2). Changes in the population density of cotton bollworm caterpillars were observed, and a relative increase was recorded in the control during the experimental period (Table 3). The application of suitable products with good biological activity ensures a well-preserved tomato production. The emphasis should be on the efficient inclusion of bioproducts in plant protection treatments.

Table 2. Effectiveness of plant protection products against cotton bollworm (*H. armigera* Hübner) in tomato grown in greenhouses

Variant	Effectiveness, %	Days after treatment					
		3		7		14	
Biological products for plant protection							
Rapax, 1000 ml/ha	Average	57.62	c	77.20	bc	81.43	bc
	max	73.33		83.33		90.48	
	min	50.00		73.33		73.33	
Dipel 2X, 1000 g/ha	Average	67.29	bc	81.67	ab	78.69	c
	max	100.00		100.00		100.00	
	min	40.00		66.67		60.00	
Helicovex, 200 ml/ha	Average	59.64	c	69.46	c	80.36	bc
	max	71.43		80.00		100.00	
	min	50.00		57.14		71.43	
Neem Azal T/S, 0.3%	Average	60.00	c	75.63	bc	77.13	c
	max	73.33		100.00		100.00	
	min	50.00		62.50		57.14	
Sineis 480 SC, 300 ml/ha	Average	78.48	a	83.04	ab	81.58	bc
	max	100.00		100.00		100.00	
	min	62.50		75.00		62.50	
Chemical products for plant protection							
Lanate 25 WP, 1000 g/ha	Average	78.33	a	83.50	ab	88.10	a
	max	100.00		100.00		100.00	
	min	66.67		66.67		66.67	
Coragen 20 SC, 200 ml/ha	Average	81.46	a	90.42	a	80.20	bc
	max	100.00		100.00		88.89	
	min	62.50		75.00		73.33	
Exalt 25 SC, 2400ml/ha	Average	79.52	a	87.26	a	87.86	a
	max	100.00		100.00		100.00	
	min	66.67		80.00		71.43	
Voliam Targo 063 SC, 800 ml/ha	Average	75.15	ab	80.74	ab	84.67	ab
	max	100.00		100.00		100.00	
	min	62.50		62.50		62.50	
Ampligo 150 ZC, 400 ml/ha	Average	76.04	a	81.46	ab	84.97	ab
	max	100.00		100.00		100.00	
	min	62.50		62.50		62.50	
Affirm 095 SG, 1500 g/ha	Average	66.67	bc	84.17	ab	82.54	bc
	max	100.00		100.00		100.00	
	min	50.00		66.67		66.67	

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

The lowest percentage of damaged fruits from the cotton bollworm 3.33% was reported in the treatments Lanate 25 WP 1000 g/ha, Coragen 20 SC 200 ml/ha, Exalt 25 SC 2400 ml/ha and Dipel 2X 1000 g/ha at percentage of the infested fruits in the control 46.67%. This indicator is with the highest values in the treatment – Neem Azal T/S 0.3%, 13.33% damaged fruits (Table 4).

Table 3. Population density of cotton bollworm (*H. armigera* Hübner) in tomato grown in greenhouses

