DOI: 10.22620/agrisci.2024.43.008

VALIDATION OF THE PHENOLOGICAL FORECAST MODEL "RIMPRO-CYDIA 3" IN THE REGION OF PLOVDIV (CENTRAL SOUTH BULGARIA)

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Abstract

The study aimed to validate the forecast model "RIMpro-Cydia 3" for the region of the city of Plovdiv and through it to signalize the most appropriate periods for control of the codling moth *Cydia pomonella* L. (*Lepidoptera: Tortricidae*) at the conditions of Bulgaria. The observations of the phenology of the pest were conducted in the period 2020 – 2022 in apple orchards in the region of Plovdiv. The model used the data from the automatic weather station, installed in the Centre of Integrated Disease Management at the Experimental Field of the Agricultural University, Plovdiv. Comparing the prediction of the model with the observed values in the region of Plovdiv, the codling moth developea two full and partial third generations per year, which overlap. Their population dynamics and density depend both on the weather conditions and on the applied plant protection measures. The second generation of the pest had a higher density and causes greater losses to the fruit crop. In this region "RIMpro-Cydia 3" model predicted correctly the development and population density of the first generation of the codling moth, while for the second generation, the model showed significant deviations in the prediction of the population density as well as the exact development periods. The farmers have to use the model data only for the forecast of the first generation of the Codling moth. The measures for efficient control of the second generation should be signalized by direct observations in the orchards.

Keywords: codling moth, *Cydia pomonella*, phenological development, forecast model, RIMpro-Cydia 3

INTRODUCTION

The invention of models brought in a better perspective and opportunities to learn more about the pests. The recent phenological models may give information about the pest's population dynamics and accurate dates/time to apply control measures. For the farmer, it is important to be aware of the pest's life cycle and its most detrimental for the crop stage. This knowledge together with the model's information helps in taking the necessary plant protection measures.

Codling moth (*Cydia pomonella* L.; *Tortricidae*) is a key pest of apples (Barnes, 1991). Crop losses caused by the codling moth on pome fruits around the world are difficult to assess. According to Vickers & Rothschild (1991), commercial orchards using broad-spectrum insecticides can keep codling moth damage below 2%. In Nova Scotia, the degree of infestation under insecticide-free conditions varied from 6 to 10% of the entire crop in an orchard over 12 years, depending on the cultivar (MacLellan, 1977). In an orchard in Lake Ontario, USA, where one generation is developing and a partial second, similar to those in southern England, the damage ranged from 7 to 35% (Glass & Lienk, 1971). In warmer climates, where two or more generations occur, damage to apples has been reported to reach 84% in Crimea (Tanskii & Bulgak, 1981), or

between 65 to 100% in Australia (Geier, 1981).

Monitoring and control of codling moth are difficult. Visual assessment of eggs in an infested orchard is very time-consuming as the eggs are hard to find. Such approach is practical only for high populations of *C. pomonella*, and is generally inaccurate. Larval populations can be estimated by collecting and examining all the fruits (including the dropped ones) from a certain number of trees. In commercial apple orchards, larval populations can be rapidly estimated by random fruit sampling, but this provides only a relative value of the proportion of fruit damaged. Larvae and/or pupae can also be caught and monitored using trap bands (corrugated cardboard, sacking or other suitable material, wrapped around tree trunks), as the fully developed larvae use them as pupation sites. Separating generations can be difficult task. Adult males can be caught with pheromone traps baited with sexual attractant (E,E)-8,10-dodecadien-1-ol. (CABI, 2020).

Many researchers have developed phenological models for this pest, based on the thermal units (degree-days), but they are not accurate enough (Glenn, 1922; Baskerville & Emin, 1969; Batiste et al. 1973; Croft & Knight, 1983; Barnett et al. 1991; Beers & Brunner, 1992; Barnes et al. 1993; Beers et al.1993; Brunner et al. 2005 a; b). Phenological models are now used in many countries around the world to determine the need for insecticide treatment (CABI, 2020)

We decide to work with the new generation of the models as "RIMpro-Cydia", created by Marc Trapman. The idea for this model began in the 90s of the last century and includes a different approach to the use of thermal units, as well as the use of other important meteorological factors. According to the prescriptions, the model predicts both important stages of the phenological development (flight, egg laying, larval hatching) and population dynamics. Until now most validation work for the model has been done on the first generation of codling moth in The Netherlands and Belgium where only a partial second generation develops. In Bulgaria, there are two complete and partial third generations of the pest and the conditions during the summer season are quite different.

