

Results of long-term use of pheromone traps to monitor harmful tortricid moths in Leningrad Region of Russia

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Abstract. Monitoring the population dynamics of harmful moths using synthetic sex attractants in Leningrad Region was carried out in the fruit experimental orchard of St. Petersburg Agrarian University (Pushkin) and small private orchards of Pushkin district. As a result of the analysis of many years temperature characteristics of vegetation seasons in the Leningrad Region and calculation of the sums of effective temperatures, it has been found that the codling moth had high numbers and developed in two full generations in 1999, 2002, 2006, 2013 and 2018. The complex of phytophagous leaf rollers as a whole can cause sometimes significant harm to both industrial orchards and homestead lands, because the economic threshold of harmfulness by yield losses is often achieved, when plants are damaged by more than one pest species, each of which causing only weak harm. As a general conclusion, the complex of orchard leaf rollers is a dynamic system. Their development and numbers ratio is influenced by weather conditions of a year and climate changes in general.

1 Introduction

Pheromone monitoring is the most important element of the modern integrated system of fruit crop protection from the complex of moths in different natural and climatic conditions [1, 2]. Our research was carried out in the Leningrad Region of the Russian Federation, where apple is a key fruit culture. A tangible loss in fruit yield here is due to the harmfulness of codling moth *Cydia pomonella* (L.) and a complex of harmful Tortricidae (Lepidoptera). Pheromones are known for all major species of this group, being widely used in traps as a method of their monitoring.

2 Materials and methods

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Monitoring the population dynamics of harmful moths using synthetic sex attractants in Leningrad Region was carried out in the fruit experimental orchard of St. Petersburg Agrarian University (Pushkin) and small private orchards of Pushkin district in 1997-2004, 2006-2014 and 2018-2019. In different years, pheromone materials produced by the company "Flora" (Estonia) and "Shchelkovo Agrokhim" (Moscow, Russia) were used in delta traps made of laminated cardboard with an adhesive surface of 18 x 10 cm. Traps for the codling moth were placed in orchards at the end of flowering, at the western or south-western sides of an apple tree at a height of about 1.5-2 m, one trap per 2 hectares, at a distance of 30-50 meters from each other [3]. Traps placed in the private orchards were checked daily, in the University experimental fruit orchard - 1-2 times a week. Adhesive papers were replaced as they were contaminated, usually in two to three weeks, and every week during the period of mass flight. Data from the nearest weather stations were used to analyze the temperature dynamics during vegetation seasons.

3 Results and discussion

The trend of climate warming in the northern European part of Russia is well known. Our main task was to study the development of the northern population of main pest of pome crops, the codling moth, in modern conditions of climate change in north-west Russia (on the example of Leningrad region). Regarding the northern edge of the pest area, the old Russian literature contains an expert assessment that only half of the caterpillars of the first generation can finish feeding before the cold [4]. Our observations in Pushkin have revealed appearance of caterpillars and even moths of a new (second) summer generation in August during the warm years between 1997 and 2019. Their offspring may completely or partially die, but this fact itself suggests that the share of first-generation caterpillars finishing development has increased significantly, and the increased wintering reserve of the pest can cause more serious harm next season. So, climate warming can lead to fuller development of the first generation, an increase in the share of healthy moths and their fertility next season, and an unpredictable increase of harmfulness.

As a result of the analysis of many years temperature characteristics of vegetation seasons in the Leningrad Region and calculation of the sums of effective temperatures (SET), we have found that the codling moth had high numbers and developed in two full generations in 1999, 2002, 2006, 2013 and 2018 [5-8] (Fig. 1).

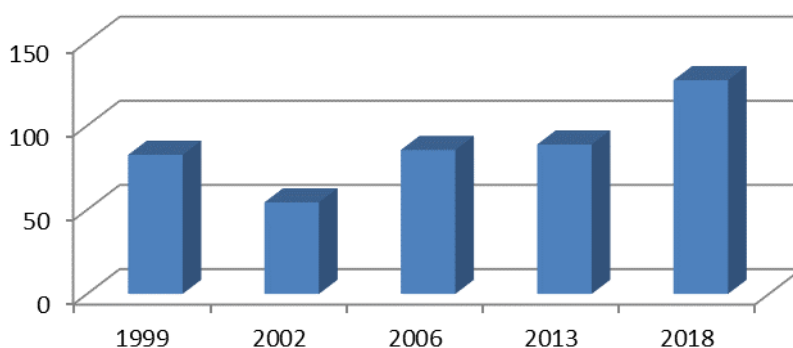


Fig. 1. Trapping *Cydia pomonella* during years with two full generations in Leningrad Region.

