

Results of "Shin-Etsu" pheromone application on immune cultivars in the apple protection system to control of codling moth

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Abstract. Codling moth is a very dangerous pest in apple orchards: the pest could damage up to 70-90% of pome fruits in the years of mass reproduction. The climate change increased the harmfulness of the pest during the last years. The aim of our study was the determination of "Shin-Etsu" dispenser application efficiency for codling moth disorientation comparing with conventional apple protection system. The experiment was done in apple orchards of JSC "Dubovoye" (Tambov oblast) in 2020-2021. The objects of the study were the scab immune cultivars Venyaminovskoye and Flagman grafted on B396 rootstock. Codling moth damaged 9.4-12.1% fruits in the control treatment after the first generation and 11.6-15.2% by the second generation. The application of the experimental protection system with dispensers decreased the fruit damage rate after the first generation up to 0.5-0.8% and second generation—0.9-1.1%. The biological efficiency of the experimental system in both cultivars was higher and reached 92.2-96.7% after the first generation and 90.5-94.0% after the second. The average yield in the "Shin-Etsu" protection system was 9.7-12.5 kg tree⁻¹ where 87-90% fruits were premium quality.

1 Introduction

One of the most dangerous and harmful phytophagous in apple orchards is the codling moth *Cydia pomonella* (L.) (*Lepidoptera: Tortricidae*). The pest could damage up to 90% of fruits during the years of mass reproduction [1]. Usually, the pest has several generations during the growing season, which harmfulness is determined by weather. We observed the increase in harmful activity of codling moth. It is supposed that it was the consequence of climate change, because of an increase in survival and fertility of insects [2, 3].

The application of chemical protection products to control codling moth strengthened an insecticidal load on agrocenosis, caused the resistance development and make the negative impact on the environment. Phytosanitary monitoring and short-term prognosis of harmfulness must be done to evaluate the need for protective measures and chose appropriate high efficiency products [4, 5].

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Because of the above mentioned, it is a very important task for the present the application of modern safe protection products with high efficiency including pheromones. French scientist Jean-Henri Fabre and German researcher Adolf Friedrich Johann Butenandt are closely connected with the history of pheromones and their impact on insects' study.

The scientists of Russian Research Institutes of Plant Protection and Biological Plant Protection study the problems of pheromone monitoring [7-8]. They achieved considerable success in protection product application in optimal terms to control codling moth, Oriental peach moth, plum piercer and some of other tortricid moth species [9-11]. The application of dispensers based on pheromone to control the codling moth is already common in various countries in fruit orchards [12-13].

Sexual pheromones of insects are widely used as the best product to monitor harmful species. The scientists and producers detect pests, watch for the dynamics of their migration and development, determine the economic level of harmfulness and take decision for application of protection products based on use of pheromones. It is possible the application of dispensers based on codling moth pheromones for producing environmentally friendly fruits as the safe plant protection product to control the codling moth [14-15]. The method comprises of the male insects disorientation (they cannot track the scent of the females) to avoid their mating with females. The result of mating lack is absence of egg laying and hatching of caterpillars, which damage fruits.

2 Material and methods

The study was done in commercial apple orchards of JSC "Dubovoye" (Tambov oblast) in 2020-2021. The experimental orchard was planted in 2012; trees grafted on B396, planting pattern 4.5 x 1,45 m (1538 tree/ha⁻¹). The objects of the study: the scab immune apple cultivars Venyaminovskoye and Flagman.

Experiment design:

- Control (without treatments);
- Experimental Protection System (EPS): dispensers "Shin-Etsu" with pheromones were applied only (500 pc. ha⁻¹). Japanese scientists created the dispenser, Shin Etsu Chemical Co. LTD produces these dispensers Shin-Etsu MD STT D. The D dispenser is pheromone complex of codling moth (dispenser E, E-8,10-dodecadiene-1-ol 2.2×10^{-4} + 1-dodecanol 1.2×10^{-4} + 1-tetradecanol 2.7×10^{-5} kg dispenser⁻¹) [6].
- Conventional protection system (CPS): Lambda-cyhalothrin + Thiamethoxam 106+141 g L⁻¹, SC (0,15 L ha⁻¹); Chlorpyrifos + bifenthrin 400 +20 g L⁻¹, EC (1,0 L ha⁻¹); Thiocloprid 480 g L⁻¹, SC (0,4 L ha⁻¹); methomyl 250 g kg⁻¹, WP (1,5 kg ha⁻¹).



