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CHEMICAL CONTROL OF *HELICOVERPA ARMIGERA* AND *SPODOPTERA EXIGUA* AND ITS EFFECTS ON THE QUALITATIVE INDICATORS OF PEPPERS

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SUMMARY

In the conditions of Khoronk settlement of Armavir marz, Armenia, *Helicoverpa armigera* (syn. *Chloridea armigera* Hübner) and *Spodoptera exigua* (syn. *Caradrina exigua* Hübner) are the chief pests damaging the pepper plants in their larval stage. In crop season 2022, experiments on these pests in pepper fields tested the insecticides that mainly control the insects. The insecticides tested against *Helicoverpa armigera* and *Spodoptera exigua* included Eforia, Belt, Decis F-Lux, and Spintor. The Arrivo served as standard, and the experiment also had a control. As a result of the conducted research, the insecticides Belt, Decis F-Lux, and Eforia showed the highest biological and economic efficiency in controlling *Helicoverpa armigera* and *Spodoptera exigua*. The study also ran a biochemical analysis of the pepper harvest to know the effects of the applied insecticides on the peppers' quality indicators.

Keywords: Pepper, *Helicoverpa armigera, Spodoptera exigua*, insecticides, biological and economic efficiency, qualitative indicators

Key findings: In the Khoronk settlement of Armavir region, Armenia, the *Helicoverpa armigera* and *Spodoptera exigua* are the chief pests of peppers, against which the insecticides Eforia, Belt, Decis F-Lux, and Spintor ran tests in the field experiments. Results revealed that insecticides Belt, Decis F-Lux, and Eforia showed the highest biological and economic efficiency in controlling these two crucial insects.

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INTRODUCTION

Vegetable farming is one of the leading and profitable branches of agriculture in Armenia. Pepper is the most common vegetable crop and ranks third after tomatoes and cabbage. Fresh peppers mainly consist of water (90%–92%), and the remaining substances are carbohydrates, proteins, fats, mineral elements, and vitamins. Carbohydrates, which

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provide calories, are often monosaccharides and polysaccharides, ranging from 3% to 5% in green peppers (Brovko *et al*., 1989). Compared with other vegetables, pepper stands out for its high cell content (2%), through which the body gets rid of toxins, cholesterol, and other harmful substances (Daryanto *et al*., 2021; Poudyal *et al*., 2023). In addition, it improves the digestive system’s function and helps enhance the beneficial bacteria community in the intestines. Therefore, a well-immune system emerges in such a case, which resists the influence of negative factors on the vital activity of an organism.

Pepper is not a source of proteins and fats for the body, as their contents are insignificant, i.e., proteins (0.8%–1.2%) and fats (0.17%). The pepper importance is mainly due to various levels of vitamins, mineral elements, and biologically active substances. On average, a 100 g of pepper fruit contains vitamin C (ascorbic acid - 150 mg), vitamin B4 (5.6 mg), vitamin E (1.58 mg), vitamin B3 (0.1 mg), vitamin B5 (0.32 mg), potassium (210 mg), phosphorus (26 mg), magnesium (12 mg), calcium (7.0 mg), sodium (4.0 mg), and iron (0.8 mg). Additionally, pepper contains a small amount of B1, B2, B6, B9, and PP vitamins and organic acids.

Besides other biologically active substances, peppers also stand out for carotenoids and polyphenols, which have pronounced antioxidant properties and suppress the formation of free radicals in the body, thereby preventing aging processes and the occurrence of diseases. Yellow and especially red peppers are rich in the earlier-mentioned antioxidants. The biological importance of pepper is primarily due to the high content of vitamin C, which is a water-soluble vitamin and does not synthesize in the human body.

Vitamin C has a vital role in keeping and maintaining the body healthy. Deficiency of this vitamin in food especially causes gum disease. It actively participates in various oxide-recovery processes and is a powerful antioxidant, protecting cellular proteins, fats, DNA, and RNA from the harmful effects of free radicals. Vitamin C is crucial for the human body to synthesize collagen protein, which is the main component of skin and structural tissues. Vitamin C also protects the heart and blood vessels, reducing blood pressure, cholesterol, and uric acid (Kretovich, 1967). The recommended daily requirement of vitamin C is 90 and 75 mg for men and women, respectively. Therefore, one sweet pepper fruit can fulfill the body's vitamin requirement.