The study aimed to validate the forecast model 'RIMpro-Cydia 3' for the region of Plovdiv and, through it, to signal the most appropriate periods for the control of the codling moth.

MATERIALS AND METHODS

The survey was conducted in the period 2020 - 2022. The "RIMpro-Cydia" model (Concept 3.0/ October 2012) was available through an annual subscription and is implemented through an automatic weather station, installed in the Centre of Integrated Disease Management (CIDM) at the Experimental Field of the Agricultural University, Plovdiv.

In 2020, some data on the phenological development of codling moth were received from the Regional Office of the Bulgarian Food Safety Agency (BFSA). A delta pheromone trap (Pherocon VI; Trece incorporated) with a sticky bottom, was placed in CIDM's apple orchard (1 ha) at the end of bloom (BBCH 65-67), which gave information about the flight dynamics of the codling moth (CM). The number of males caught in the trap was reported weekly. The pheromone capsule was replaced in 45 days, according to the manufacturer`s recommendations. Sticky bottoms were replaced when soiled. Visual observations on 10 randomly placed trees were also made (twice a month) to establish the wormy fruits. Eleven insecticidal treatments were conducted in the orchard: the first two against aphids and apple sawfly with Calypso 480SC (thiacloprid); the next 9 against codling moth larvae with Madex Top (granulovirus, isolate V15) and Coragen 20SC (chlorantraniliprole). All used insecticides were suitable for IPM. Timings for

insecticide treatments were determined according to the predictions of the "RIMpro-Cydia 3" model.

In the next year (2021) in the CIDM apple orchard, a new pheromone trap with a sticky bottom was placed, at the end of the bloom of the apple trees (the middle of April). In May, pheromone dispensers for mating disruption (GINKO – 500 pieces per ha) were placed in the same orchard, which caused a collapse in catches of moths. For this reason, on the 1st of June we hang an additional pheromone trap in the organic apple orchard (0.5 ha) of the Agro-Ecological Center (AEC) at the Agricultural Uniersity, Plovdiv. The trap was checked every 10 days. In addition to the pheromone dispensers, 10 insecticide treatments were conducted in the CIDM orchard – the first one was with Dena EC (deltamethrin) against the apple sawfly and the following nine treatments - with Madex Top for CM. No pest control activities have been carried out in the organic orchard in 2021.

In 2022, the pheromone dispensers for mating disruption were placed in the CIDM orchard, at the end of bloom (the middle of April) and a pheromone trap was placed only in the organic orchard where only two treatments against CM were made, with Madex Top. In the CIDM orchard, six insecticide treatments were conducted with the same insecticide. Treatment time was determined based on the model`s prediction. Egg laying, hatching and penetration of the larvae in fruits (% wormy fruits) we established through visual observations on 10 trees in both orchards during 2021-2022. Observations were conducted every 10 days.

The information about the phenological development of the CM, obtained from observations in fruit orchards, was compared with the data from the model „RIMpro-Cydia" 3.0.

RESULTS AND DISCUSSION

In 2020 control measures for the codling moth (chemical treatment) in CIDM's apple orchard were signalized only with the help of "RIMpro-Cydia" model. Eleven insecticidal treatments were carried out at the right moments, which reduced the density of the pest and prevented large damage – the wormy fruits did not exceed 5%. Observations in 2020 (Fig. 1) showed a relatively accurate match of the actual phenological development of the CM to the predicted by the "RIMpro-Cydia 3" model (Fig. 2).

The pest had two generations during the year – the first with higher density in May and June; the second with lower density in July and August. There was a weak flight and egg laying in late August - early September, which can be explained by the appearance of a partial third generation, but with very low density. The important moments for conducting the PP control activities as the start of the flight at the end of April; the beginning of egg laying in early May; the beginning of hatching in the second ten days of May, etc. had a slight deviation, which was rather due to the irregular visual observations.

The results in the first year were very optimistic, and our view was that the "RIMpro-Cydia 3" model can help farmers by signaling the necessary deadlines for conducting PP activities related to protecting apple production from the codling moth. In 2021, in CIDM's apple orchard, ten insecticidal treatments were conducted – the first one against apple sawfly larvae and the next nine against the codling moth. At the beginning of May the pheromone dispensers for mating disruption were hung in the orchard. The dispensers were placed a month later than the usual time (late delivery). The nine treatments of insecticides were conducted because Madex Top is a microbiological insecticide and it is effective for seven up to eight days after application.

