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Biological Control of Codling Moth, *Cydia pomonella* (L.) in Apple Orchards of Bulgaria Using Ginko® Dispensers

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ABSTRACT

The codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae), is a significant pest of pome fruit and walnut orchards worldwide and it is a particular problem in Bulgaria. Codling moth resistance to many insecticides has been recently detected in Bulgaria. Codling moth (CM) mating disruption with Ginko® dispensers was evaluated in four successive years from 2019 to 2022 as part of an anti-resistance strategy. In an isolated 3 ha apple orchard in the Plovdiv district of South-Central Bulgaria, close to the town of Perushtitsa, field tests were conducted for the control of the codling moth (CM), *C. pomonella*, via mating disruption (MD) using pheromone Ginko® dispensers. The pheromone dispensers were hung in the upper third of tree canopies with a density of 500 dispensers/ha before CM flight started. Dynamics of CM flights was monitored by pheromone traps installed in the trial plot and in a conventionally treated reference orchard. Two types of baits were used in the traps: PHEROCON® CM L2–codlemone lures and PHEROCON® CM DA COMBO-P + AA lures (Trécé Inc., USA) in the orchards for mating disruption. The PHEROCON® CM L2 lures were changed at 4-week intervals and PHEROCON® CM DA COMBO-P + AA lures at 8-week intervals. PHEROCON® VI Delta sticky traps baited with PHEROCON CM DA COMBO- P + AA lures and standard CM L2 caps were installed, for comparison, in a reference orchard located in the Plovdiv region. Fruit infestation was periodically assessed till the harvest time. In both years fruit damage remained lower till late July and increased slightly only in August. At harvest, fruit damage remained below 1%. It was obvious that mating disruption could be useful strategy for the control of codling moth in Bulgarian apple orchards, specifically when the plot is isolated from external sources of infestation and the population density of the pest is low.

Keywords: biological control, apple, codling moth, *Cydia pomonella*, mating disruption, Ginko® dispensers

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INTRODUCTION

The codling moth (CM), *Cydia pomonella* (Lepidoptera:Tortricidae) is a major global pest of pome fruits (apples and pears) and walnuts (Reyes *et al.,* 2007; Voudouris *et al.,* 2011; Yang and Zhang, 2015; Knight *et al.,* 2019). Environmentally compatible area-wide integrated pest management (IPM) methods, such as pheromone-mediated mating disruption (Witzgall *et al.,* 2008), attract-kill strategy (Charmillot *et al.*, 2000) and sterile insect technique (SIT) (Bloem *et al.,* 2007) have been successfully used to suppress *C. pomonella* populations (Calkins and Faust, 2003; Witzgall *et al.,* 2008). However, a major limitation of these approaches is their ineffectiveness against a high density of pest population (Calkins and Faust, 2003).

Cydia pomonella (L.) is a key insect pest of apple, pear and walnut in Bulgaria. Till the present time it has been controlled by routine applications of a broad spectrum of insecticides, such as organophosphates, to maintain this pest at an economically acceptable level. Disadvantages of such practices include the mandatory restricted re-entry and preharvest intervals, strongly negative effects on beneficial species and eventually insecticide resistance. The presence of strong insecticide resistance was reported for codling moth strains collected from some orchards in Bulgaria (Charmillot *et al.,* 2007). Increasing resistance hinders effective management of the pest and thereby threatens apple production. Intensive use of chemicals is also in a strong contradiction with principles of sustainable horticulture. Hence there is an obvious and urgent need for development of less intrusive control practices, involving non-chemical, sustainable strategy.

Mating disruption (MD) is one of the alternative means of control. Pheromone-mediated mating disruption represents an important tool to manage insect pests in agriculture and forestry and relies on the release of synthetic sex pheromones from dispensers in crops, interfering with mate finding and reproduction of a pest through both competitive and non-competitive mechanisms (Benelli *et al.*, 2019). The objective of the present research was to evaluate the efficacy of the recently developed dispensers Ginko® (Summit Agro, Bulgaria) for codling moth, as an alternative method for control of this pest under Bulgarian conditions.

