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Control of codling moth by "attract and kill" formulation in Bulgaria

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"Attract and kill" method, using LastCall™ CM, in form of a viscous paste containing codlemone to attract male moths and permethrin to kill them, has been recently proposed as a biological method for controlling codling moth, *Cydia pomonella* L. The trials were carried out in a 0.5 ha apple orchard in South-Central Bulgaria, in 2007–2008. LastCall™ CM was applied five times per season, at the dosage of 3000 droplets per ha each time. "Attract and kill" method retained sufficient level of activity for about 30 days. Fruit damage rate in the trial orchard amounted at harvest only 1.0 % in 2007 and 1.9 % in 2008, whereas in the reference, conventionally treated orchard it reached 18.7 % and 33.8 %, respectively. It has been confirmed that LastCall™ CM shows a high efficacy, regardless of the size of treated area. The "attract and kill" strategy may present a solution for small size orchards and orchards of irregular shape.

Key words: "attract & kill method", *Cydia pomonella* , diapausing larvae, flight monitoring, fruit damage, LastCall™ CM.

Introduction. The codling moth (CM), *Cydia pomonella* L. (Lepidoptera: Tortricidae), is a pest of worldwide importance in commercial apple growing (Lösel et al., 2000). In Bulgaria it causes damage to apple, pear, quince, apricot and walnut (Andreev, 2007). Currently, codling moth control relies primarily on conventional spray applications, predominantly of organophosphates and some pyrethroids. The appearance of CM strains resistant to these groups of insecticides forces to develop new methods of control compatible with the principles of integrated pest management (Croft and Riedl, 1991). As an alternative to conventional treatments, new methods were proposed, as mass trapping and mating disruption. It was reported, however, that mass trapping is not effective enough for control of codling moth (Charmillot and Baggiolini, 1975; Proverbs et al., 1975; Madsen et al., 1976; Willson and Trammel, 1980). Mating disruption has been more widely spread (Thomson, 1997;

Waldner, 1997), despite a number of problems associated with this strategy, such as needed large size of treated plots and high cost of pheromone active ingredients (Charmillot, 1990: Minsk, 1997)

Another approach based on semiochemicals is the "attract and kill" strategy, involving the combination of a semiochemical lure with an insecticidal effector (Howse et al., 1998). The principle has already been applied for control of codling moth. The "attract and kill" method was first developed by Novartis Crop Protection, Bayer and IPM Technologies. At the beginning of XXI century two "attract and kill" products for control of codling moth were distributed: Appeal 04 PA and LastCall™ CM (Sirene CM). During the last two years only LastCall™ CM was available, produced by the American company APTIV Inc. (formerly IPM Technologies).

This method has been applied with success for control of CM in many countries (Hofer, Brasel, 1992; Charmillot et al., 1996, 1997; Dickler et al., 1998: Lösel et al., 1998 a, b, 2000; Ioratti, Agneli, 2002; Pluciennik, Olszak, 2002; Pluciennik et al., 2006). The aim of this study was to test the efficacy of the "attract and kill" method for control of codling moth, as an alternative to conventional treatments in integrated fruit growing in Plovdiv region, South-Central Bulgaria.

Object, methods and conditions. The trial was carried out in isolated young commercial apple orchard of 0.5 ha, located in the village Markovo, near Plovdiv in South-Central Bulgaria, in 2007–2008 growing seasons. This orchard was established in the spring of 2005 with different apple cultivars, as 'Florina', 'Chadel' and 'Jonagold'. The first bearing was in 2007.

LastCall™ CM contains 0.16 % codlemone E-8, E-10 dodecadien-1-ol (E8,E10,-12:OH) and 6 % permethrin. It comes in an applicator tube, completed with a calibrated pump that deposits metered droplets of the product. Each droplet is 50 microlitres in volume. The dosage is 3 000 droplets per ha. Tubes are packed with 150 grams formulation or 3000 droplets. In our trial, LastCall™ CM was applied five times during the entire season; three droplets per tree and 3 000 droplets per ha were put at every application. Droplets were placed either on the central leader or on branches in the upper third of the canopy, where codling moths are the most active. The first application was performed before appearance of the first CM males in the pheromone traps installed; next they were made at four to five week intervals. Each application required approximately 3 man-hours per ha.

Another commercial orchard of 1.8 ha located in the same region served as a conventional reference. 16–18 treatments were applied there during the season to control CM and other pests.

During the season, sampling of fruit damage has been carried out on 1 000 fruits in the reference and in the trial plot. Preharvest and harvest checks for damage were carried out in September and October on 2 000 fruits. In June, 20 corrugated cardboard band traps were wrapped around tree trunks in the trial plot and 40 band traps in the reference. They were recovered in autumn and diapausing larvae were counted, in order to estimate the hibernating population of CM.

Results. In 2007 in the reference commercial orchard in Plovdiv region, the first flight of CM began on April 10, successively intensified to reach its maximum by the second decade of the month. The second peak appeared in the second decade of

May. Flight of the second generation, which did not overlap the first one, started at the beginning of July, reached its maximum during the second decade of the month and then declined. However, another peak of flights appeared in the third decade of August. The flights finished on the 19th of September (Fig. 1).