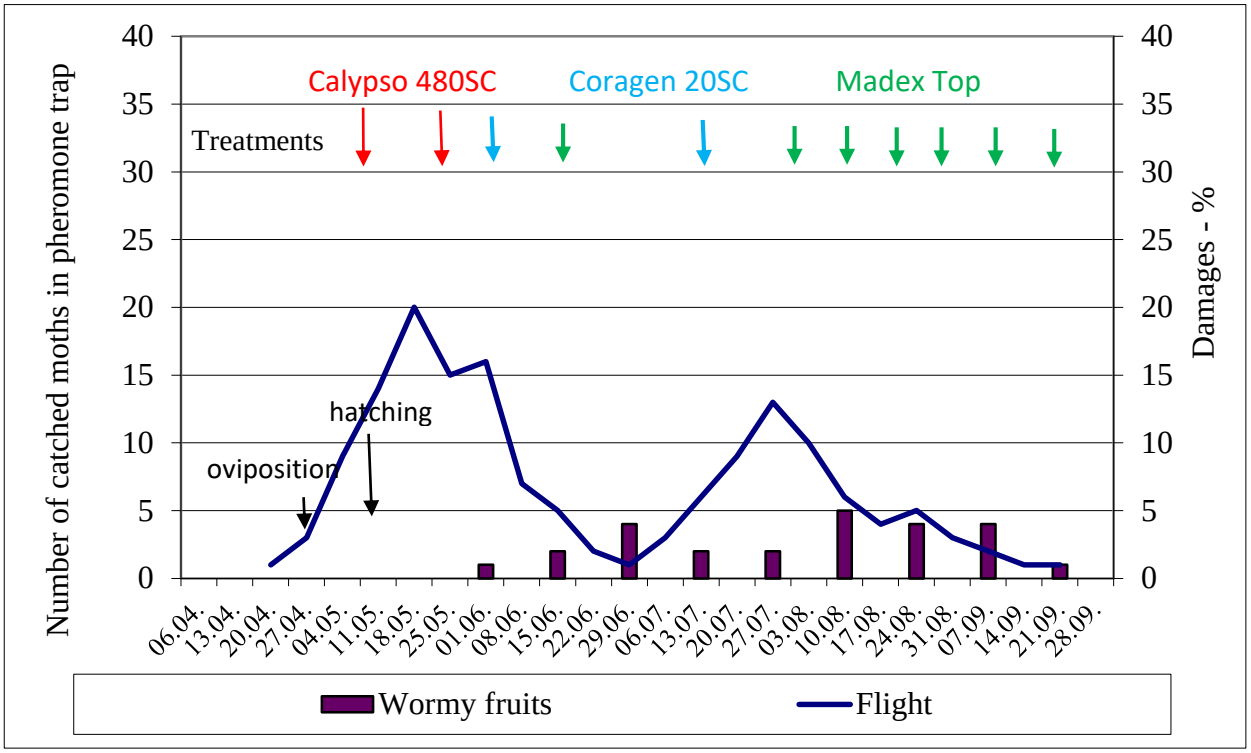

Figure 1. Flight dynamic and damages of the codling moth during 2020 in the apple orchard of CIDM at AU-Plovdiv