MATERIAL AND METHODS

Ginko ® dispensers used in the present study in apple orchards were from Summit Agro distributers in Bulgaria. The dispensers consisted of two tubes filled with pheromone; joined and sealed at each end. The tubes aligned parallel to each other do have a space in between and can be easily slipped over lateral branches of trees. Each dispenser contained pheromone mixture of (E,E)-8,10-Dodecadien-1-ol (52.4%), Dodecan-1-ol (30,6 %) and Tetradecan-1-ol (7.1%).

In the years 2019-2022, the trial was carried out in a well-isolated, 3 ha private apple orchard near the town of Perushtitsa, Plovdiv region, South-Central Bulgaria. The orchard was established in the autumn of 2014. The trial on mating disruption (MD) was carried out using Ginko® dispensers. This farmer began to use the pheromone dispensers Ginko® from 2017.

In the years of our study the dispensers were installed in April, before an expected start of CM flight. They were hung in the upper third of tree crowns, at a density of 500 dispensers/ha.

A 2.2-ha orchard located near the city of Plovdiv, served as a conventionally treated reference. Twelve treatments were applied there in 2019 season and eleven to ten in 2020 - 2022 to control CM, leaf miners, leaf rollers, aphids and mites with conventional chemical insecticides.

Monitoring of CM flights was carried out by sex trapping. All traps were installed before CM flights started. Traps were baited with standard PHEROCON® CM L2 – codlemone lures, which were changed at 4- and 8-week intervals. A new product, PHEROCON® CM DA COMBO + AA lure (Trécé Inc., USA) was also used separately for the orchards with MD during the years of study. These lures were also changed at 4- and 8-week intervals. PHEROCON® VI Delta sticky traps baited with PHEROCON CM COMBO + AA lures and standard CM L2 caps were also installed, for comparison, in a reference orchard located nearby. Fruit damage by CM was evaluated randomly from 500-1000 fruits periodically during the season and on 1000 - 2000 fruits before and at harvest. Sampling was done in both reference orchard and in the trial plot simultaneously.

Data on catches of male moths in the pheromone traps were considered as totals for each date and presented in a graphical form. Rate of fruit damage by CM was expressed as percentage of damaged fruits. Significance of differences in damage rate between the trial and reference orchards was analyzed using Chi-square tests.

RESULTS

In 2019, the first flights of codling moth in the reference orchard appeared on April 21. The flight of the overwintered generation of CM reached to maximum by the end of April (Fig. 1) to second week of May and remained till the second week of June. The flight of the second generation, which overlapped the first one, started in the last week of June with a maximum number recorded in the third week of August. The decrease in number was observed in the month of September and population was over by the 21st of September and overall, 252 moths were trapped in the reference orchard.

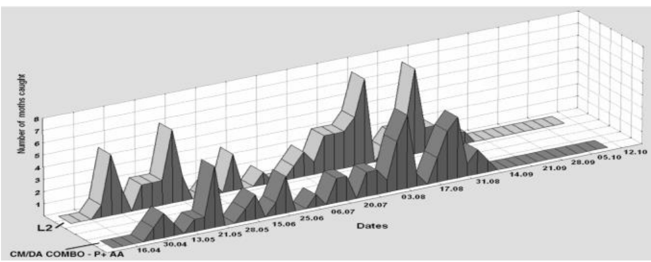

Figure 1. Number of codling moths captured in the reference orchard in 2019 with CM L2 and Combo CM DA lures.

In 2019, the first flights of codling moth in the trial orchard appeared on May 2 and the flight of the first generation finished in the second week of June. The flight of second generation began in the third week of June and finished on August 13. The population density was low. In the trial plot the new lures were fully effective and L2 traps caught 18 moths compared to 23 moths that were recorded in CMDA combo- P + AA lure traps (Fig. 2).