Fig.1. “Shin-Etsu dispenser with pheromone complex.

The field trial was done in the plot 2 ha area. This plot was surrounded from three sides the other apple orchards. Because of this, we added 5% dispensers more on the borders of the experimental plot.

We hung up the pheromone dispensers in the growing stage “beginning of flowering”, at the height of 2/3 tree from the ground surface in the north in the middle of canopy. The distance between the treatments was 30 m.

We recorded the fruit damage after the first and second generations of codling moth according to accepted methods [16].

3 Results and discussion

During the years of the study, the weather differed from the averages values of 50 last years. The average daily air temperature in May was lower, but in June it was higher at 1.90C than usual in 2020. The rainfall was more on 20 mm in May and 49 mm in June in this year. In July and August, the air temperature had no significant differences. The amounts of rain in these months was lower than usual (at 34 mm and 44 mm respectively).

In the 2021, the average daily temperature from May to August was higher than the multiyear average at 1.3 ... 4.60C. The amount of rainfall was higher at 12.7 mm (in May) and 8.7 mm (in June) was higher than the multiyear average. Later, the rainfall was lower than usual—at 25.6 mm (in July) and at 33.2 mm (in August).

The temperature +10⁰C (effective temperature – ET, effective temperature sum - ETS) is the threshold value for the codling moth development. The researchers use the dynamics of ET sums growth to forecast the codling moth development. The date, when the ETS reaches 500⁰C, is used to determine the degree of the second generation development in two-three weeks before the beginning of caterpillar hatching.

When SET reaches 550-600^oC (in the beginning of August usually in the Central Russia), it would be start for the second generation development and SET 900^oC is well for a mass reproduction. The value of SET was 731.1C in July 2020 and 959.7^oC in 2021 (Table 1).

Table 1. The accumulation of effective temperature sum, ^oC.

Years	Months			
	May	June	July	August
2020	103.1	397.5	731.1	1001.3
2021	227.0	550.0	959.7	1351.4

The above mentioned SET value was reached in the first decade of July in 2020. Because of this, we expected the second generation 50-70% from the first generation size. In 2021, the SET value was reached already in the 3rd decade of May and we predicted the second generation development 55-85% from the first generation size. The first generation butterflies flew from 20 to 30 May in 2020. In 2021, we observed it at a longer period— from 10 to 30 May. We observed the most activity of the second generation from 20 to 30 July in 2020, and from 10 to 20 July in 2021.

The fruit damage by codling moth in the Control varied according to the cultivars and moth generations. The second generation damaged fruits at 1.3-5.8% more strong compare to the first. In 2020, the first generation moth butterflies damaged 12.1% fruits of cv. Venyaminovskoye, but the second generation damaged 14.2% fruits; we observed on the cv. Flagman 9.4% and 15,2% damaged fruits, respectively. The rate of fruit damage was 10.1% and 12.7% (cv. Venyaminovskoye), 10.3% and 11.6% (cv. Flagman).