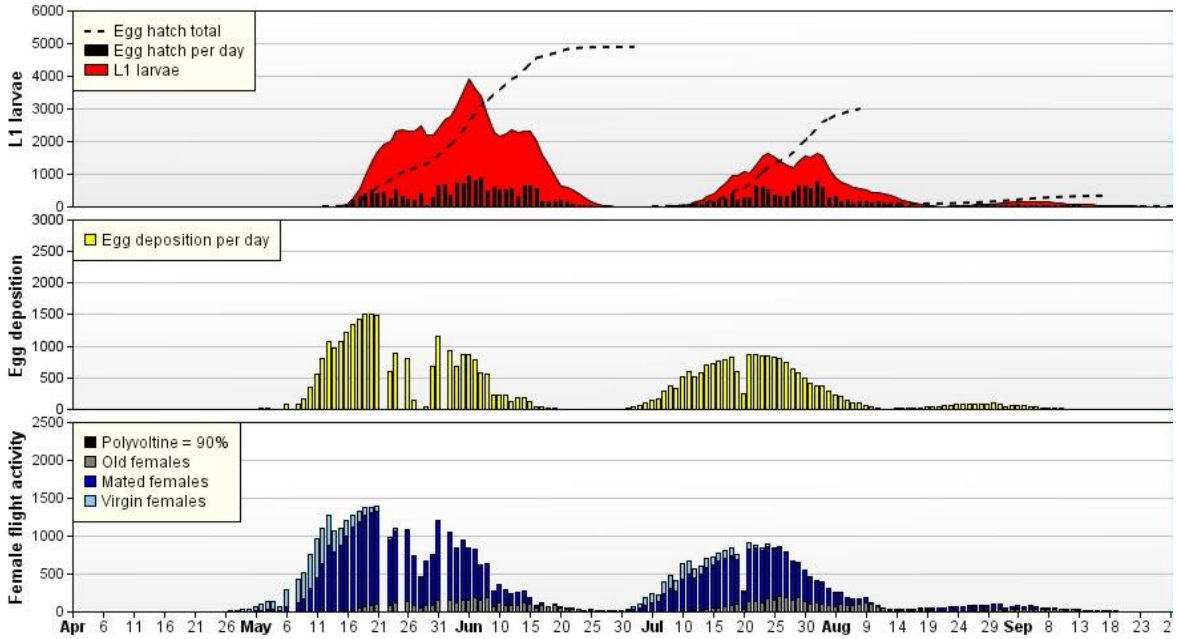

Figure 2. Phenological development of the codling moth during 2020 in the region of Plovdiv, according to the „RIMpro-Cydia 3“ model

Unfortunately, the treatment was conducted according to a fixed schedule rather than when it was proven necessary. Both methods reduced the density of the pest and prevented the fruit harvest from large damages – although the wormy fruits exceeded 10% during August, with the highest being 16% (Fig. 3). Our observation during the year showed that

the two generations of the codling moth overlapped and the second in July had a higher density (Fig. 3). Unfortunately, the information from the "RIMpro-Cydia 3" model did not correspond to the real development of the pest. The flight of the first generation, the oviposition and hatching for the model and our observation were the same but for the second generation, the model predicted low population density of the pest and a small number of eggs laid which had to lead to a small percentage of wormy fruits (Fig. 4). Actually, the second generation had higher population density and an increased percentage of wormy fruits op to 45% in the organic orchard, where in 2021 no plant protection measures have been conducted. There was a real decrease in the population density in August, but flight and damage were still observed. At this time, according to the model, the activity of the pest should almost cease. We attribute this difference to the fact that the model does not comply with the thermo-adapted population of CM in Bulgaria particularly in the region of Plovdiv. It was created by a scientist who used data from the development of the pest in northern latitudes.

The summer of 2021 in Bulgaria was very hot and dry. Our observations showed that the "RIMpro-Cydia 3" model, under such conditions, shows certain deviations in the forecast values in the second half of the growing season. For this reason, we recommend that farmers use the model data only for the first generation of the CM. The measures for efficient control of the second generation should be signalized by direct observations in the orchards.

In 2022, according to the forecast model "RimPro 3", the CM was supposed to develop two full and partial third generations, which differ over time. Due to the cool spring, the moth flight began in the third decade of April. The first generation had a higher density and developed in May and June. Due to the hot and dry summer, the second generation, which developed in June and July, had a lower density. In August, a partially third generation developed at very low density (Fig. 5).