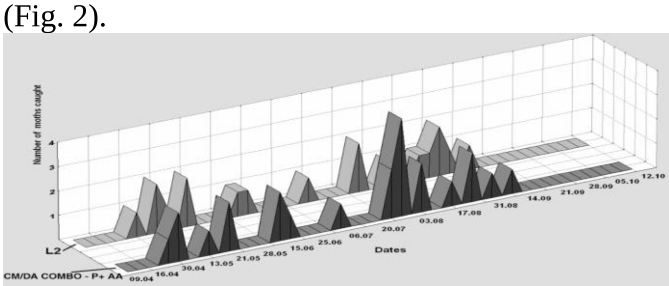

Figure 2. Number of codling moths captured in the trial orchard in 2019 with CML2 and Combo CM DA lures.

In 2020, the first flights of codling moth in the reference orchard appeared on April 24. The flight of the overwintered generation of CM reached the maximum on May 22nd (Fig. 3) and remained till the June 23rd. The flight of the second generation, which not overlapped the first one, started in the first week of July with a maximum number recorded in the second week of July. The decrease in number was observed in the month of September and population was over by the 11st of September and overall, 111 moths were trapped in the reference orchard in L2 traps, compared to 32 moths that were recorded in CMDA combo- P + AA lure traps.

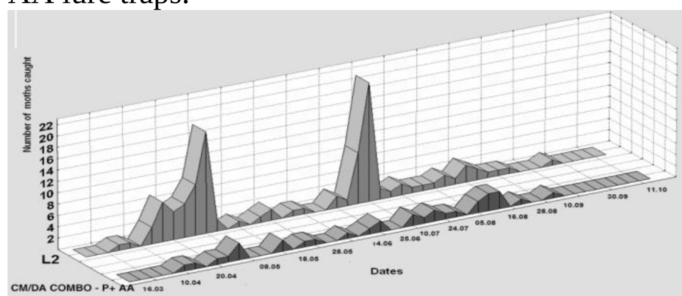

Figure 3. Number of codling moths captured in the reference orchard in 2020 with CML2 and Combo CM DA lures.

In 2020, the first flights of codling moth in the trial orchard appeared on April 29th. The flight of the first generation finished in the third week of June. The flight of second generation began in July and finished on September 4th . The population density was low. In the trial plot the new lures were fully effective and L2 traps caught 11 moths compared to 19 moths that were recorded in CMDA combo- P + AA lure traps (Fig. 4).

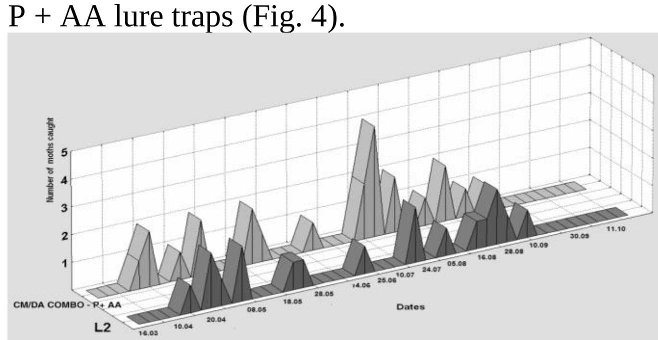

Figure 4. Number of codling moths captured in the trial orchard in 2020 with CML2 and Combo CM DA lures.

In 2021, the first flights of codling moth in the reference orchard appeared on April 30th. The flight of the overwintered generation of CM remained till the 22nd of June. The flight of the second generation started in the first week of July. The decrease in number was observed in the month of September and population was over by the 17th and overall, 123 moths were trapped in the reference orchard in L2 traps, compared to 37 moths that were recorded in CMDA combo- P + AA lure traps. (Fig. 5).