Several factors, like environmental conditions and the use of fertilizers, growth promoters, pesticides, and other chemicals, influence the intensity of vitamin C synthesis, as well as the ratios of the mentioned vitamins, carbohydrates, mineral elements, and other biologically active compounds (Gruzdev *et al.*, 1987).

Various pests also severely damage the peppers in the conditions of the settlement of Khoronk, Armavir marz; however, the *Helicoverpa armigera* (syn. *Chloridea armigera* Hübner) and *Spodoptera exigua* (syn. *Caradrina exigua* Hübner) are the most dangerous insects which damage the fruits and even the whole foliage. Overall, controlling these pests is very difficult because the insecticide preparations selected for foliar application may not be very effective, and often, the spray application is at inappropriate times, resulting in the farming community facing a massive loss in this important crop.

MATERIALS AND METHODS

During the crop seasons 2020–2021, conducting stock studies against pests, *Helicoverpa armigera,* and *Spodoptera exigua*, sought the most effective insecticides for testing in production conditions of the Khoronk settlement of Armavir Region, Armenia (Terlemezyan and Ghazaryan, 2022, 2023). The experiments ran on the Hayk variety. In production experiments during crop season 2022, the following insecticides, i.e., Eforia, Decis F-Lux, Belt, and Spintor, comprised the treatments to control the *Helicoverpa armigera* and *Spodoptera exigua,* with Arrivo, a widely used insecticide in agricultural production, as a standard. The experiment also had a control (no-injection) version. The selected insecticides had groupings of two versions (in charts), with each insecticide preparation sprayed only once.

Each treatment occupied an area of 1000 m^2, and all the experiments had three replicates. The threshold consideration of economic harm to pests was 3–5 larvae per 100 plants (Pikushova and Veretelnik, 2009). Spraying transpired with the help of a motorized sprayer. In experiments, the solution consumption was 500 L ha^{-1}. Calculations of the biological effectiveness of the tested insecticides against the insects *Helicoverpa armigera* and *Spodoptera exigua* were at one, five, 10, and 15 days after each treatment, using Gar's method (Gar, 1963) with the following formula:

$$E = \frac{B-A}{B} \times 100$$

Where:
E = biological efficiency of insecticides (%)
B = the number of pests before treatment
A = the number of pests after treatment

The main results of the research underwent mathematical analysis using the method of dispersion analysis (Orlov, 2006; McKenzie, 2015; Mamajanyan, 2018; Altoveros, no date).

Running economic efficiency calculations was according to the appropriate methodology (Determination of the Economic Efficiency of Research and Development Work in Agriculture, 1977; Zakharenko and Goncharov, 1984; Goncharov, 2017).

It is a fact that in addition to the direct toxic effect on harmful insects, the residues of pesticides, especially preparations of organic synthesis, penetrate the tissues of protected crops and are involved in their metabolic processes, thereby affecting the functional life of the plant.

Naturally, such interaction affects the activity and direction of the synthesis of individual compounds in plants; as a result, goes through quantitative and qualitative changes, affecting the quality of the obtained harvest (Gruzdev *et al*., 1987; Balayan *et al*., 2010; Hanisyan, 2012; Atshemyan and Mirzoyan, 2015; and Atshemyan *et al*., 2019, 2020).

Based on the above, biochemical analyses helped determine the effects of the applied insecticides on the prime qualitative indicators of the peppers. The assessments used universal methods accepted for biochemical research (Pleshkov, 1968) in the Pesticide Residues and Biochemical laboratory of the Food Safety Risk Analysis and Assessment Research Center of the Ministry of Economy of the Republic of Armenia. Determination of dry substance employed heating the sample at gradually higher temperatures, with soluble sugars determined with the help of sulfuric acid by recovery of copper oxide (Bertrand method), total nitrogen by converting into ammonia and obtaining the corresponding salt of sulfuric acid (Kjeldahl's approach), total acidity by titration, and vitamin C by recovery of 2,6-dichlorophenolindophenol blue indicator.