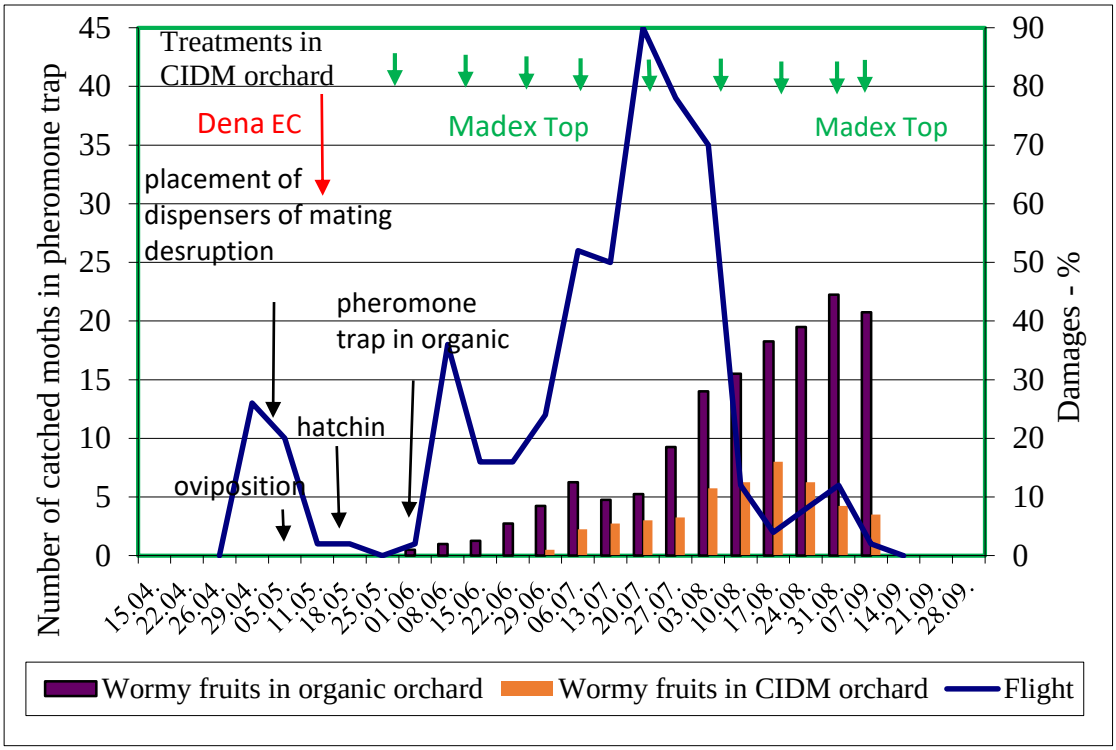

Figure 3. Flight dynamic and damages of the codling moth during 2021 in the apple orchard of CIDM and organic orchard of AEC at AU-Plovdiv

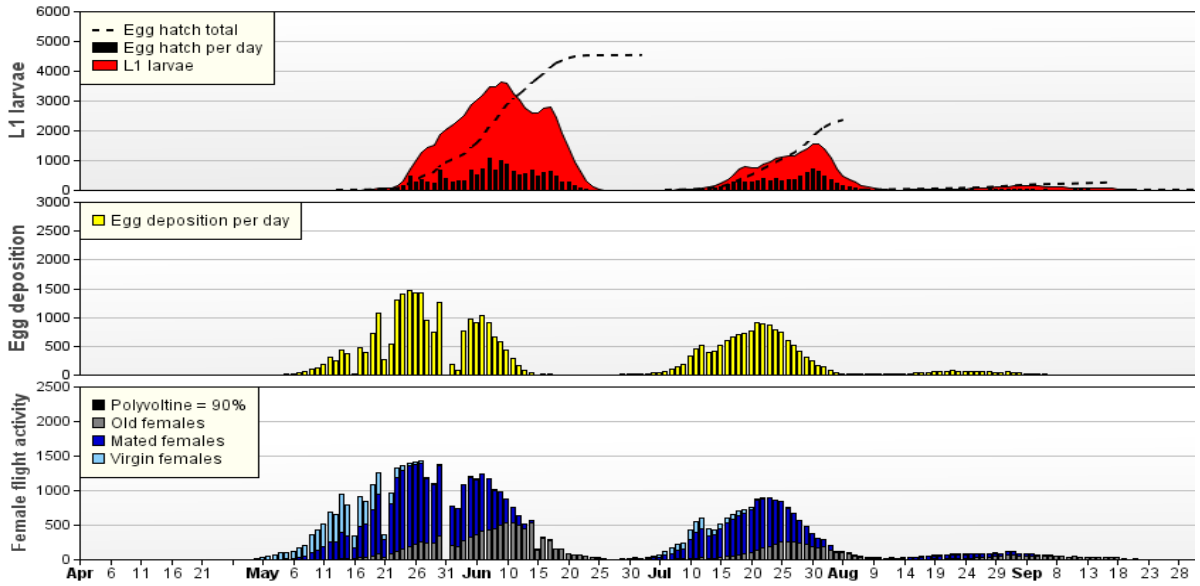

Figure 4. Phenological development of the codling moth during 2021 in the region of Plovdiv, according to the „RIMpro-Cydia 3"model