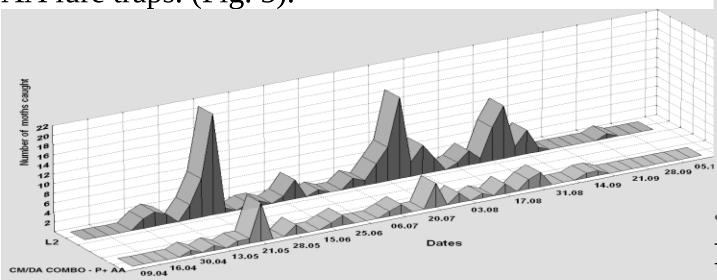

Figure 5. Number of codling moths captured in the reference orchard in 2021 with CML2 and Combo CM DA lures.

In 2021, the first flights of codling moth in the trial orchard appeared on 30th of April till the 4th of May and the flight of the first generation finished in the third week of June. The flight of second generation began in July and finished on August 26. The population density was low. In the trial plot L2 traps caught 8 moths compared to 13 moths that were recorded in CMDA combo- P + AA lure traps (Fig. 6).

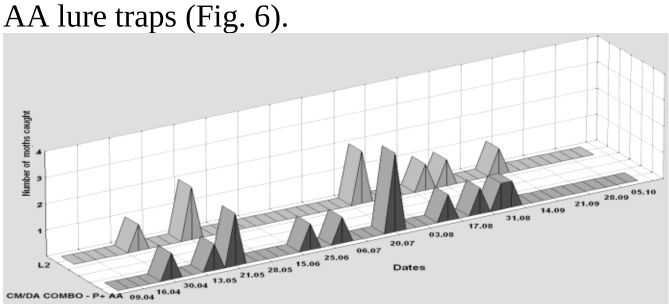

Figure 6. Number of codling moths captured in the trial orchard in 2021 with CML2 and Combo CM DA lures.

In 2022, the first flights of codling moth in the reference orchard appeared on April 28th. The flight of the overwintered generation of CM reached to maximum by the third decade of May (Fig. 7) and remained till the third week of June. The flight of the second generation started in the first week of July with a maximum number recorded in the second week of July. The decrease in number was observed in the month of September and population was over by the 19st of September and overall 104 moths were trapped in the reference orchard in L2 traps, compared to 31 moths that were recorded in CMDA combo- P + AA lure traps

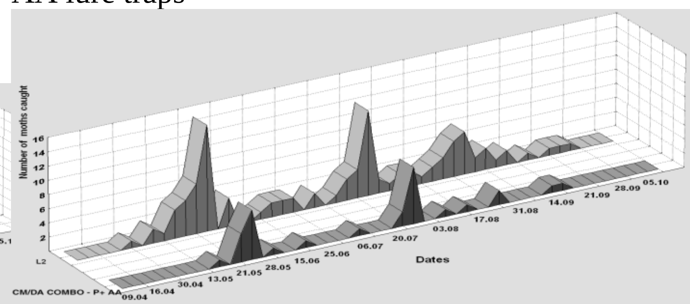

Figure 7. Number of codling moths captured in the reference orchard in 2022 with CML2 and Combo CM DA lures.

In 2022, the first flights of codling moth in the trial orchard appeared on 30th of April till the 2nd of May and the flight of the first generation finished in June. The flight of second generation began in July and finished on August 29. The population density was low. In the trial plot L2 traps caught 7 moths compared to 12 moths that were recorded in CMDA combo- P + AA lure traps (Fig. 8).