Variant	Number of caterpillars	Before treatment	Days after treatment		
			3	7	14
Biological products for plant protection					
Rapax, 1000 ml/ha	Average	6.00	2.75	1.50	1.25
	max	8.00	4.00	2.00	2.00
	min	3.00	1.00	1.00	1.00
	SD	2.16	1.26	0.58	0.50
Dipel 2X, 1000 g/ha	Average	5.00	1.75	1.00	1.25
	max	8.00	3.00	2.00	2.00
	min	3.00	0.00	0.00	0.00
	SD	2.16	1.50	0.82	0.96
Helicovex, 200 ml/ha	Average	5.50	2.25	2.00	1.50
	max	7.00	3.00	3.00	3.00
	min	4.00	2.00	1.00	0.00
	SD	1.73	0.50	1.15	1.29
Neem Azal T/S, 0.3%	Average	5.75	2.50	1.75	1.75
	max	8.00	4.00	3.00	3.00
	min	3.00	1.00	0.00	0.00
	SD	2.06	1.29	1.26	1.50
Sineis 480 SC, 300 ml/ha	Average	5.50	1.50	1.25	1.50
	max	8.00	3.00	2.00	3.00
	min	2.00	0.00	0.00	0.00
	SD	2.65	1.29	0.96	1.29
Chemical products for plant protection					
Lanate 25 WP, 1000 g/ha	Average	5.00	1.25	1.00	0.75
	max	6.00	2.00	2.00	2.00
	min	3.00	0.00	0.00	0.00
	SD	1.41	0.96	0.82	0.96
Coragen 20 SC, 200 ml/ha	Average	5.50	1.25	0.75	1.25
	max	8.00	3.00	2.00	2.00
	min	3.00	0.00	0.00	1.00
	SD	2.08	1.26	0.96	0.50
Exalt 25 SC, 2400 ml/ha	Average	5.75	1.50	1.00	1.00
	max	8.00	2.00	2.00	2.00
	min	2.00	0.00	0.00	0.00
	SD	2.63	1.00	0.82	1.15
Voliam Targo 063 SC, 800 ml/ha	Average	6.00	1.75	1.50	1.25
	max	8.00	3.00	3.00	3.00
	min	3.00	0.00	0.00	0.00
	SD	2.16	1.26	1.29	1.26
Ampligo 150 ZC, 400 ml/ha	Average	6.25	1.75	1.50	1.25
	max	8.00	3.00	3.00	3.00
	min	3.00	0.00	0.00	0.00
	SD	2.36	1.26	1.29	1.26
Affirm 095 SG, 1500 g/ha	Average	5.25	2.00	1.00	1.25
	max	6.00	3.00	2.00	2.00
	min	3.00	0.00	0.00	0.00
	SD	1.50	1.41	0.82	0.96
Control	Average	5.25	5.50	5.75	6.25
	max	7.00	7.00	7.00	7.00
	min	4.00	4.00	5.00	5.00
	SD	1.50	1.29	0.96	0.96

Table 4. Damages on the fruits caused by cotton bollworm (*H. armigera* Hübner)

Variants (Plant protection products)	Number of recorded fruits	Number of damaged fruits	% damaged fruits
Bioproducts			
Rapax - 1000 ml/ha	30	2	6.67
Dipel 2X - 1000 g/ha	30	1	3.33
Helicovex - 200 ml/ha	30	2	6.67
Neem Azal T/S 0.3%	30	4	13.33
Sineis 480 SC - 300 ml/ha	30	2	6.67
Chemical insecticides			
Lanate 25 WP - 1000 g/ha	30	1	3.33
Coragen 20 SC - 200 ml/ha	30	1	3.33
Exalt 25 SC - 2400 ml/ha	30	1	3.33
Voliam Targo 063 SC - 800 ml/ha	30	3	10.00
Ampligo 150 ZC - 400 ml/ha	30	2	6.67
Affirm 095 S - 1500 g/ha	30	2	6.67
Control (untreated)	30	14	46.67

The products included in this study demonstrate very good biological activity against cotton bollworm. Most of them are effective for control of other pests and have a wider range of action, which allows them to be used successfully to control several species when they occur simultaneously, such as Lanate 25 WP, Coragen 20 SC, Exalt 25 SC, Sineis 480 SC, Voliam Targo 063 SC, Ampligo 150 ZC and Neem Azal T/S. In this way, the number of treatments can be reduced and the risk of pesticide contamination and the emergence of resistance can be reduced. The good effectiveness of organic products allows them to be used not only for organic production, but also for integrated, by including them in rotational treatments with chemical insecticides and limiting their intensive use. In this way an integrated production of tomato in greenhouses will be ensured and it will be well protected, according to the requirements of the EU Directive on integrated pest management in agricultural crops (Directive 2009/128/EC) and Regulation No. 9/2021 for integrated production.