The vegetation seasons of five years with the full development of the second generation of the codling moth were characterized by high temperature compared to the many year average data against the background of precipitation deficit (Table 1).

Table 1. Analysis of meteorological data of vegetation seasons with two full generations of *Cydia pomonella* in Pushkin.

Month	Temperature, °C						Precipitation					
	norm	anomaly					norm, mm	% of norm				
		1999	2002	2006	2013	2018		1999	2002	2006	2013	2018
May	11.3	-3.2	+1.5	+0.9	+3.1	+3.8	46	43	45	132	111	24
June	15.7	+4.9	+1	+1.2	+4.1	+0.5	71	45	105	80	52	32
July	18.8	+2.9	+2.7	+1.1	+2.0	+2.1	79	35	147	21	106	122
August	16.9	0	+2.4	+2.5	+1.7	+2.3	83	64	48	57	117	75
September	11.6	+1.9	+0.7	+3.2	+0.5	+3.7	54	28	96	61	86	66
May - September	14.9	+0.7	+1.2	+1.4	+1.9	+2.6	333	44	91	64	97	70

It should be also noted that the 2010 summer was similarly warm, but almost daily rains in May and June negatively affected the development of the first generation, thus reducing its number (totally 9.6 males were caught per trap during the season). The codling moth flight dynamics confirms the SET calculation data for the Leningrad region. The beginning of moth flight in years with two full generations was noted at the end of May at SET 88.4 – 144.2°.

For example, 2018 observations on the flight dynamics and the codling moth number have shown that the SET 500° required for the development of the first generation [9] was reached before July 20, and SET 1000° required for the development of the full second generation – by the end of the first third of September. Consequently, we can assume that a substantial part of the population had emerged from diapause by early July and produced a powerful surge in the moth flight of first generation, which has initiated the development of second generation of the codling moth. Pre-diapausing caterpillars have been found in the fruit drop during July-August. A weak moth flight of the second generation has been recorded in the last third of August, which nevertheless indicates the complete development of this generation and even the withdrawal of a small part of the caterpillars from the diapause. Eggs of the third generation have not been found. But even if the egg laying has happened, the all caterpillars hatched in September certainly have died due to a steady decrease of the average daily temperature below 10°C since September 25 and the first frosts since October 8.

Regarding harmful leaf rollers (Tortricidae), Bichina and Markelova [10] listed more than 50 species of this group in orchards on the territory of the former USSR in addition to the codling moth. Markelova [11] mentioned 14 tortricid species as pests of fruit and berry crops in Leningrad Region, of which *Archips rosana* (L.) and *Exapate congelatella* (Cl.) were the most harmful species of berries. Our long-term trials of 54 standard and experimental preparations of synthetic sex pheromones have revealed 41 species of Tortricidae trapped in orchards of the Pushkin district of Leningrad Region, of which 16 species have been found in apple orchards: *Acleris bergmaniana* (Linnaeus), *Adoxophyes orana* (Fischer von Röslerstamm), *Aethes rubigana* (Treitschke), *Ancylys badiana* (Denis & Schiffermüller), *Aphelia paleana* (Hübner), *Apotomis infida* (Heinrich), *Archips podana* (Scopoli), *A. rosana* (Linnaeus), *Choristoneura diversana* (Hübner), *Clepsis spectrana* (Treitschke), *Cnephasia stephensiana* (Doubleday), *Cochylys dubitana* (Hübner), *C. posterana* Zeller, *Cydia nigricana* (Fabricius), *C. pomonella* (Linnaeus), *C. servillana* (Duponche), *Dichrorampha petiverella* (Linnaeus), *Enarmonia formosana* (Scopoli), *Eupilema foenella* (Linnaeus), *E. scutulana* (Denis & Schiffermüller), *Eucosma*