RESULTS AND DISCUSSION

Results of the data analysis of the different insecticides' biological effectiveness against the harmful insects, i.e., *Helicoverpa armigera* and *Spodoptera exigua,* in pepper fields are available in Table 1. All the treatments had Provet as an adhesive additive at the rate of 0.4 L ha^{-1}. From the data of Table 1, all the insecticide preparations tested against insects *Helicoverpa armigera* and *Spodoptera exigua* showed a high biological efficiency in controlling those two harmful insects.

Thus, the insecticide preparations included in scheme 1 against *Helicoverpa armigera* provided 78.9% to 84.6% efficiency and 80.9% to 82.8% efficiency against *Spodoptera exigua* after 10 days of application. In scheme 2, this indicator varied between 77.7% to 84.2% in the case of *Helicoverpa armigera*, while 81.8% to 83.3% in the case of *Spodoptera exigua*, and in using the standard option-3, it was 65.2%.

Table 1. Biological effectiveness of insecticides against *Helicoverpa armigera* and *Spodoptera exigua* on pepper in the conditions of Khoronk community, Armenia.

Pests	Variants	Active ingredients	Consumption norm (L/ha, kg/ha)	Biological efficiency (%)	
				Helicoverpa armigera	*Spodoptera exigua*
Helicoverpa armigera *Spodoptera exigua*	Scheme 1				
	Belt	Flubendiamide	0.1	78.9	80.9
	Decis F-Lux	Deltametrin	0.4	84.6	82.8
	Eforia	Lambda-cyhalothrin + Thiamethoxam	0.5	81.8	81.2
	Scheme 2				
	Belt	Flubendiamide	0.1	80.0	81.8
	Decis F-Lux	Deltametrin	0.4	84.2	83.3
	Spintor	Spinosad	0.5	77.7	82.3
	Scheme 3				
	Arrivo	Cypermethrin	0.3	65.2	65.2

Table 2. Economic efficacy of tested insecticide preparations against *Helicoverpa armigera* and *Spodoptera exigua* (on variety Hayk).

Pests	Variants	The average yield (kg/ha)	Additional harvest (kg/ha)	Selling price of 100 kg yield (USD)	Price of extra yield (USD)	Expenses spent on receiving and transporting additional crops (USD)	Net profit (USD)
Helicoverpa armigera *Spodoptera exigua*	Scheme 1 Belt Decis F-Lux Eforia	49620	21330	42.5	9065.2	3577.5	5487.7
	Scheme2 Belt Decis F-Lux Spintor	47830	19120	42.5	8125.0	3225.0	4901.0
	Scheme 3 Arrivo (sample)	41080	12790	35.0	4475.0	1972.5	2504.0
	Check (not sprayed)	28290	-	25.0	-	-	-

As a result of mathematical analysis, it revealed that with *Helicoverpa armigera*, the effect of Belt is not significant in scheme 1, but with Decis F-Lux significantly increased by 5.3, and with Eforia, a substantial increase by 2.5. In scheme 2, the effect of Belt is insignificant, with Decis F-Lux a significant rise by 4.9, and nonsignificant with Spintor. In the case of *Spodoptera exigua*, in scheme 1, Belt indicated a nonsignificant effect, but Decis F-Lux has a significant increase by 3.5, while a nonsignificant effect also from Eforia. For scheme 2, the impact of Belt gave a 2.5 significant increase, Decis F-Lux's influence a 4.0 significant increase, and Spintor by 3.0. In other words, Decis F-Lux preparation is the most effective of the two schemes. The experimental error was $Sx_0\% = 0.9\%$, and the least significant difference was $LSD_{0.5} = 2.1$.