Conclusion

Very good effectiveness (>84%) of the insecticides Lanate 25 WP 1000 g/ha, Coragen 20 SC 200 ml/ha, Exalt 25 SC 2400 ml/ha, Voliam Targo 063 SC 800 ml/ha, Ampligo 150 ZC 400 ml/ha and Affirm 095 SG 1500 g/ha to the cotton bollworm (*Helicoverpa armigera* Hübner) was established. Good effectiveness (>77%) of the bioproducts Rapax 1000 ml/ha, Dipel 2X 1000 g/ha, Helicovex 200 ml/ha, Neem Azal T/S 0.3% and Sineis 480 SC 300 ml/ha to the cotton bollworm (*Helicoverpa armigera* Hübner) was also found. The assessment of the biological activity of the tested plant protection products allows for effective integrated control of this pest, as the plant protection products can be applied in a rotary manner depending on the phenophase of the culture, population density and stage of development of the pest.

References

Bouslama T, Chaieb I, Rhouma A and Laarif A, 2020. Evaluation of a *Bacillus thuringiensis* isolate-based formulation against the pod borer, *Helicoverpa armigera* Hübner (Lepidoptera:Noctuidae). Egyptian Journal of Biological Pest Control, 30, 1-7. https://doi.org/10.1186/s41938-020-00218-z

Broza M and Sneh B, 1994. *Bacillus thuringiensis* spp. *kurstaki* as an effective control agent of lepidopteran pests in tomato fields in Israel. Journal of Economic Entomology, 923-928. https://doi.org/10.1093/jee/87.4.923

Chaeychomsri S, Chaeychomsri W, Ikeda M and Kobayashi M, 2015. Characterization of the *Helicoverpa Armigera* nucleopolyhedrovirus during serial passage in cell culture. Journal of Advanced Agricultural Technologies, 2, 63-70. doi:10.12720/joaat.2.1.63-70

Chakraborty K, Santosh R and Chakravarthy AK, 2011. Incidence and abundance of tomato fruit borer, *Helicoverpa armigera* (Hubner) in relation to the time of cultivation in the northern parts of West Bengal, India. Current Biotica, 5, 91-97.

Cherif A and Grissa-Lebdi K, 2017. Monitoring of four noctuidae species with pheromone traps and chemical control of *Helicoverpa armigera* (Hubner 1808) in Tunisian tomato open field crops. Journal of new sciences, Agriculture and Biotechnology, 42, 2278-2289.

Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides. OJ L 309, 24.11.2009, p. 71.

Duncan D, 1955. Multiple range and multiple F-test. Biometrics, 11, 1-42.

Duraimurugan P and Regupathy A, 2005. Synthetic pyrethroid resistance in field strains of *Helicoverpa armigera* (Hubner). American Journal of Applied Sciences, 2, 1146-1149.

Guerrero S, Brambila J and Meagher RL, 2014. Efficacies

of four pheromone-baited traps in capturing male Helicoverpa (Lepidoptera: Noctuidae) moths in northern Florida. Florida Entomologist, 1671-1678.
https://doi.org/10.1653/024.097.0441

Henderson CF and Tilton EW, 1955. Tests with acaricides against the brow wheat mite. Journal of Economic Entomology, 48, 157-161. https://doi.org/10.1093/jee/48.2.157

Houessou E, Togbe CE, Logbo J and Zannou-Boukari E, 2018. Efficacy of neem extracts in the control of tomato insect pest *Helicoverpa armigera* in Southern Benin. Journal of Chemical, Biological and Physical Sciences, 89, 611-618.

Hussain D, Saleem HM, Saleem M and Abbas M, 2014. Monitoring of Insecticides Resistance in Field Populations of *Helicoverpa armigera* (Hub.)(Lepidoptera:Noctuidae). Journal of Entomology and Zoology Studies, *2*, 01-08.