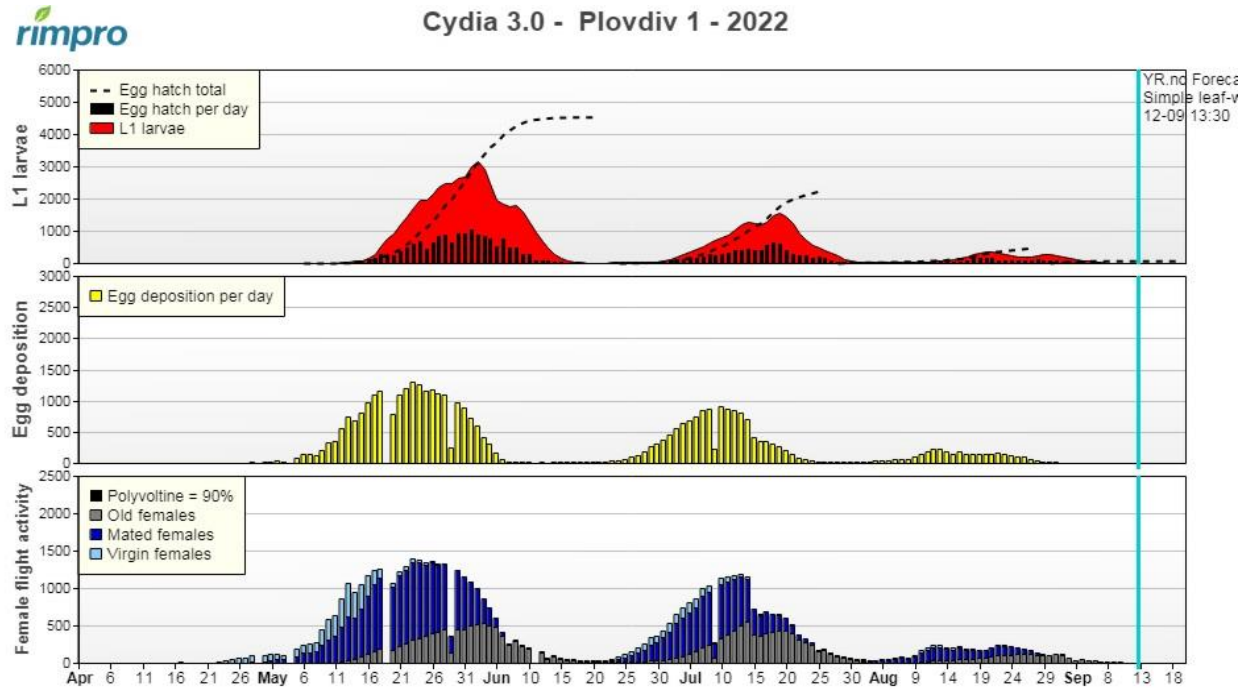

Figure 5. Phenological development of the codling moth during 2022 in the region of Plovdiv, according to the „RIMpro-Cydia 3" model

During our actual observations in the organic orchard of the AEC, we found that the pest flight occurred in several peaks and then decreased, but almost without interruption throughout the growing season. No flightless period of moths was observed between generations. The first generation developed from the end of April to the end of June, and the second in July and August, having a higher density (Fig. 6). It is impossible to say for sure whether there was a partial third generation, but if this happened, then its flight was in August when it overlapped with that of the second generation in September.

According to the model and our observations, egg-laying began in early May. The first damaged fruits - the hatching of larvae, were found in the second decade of May. This was also a match of the real data of the forecast model. Since the beginning of June, the percentage of damaged fruits began to rise. In the organic orchard (AEC), the maximum was in mid-July and did not exceed 60%. In this orchard, two treatments with Madex were conducted in 2022, but they were not sufficient for effective pest control. According to the model, the maximum of second-generation damage should also be in mid-July, but the real increase was significantly higher than predicted due to the higher density of adult individuals. The damage in August was probably caused by the third generation, but the fall of the wormy fruits led to a certain decrease.