Indicators of economic efficiency of tested preparations of insecticides against *Helicoverpa armigera* and *Spodoptera exigua* appear in Table 2. Costs spent obtaining additional crops include the cost of pesticides purchased against pests and labor and expenses in obtaining, harvesting, and transporting the added crops. According to the data obtained in controlling the insects

Table 3. The effect of insecticides on the prime qualitative indicators of pepper according to the control schemes of *Helicoverpa armigera* and *Spodoptera exigua.*

Pests	Variants	Dry substances (%)	Sugar (%)			Total nitrogen (%)	Organic acids (%)	Vitamin C (%)
			Monosaccharides	Polysaccharides	Total			
Helicoverpa armigera	Control	8.4	2.7	0.22	2.92	0.78	0.10	83.2
	Arrivo (sample)	8.5	2.9	0.24	3.14	0.80	0.10	85.4
Spodoptera exigua	Belt+Decis F-Lux +Eforia	9.0	3.3	0.28	3.58	0.86	0.08	106.3
	Belt+Decis F-Lux+Spintor	8.8	3.2	0.26	3.46	0.84	0.08	104.2

Helicoverpa armigera and *Spodoptera exigua* compared with the control in schemes 1 and 2, harvests had an additional yield of 21,300 and 19,100 kg, respectively. In the Arrivo sample version (scheme 3) versus the control, the added harvest was only 12,790 kg. The net profit in the mentioned versions was USD 5,487.7, 4,901.0, and 2,504.0, respectively.

The effects of the applied insecticide preparations on the core quality indicators of peppers occur in Table 3. In carrying out the biochemical analysis, the pepper samples came from the check, Arrivo, Belt + Decis F-Lux + Eforia, and Belt + Decis F-Lux + Spintor versions of the *Helicoverpa armigera* and *Spodoptera exigua* control scheme were during the technical ripening period of the fruits, on September 14. The obtained samples were from the middle layer of pepper plants.

It was evident from the table that all the insecticides tested against the insects *Helicoverpa armigera* and *Spodoptera exigua*, including Arrivo as a sample, do not negatively affect the primary quality indicators of pepper, and more so, improve the fruit yield to one or other extent. Firstly, it was noteworthy that the insecticide preparations enhance the ascorbic acid - vitamin C in the fruits, an essential indicator due to the biological significance of pepper for the body.

The results recorded in the treatment of Belt + Decis F-Lux + Eforia version were particularly outstanding, where application made to combat both *Helicoverpa armigera* and *Spodoptera exigua*, the mentioned version increases the vitamin C in the pepper by 27.8%. However, in the Belt + Decis F-Lux + Spintor version, vitamin C content has increased by 25% compared with the control treatment. The combination of Belt + Decis F-Lux + Eforia and Belt + Decis F-Lux + Spintor contributes to accumulating monosaccharides in pepper fruits, increasing sugars' total content by 18.4% to 22.6%.

Although pepper is not only rich in nitrogen-containing compounds, particularly in proteins, it is worth noting that the total nitrogen content in the pepper fruits of the treatments, i.e., Belt + Decis F-Lux + Eforia and Belt + Decis F-Lux + Spintor, was higher (10.2% and 7.6%, respectively), compared with the control version, and the dry matter contents were also high by 7.1% and 4.7%, respectively. It was interesting to find out what causes stimulation of the applied insecticides on the chief qualitative indicators of the peppers. In biology, the Arndt-Schultz law applies, according to which poisons at low concentrations stimulate the functional life of plants while suppressing the plants at higher concentrations.

Initially, it was notable that pesticides of organic origin indiscriminately penetrate the cells and tissues of protected plants. With their residues considered foreign substances for plants, plants activate their resistance system (enzymes, activation of physiological and biochemical processes) to neutralize them. As a result, the functional activity of plants improves, causing positive changes in the quality indicators of the harvest (Atshemyan *et al*., 2019, 2020).

Undoubtedly, the biological effects of the pesticides on pepper plants were unclear. It is caused by several exogenous and endogenous factors (environmental conditions, morphological and physiological features of plants, stages of development, direction of biochemical processes, and type and density of preparation) (Gruzdev *et al*., 1987; Atshemyan *et al*., 2019, 2020).

CONCLUSIONS

According to the proposed options, controlling harmful insects, i.e., *Helicoverpa armigera* and *Spodoptera exigua* in peppers, has justification from biological, economic, and environmental points of view. At the same time, regardless of the application method, the applied insecticides do not negatively affect the primary quality parameters of the peppers but also improve the quality of the obtained crop.

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