Jeyarani S, Sathiah N and Karuppuchamy P, 2010. Field efficacy of *Helicoverpa armigera* nucleopolyhedrovirus isolates against *H. armigera* (Hubner) (Lepidoptera:Noctuidae) on cotton and chickpea in Tamil Nadu. Plant Protect. Sci., 46, 116-122. doi:10.17221/30/2009-PPS

Jousen N, Agnolet S, Lorenz S, Schone SE, Ellinger R, Schneider B and Heckel DG, 2012. Resistance of Australian *Helicoverpa armigera* to fenvalerate is due to the chimeric P450 enzyme CYP337B3. Proceedings of the National Academy of Sciences, 109, 15206-15211. doi:10.1073/pnas.1202047109

Karim S, 2000. Management of *Helicoverpa armigera*: A Review and Prospectus for Pakistan. Pakistan Journal of Biological Sciences, 3, 1213-1222. doi:10.3923/pjbs.2000.1213.1222

Kranthi KR, Jadhav D, Wanjari R, Kranthi S and Russell D, 2001. Pyrethroid resistance and mechanisms of resistance in field strains of *Helicoverpa armigera* (Lepidoptera:Noctuidae). Journal of Economic Entomology, 94, 253-263.

Lammers JW and MacLeod A, 2007. Report of a Pest Risk Analysis *Helicoverpa armigera* (Hübner, 1808). Plant Protection Service (NL) and Central Science Laboratory (UK) joint Pest Risk Analysis for *Helicoverpa armigera*, Wageningen, 18, The Netherlands.

Martin T, Ochou OG, Vaissayre M and Fournier D, 2003. Organophosphorus insecticides synergize pyrethroids in the resistant strain of cotton bollworm, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) from West Africa. Journal of Economic Entomology, 96, 468-474. doi:10.1093/jee/96.2.468

Mustafiz SB, Chowdhury Md TI and Akter A, 2015. Efficacy of some botanicals in controlling fruit borer (*Heliothis armigera*) in tomato. Academic Journal of Entomology, 8(3), 140-149. doi:10.5829/idosi.aje.2015.8.3.95246

Nyambo BT, 1989. Assessment of pheromone traps for monitoring and early warning of *Heliothis armigera* Hübner (Lepidoptera, Noctuidae) in the western cotton-growing areas of Tanzania. Crop Protection, 8, 188-192. doi:10.1016/0261-2194(89)90025-2

Pomari-Fernandes A, de Freitas Bueno A, Sosa-Gómez DR, 2015. Helicoverpa armigera: current status and future perspectives in Brazil. Current Agricultural Science and Technology, 21, 1-7.

Radonjić S and Hrnčić S, 2012. The cotton bollworm *Helicoverpa armigera* (Lepidoptera: Noctuidae) – is it becoming a serious pest on pepper and tomato in Montenegro? Integrated Control in Protected Crops, Mediterranean Climate IOBC-WPRS Bulletin, 80, 35-38.

Regulation No. 9 of 26 February 2021 on integrated production of plants and plant products and control over integrated production. Issued by the Minister of Agriculture, Food and Forestry, State Gazette No 21, March 2021 (Bg).

Shah KD, Jhalas RC and Dhange R, 2017. Standardization of pheromone traps for the mass trapping of *Helicoverpa armigera* (Hubner) Hardwick in Tomato. Current Agriculture Research Journal, 5, 45-49. http://dx.doi.org/10.12944/CARJ.5.1.05

Vojoudi S, Saber M, Hejazi MJ and Talaei-Hassanloui R, 2011. Toxicity of chlorpyrifos, spinosad and abamectin on cotton bollworm *Helicoverpa armigera* and their sublethal effects on fecundity and longevity. Bulletin of Insectology 64, 189-193.

Wakil W, Ghazanfar MU, Nasir F, Qayyum MA and Tahir M, 2012. Insecticidal efficacy of *Azadirachta indica*, nucleopolyhedrovirus and chlorantraniliprole singly or combined against field populations of *Helicoverpa armigera* Hübner (Lepidoptera:Noctuidae). Chilean Journal of Agricultural Research, 72, 53-61. http://agropedia.iitk.ac.in/content/tomato-fruit-borer