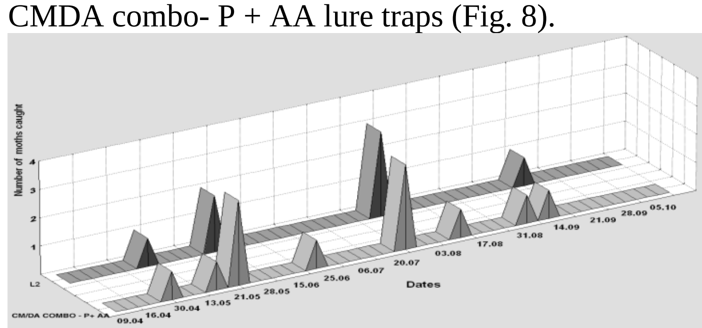

Figure 8. Number of codling moths captured in the trial orchard in 2022 with CML2 and Combo CM DA lures

The flight dynamics of codling moth in the tral orchard was non tipical due to using of pheromone dispensers for many years. The data obtained show a good efficacy of Ginko® dispensers in the control of *C. pomonella* damage, better than insecticide reference strategies. In the trial plot, where the Ginko®, dispensers were installed, no damage of fruits due to CM was noted till the last week of July in 2019-2020 and till August in 2021-2022 by both cultivars. Fruit damage was low, reaching finally to 0.1-0.2% by cultivar Golden B and 0.2-0.4% by Granny Smith at harvest. In the reference orchard, located in the same region and treated with a conventional protection programme the first signs of damage to fruitlets was recorded in June and the successive damage progressed to reach the value of 1.5–1.7% by cultivar Golden B and from 1.9- 2.2 % by Granny Smith. In 2019 - 2022, fruit damage rates were different between the treated plot and the reference orchard already at the first control in June (Chi-square tests, $P = 0.002$) and thereafter until harvest (Chi-square tests, $P < 0.001$).

DISCUSSION

C. pomonella, is causing heavy losses in apple production in Bulgaria. 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. 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. In some commercial orchards of Bulgaria, in spite of numerous treatments with chemical pesticides, fruit damage rate is still high. Conventional methods of controlling codling moth became ineffective, apparently due to appearance of CM strains resistant to commonly used insecticides. The latter was proved in the study of Charmillot *et al.* (2007), who detected resistance to organophosphates and pyrethroids by testing diapausing CM larvae collected in several Bulgarian orchards.

Intensive use of chemicals, and thereby risking pesticide resistances, is also in contradiction with the principles of sustainable horticulture. Chemical pesticides create the risk of contaminating fruits with toxic residues. Recently, the regulation of the EU banned the use of many insecticides. An alternative to conventional methods of control is the pheromone-based mating disruption (MD). Some earlier studies have demonstrated the potential of sex pheromens that could disrupt mating in codling moth, *Cydia pomonella* L. (Gut *et al.*, 1992; Gut and Brunner, 1998; Judd *et al.*, 1996; Barnes and Bloomefield, 1997; Charmillot *et al.*, 1997; Waldner, 1997; Zingg, 2001). Present study was, therefore, a timely one to demonstrate that mating disruption could be a useful strategy to control this insect under field conditions. The results obtained with mating disruption, were encouraging. Ginko®, dispensers effectively inhibited flights of CM as well as fruit damage. Our previous results with Isomate C plus dispensers received from CBC (Europe) Ltd., Milano, Italy in 2006-2008 also were quite encouraging though the dispenser load required was on higher side (Kutinkova *et al.*, 2009, 2010). Our aim in the present study was to use minimum number of dispensers with higher potential of moth control. Accordingly, Ginko® dispensers with the reduced rate of 500 per/ha in comparison with Isomate C plus (1000/ha) showed that the number of dispensers used does not affect the effectiveness of mating disruption. (Kutinkova *et al.*, 2018) reported positive results using Cidetrak® CM DA Combo™ Meso™ with reduced rate of 80 and 20 dispensers per ha for control codling moth. This was encouraging in the sense that reduced rate of dispensers used would help growers to decrease labor in the field and reduce the costs involved in the use of this technology. This would also help in reducing the pesticide load used for managing apple pest complex (Kovanci, 2017).

In conclusion, Ginko ® dispensers are effective, when used at dosage 500 dispensers per ha, applied once during the season, before the first onset of codling moth. Mating disruption could be useful strategy for the control of codling moth in Bulgarian apple orchards, specifically when the plot is isolated from external sources of infestation and the population density of the pest is low.

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