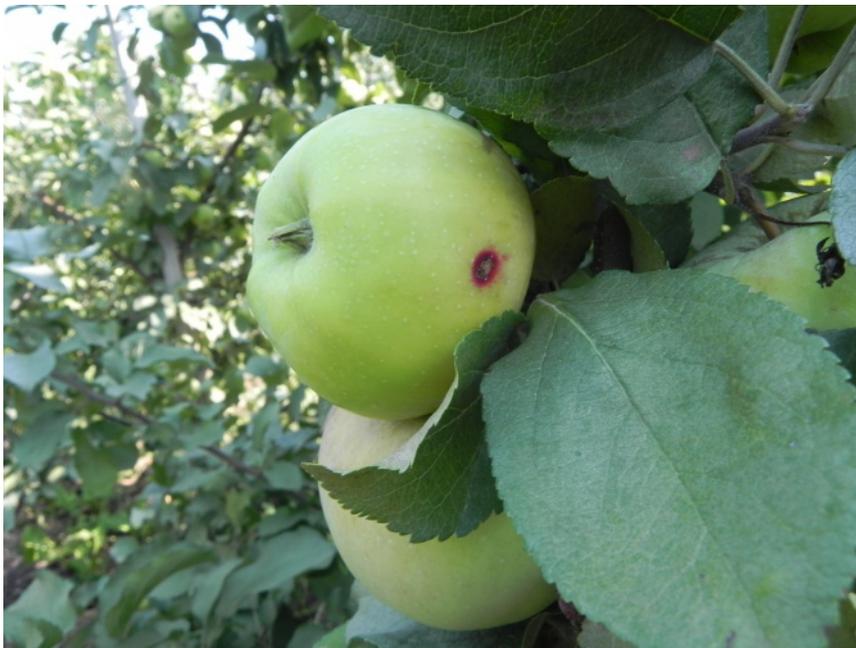


Fig. 2. Apple tree fruit damages, cv. Flagman.

The fruit damage in the EPS treatment varied from 0.5% to 0.8% after the first generation and from 0.9% to 1.1% (second generation). It confirms the high efficiency of pheromone dispensers.



Fig. 3. The fruits of the cv. Venyaminovskoye in the treatments with the "Shin-Etsu" dispensers.

The fruit damage was higher in the CPS treatment—from 0.8% to 1.4% (first generation) and from 1.3 to 1.7% (second generation). As a whole, the efficiency of EPS was higher in both cultivars during the study. The biological efficiency of EPS in controlling the first generation of codling moth was 92.2-96.7% and second—90.5-94%. In the CPS treatment, the biological efficiency was 86.4-93.4% (the first generation) and 85.3-90.3% (the second generation) (Table 2).

Table 2. Biological efficiency of pheromone dispenser application to control the codling moth, %

Treatment	2020		2021	
	First generation	Second generation	First generation	Second generation
Venyaminovskoye				
EPS	96.7	94.0	93.3	92.3
CPS	93.4	91.0	90.0	87.0
Flagman				
EPS	94.6	92.9	92.2	90.5
CPS	88.2	90.3	86.4	85.3

The average yield in the EPS treatment was 9.7-12.5 kg tr.⁻¹ and the part of first commercial grade quality fruits was 87-90%. The yield in the CPS treatment was lower, 7.8-10.3 kg tr.⁻¹ and the part of first commercial grade quality fruits was 83-88% (Table 3). Thus, the application of the EPS with pheromone dispensers stimulated higher yield with better quality of fruits and biological efficiency to control the codling moth.

Table 3. The impact of different protection treatments on yield and quality of fruits.

Treatment	2020			2021		
	Yield, kg tr. ⁻¹	First commercial quality grade, %	Second commercial quality grade, %	Yield, kg tr. ⁻¹	First commercial quality grade, %	Second commercial quality grade, %
Venyaminovskoye						
Control	6.1	17	25	8.7	13	30
EPS	10.4	90	10	12.5	89	11
CPS	8.6	88	12	10.3	86	14
LSD₀₅	0.4			1.0		
Flagman						
Control	5.2	15	20	7.3	11	25
EPS	9.7	89	11	11.6	87	13
CPS	7.8	87	13	9.8	83	17
LSD₀₅	0.7			0.9		

4 Conclusions

“Shin-Etsu” dispensers had high biological efficiency, it could be compared with chemical plant protection product application. Using of pheromone dispensers to control the moth population size stimulated high commercial yields and decrease in insecticide load in 2020-2021. Biological efficiency in the EPS treatment was 92.2-96.7% with high-quality fruits.

We determined that fruit damage by the codling moth caterpillars in the Control was 9.4.-15.2%, in the treatment with pheromone dispensers—0.5-1.1% and in the treatment with insecticides—0.8-1.7%. These results confirm that “Shin-Etsu” dispensers could be a good alternative for chemical insecticides. The application of pheromone dispensers in orchards with scab immune cultivars makes it possible to decrease significant pesticide load to grow ecologically friendly fruits.

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