campoliliana (Denis & Schiffermüller), *E. cana* (Haworth), *Eulia ministrana* (Linnaeus), *Gypsonoma minutana* (Hübner), *G. sociana* (Haworth), *Grapholita funebrana* (Treitschke), *Hedya dimidiana* (Clerck), *H. nubiferana* Haworth, *Notocelia rosaeolana* (Doubleday), *Pammene rhediella* (Clerck), *Pandemis cerasana* (Hübner), *P. corylana* (Fabricius), *P. heparana* (Denis & Schiffermüller), *Phalonidia manniana* (Fischer von Röslerstamm), *Ptycholoma lecheana* (Linnaeus), *Rhopobota naevana* (Hübner), *Spatalistic bifasciana* (Hübner), *Spilota ocellana* (Denis & Schiffermüller), *Syndemis musculana* (Hübner), and *Tortrix viridana* Linnaeus.

This complex of phytophagous leaf rollers as a whole can cause sometimes significant harm to both industrial orchards and homestead lands, because the economic threshold of harmfulness by yield losses is often achieved, when plants are damaged by more than one pest species, each of which causing only weak harm. The most abundant in the Leningrad Region orchard pests during the last decade were *Cydia pomonella*, *Hedya nubiferana*, *Archips podana*, and *Spilota ocellana*. Their numbers ratio in pheromone traps varied depending on the conditions of a vegetation season. As an example, we provide a comparison of *C. pomonella* and *A. podana* moths trapped in 2000-2019 (Fig. 2). In 2019, the warm May (+0.8) and especially June (+3.8 above norm) with the deficit of precipitation have caused a great increase in the number of *Pandemis cerasana* moths (52.1 males/trap per season), being a limiting factor for the development of *Archips rosana* and *Spilota ocellana*.

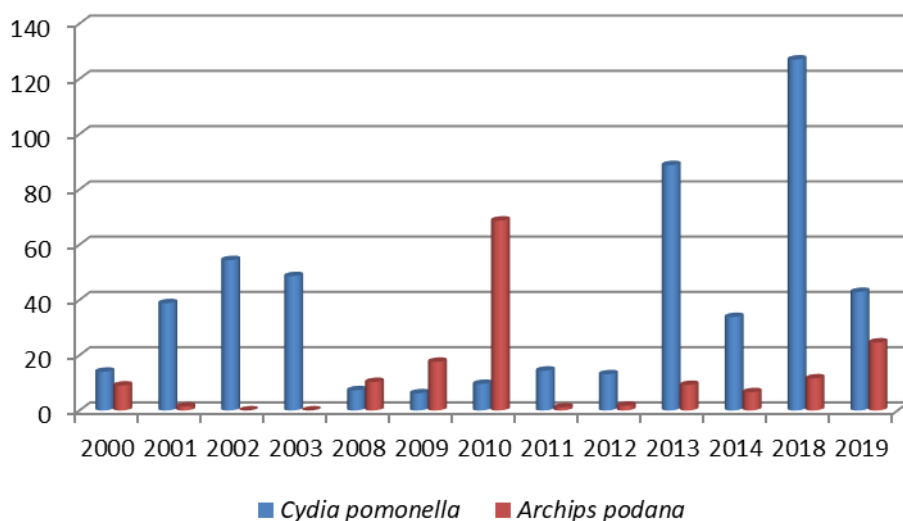


Fig. 2. Trapping *Cydia pomonella* and *Archips podana* in 2000-2019 in Pushkin.

As a general conclusion, the complex of orchard leaf rollers is a dynamic system. Their development and numbers ratio is influenced by weather conditions of a year and climate changes in general. There is a trend to complicate the tortricid species composition due to the significance growth of potential apple pests. Such pests as *Eulia ministrana*, *Rhopobota naevana*, *Choristoneura lafauryana* (Ragonot), *Pandemis dumetana* (Treitschke), and *Gypsonoma dealbana* (Frölich) can join the codling moth as important pests of apple orchards. Pheromone monitoring allows controlling the composition and dynamics of the tortricid complex. It is a reliable way for use in both industrial orchards and homestead lands.

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