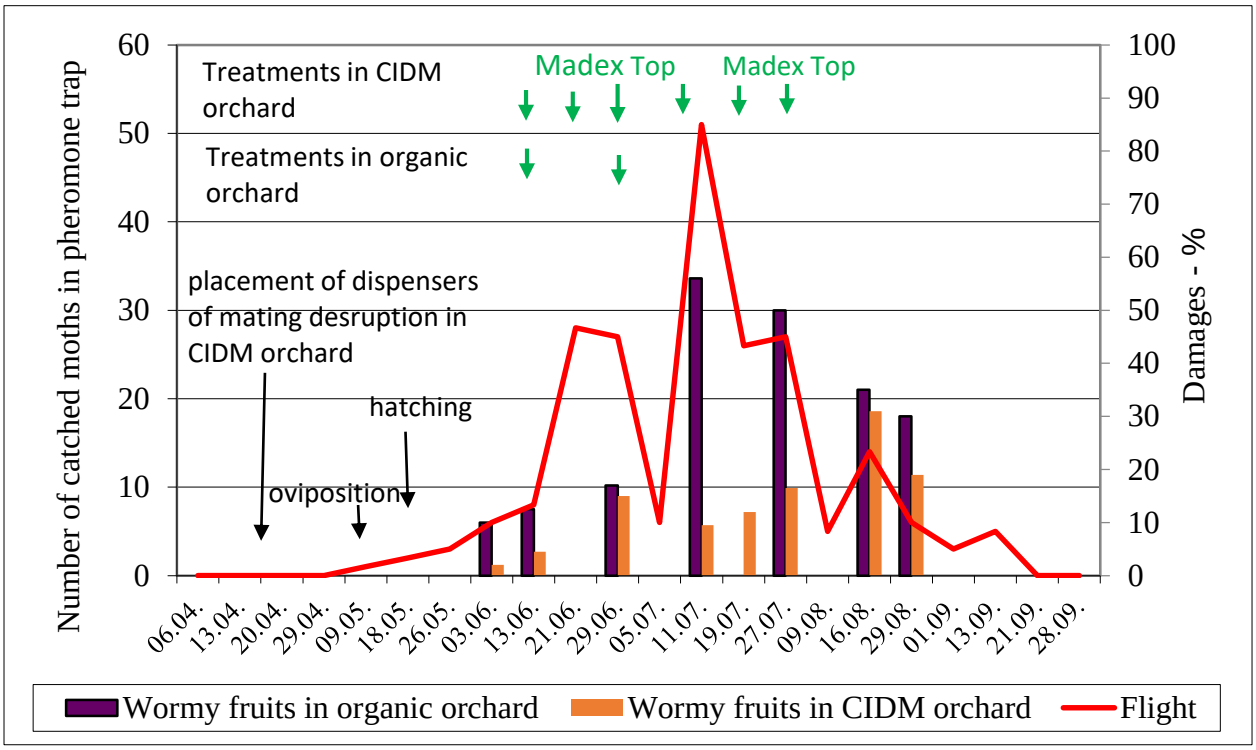

Figure 6. Flight dynamic and damages of the codling moth during 2022 in the apple orchard of CIDM and organic orchard of AEC at Agricultural University - Plovdiv

In the CIDM orchard a combined CM control system was carried out by mating disruption with sex pheromones and treating with a viral insecticide, similar to the one carried out in the previous year. Observations showed that the system relatively successfully controlled the infestation on fruits of the first generation of the pest, until the end of June. However, for the second generation, in July and August, the attack on the fruit increased and reached 30-35% in August (Fig. 6). It is known that pheromone dispensers gradually evaporate, and 2.5-3 months after insertion, their efficacy decreases by 50%. Therefore, their action must be supported at a very high density of the pest, as was done.

Observations in 2022 confirmed that the "RIMpro-Cydia 3" model predicted the emergence and phenological development of the first generation of the CM accurately. However, the forecast of the model for the second generation showed a significantly lower density than the real one and earlier development. The predicted damage from the larvae was also significantly less than the real ones. The model did not predict that generations overlap. The results were similar to those from 2021.

CONCLUSION

In the region of Plovdiv, the codling moth develops two full and partial third generations per year, which overlap each other. Their population dynamics and density depend both on the weather conditions during the year and on the plant protection control measures carried out. The second generation of the pest has a higher density and causes greater losses to the fruit crop. In the region of Plovdiv, the "RIMpro-Cydia 3" model predicts correctly the development and population density of the first generation of the codling moth. For the second generation, the model shows significant deviations in the prediction of the population density as well as the exact development periods. Farmers should use the model's data only for forecasting the first generation of the codling moth. The measures for efficient control of the second generation should be signaled by direct observations in the orchards.

ACKNOWLEDGMENTS:

The authors acknowledge the financial support by the Bulgarian National Science Fund through the research project KP-06-IP-Kitai/2 "Research on sustainable pest and disease management in apple orchards in Bulgaria and China based on precision ecological control methods".

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