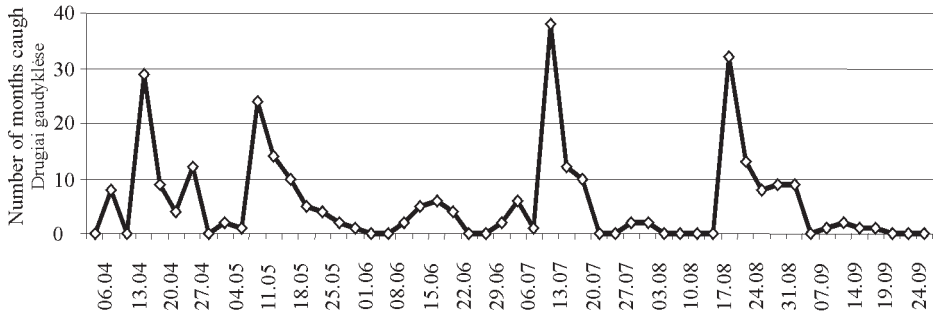

Fig. 1. Dynamics of CM flights in the reference orchard near Plovdiv in 2007
1 pav. Obuolinio vaisėdžio skraidymo dinamika modeliniame Plovdivo regiono sode 2007 m.

In 2008, the first flight of CM in the reference orchard began on April 12 and successively intensified to reach the first maximum by the third decade of April (Fig. 2). The second peak appeared in the first decade of May. Flights of this generation continued, albeit with a rather low intensity, in June. Flights of the second generation, which overlapped the first one, started in the third decade of June and reached its maximum during the second decade of July. However, another peak of flights appeared in the first decade of August. The flights finished on the 15th of September.

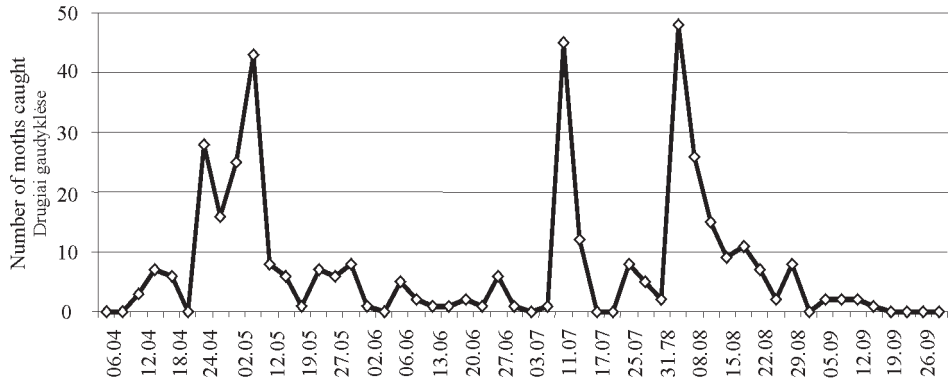

Fig. 2. Dynamics of CM flights in the reference orchard near Plovdiv in 2008
2 pav. Obuolinio vaisėdžio skraidymo dinamika modeliniame Plovdivo regiono sode 2008 m.

For the whole season, two traps installed in the reference orchard caught 291 moths in 2007 and 390 in 2008. In the trial plot the pheromone traps caught only 3 moths during the whole 2007 growing season and 5 moths in 2008. The "attract and kill" efficacy of LastCall™ CM remained relatively stable over a period up to four weeks, after that it began to decrease. In the summertime, mainly in July, few codling moths appeared in the pheromone traps installed in the trial plot. Then the next application of LastCall CM was immediately executed, to avoid any damage to fruits.

In 2007, damage rate in the trial plot was nil on June 8 (Table).

Table. Evolution of fruit damage and of the overwintering population of CM in the trial plot and in the reference orchard in successive years

Lentelė. Peržiemojusios kartos obuolinių vaisėdžių padarytų pažeidimų tendencija bandomuosiuose ir tradiciniuose soduose vėlesniais metais

Index Indeksas	Date Data	Trial Bando-mieji sodai	Reference Tradiciniai sodai	Date Data	Trial Bando-mieji sodai	Reference Tradiciniai sodai
	2007 year / metai			2008 year / metai		
Fruit damage Pažeisti vaisiai (%)	June Birželio 8 d.	0	0.3	June Birželio 3 d.	0.0	0.2
	June Birželio 26 d.	0	22.4	June Birželio 19 d.	0.2	1.4
	July Liepos 7 d.	0.5	0.0	July Liepos 3 d.	0.4	0.8
	July Liepos 14 d.	0.6	1.9	July Liepos 17 d.	0.5	1.7
	August Rugpjūčio 10 d.	0.7	2.1	August Rugpjūčio 13 d.	0.6	2.3
	August Rugpjūčio 25 d.	0.8	9.8	August Rugpjūčio 27 d.	1.2	4.8
	September Rugsėjo 3 d.	1.0	12.3	September Rugsėjo 5 d.	1.3	26.3
	October Spalio 5 d.	1.0	18.7	September Rugsėjo 26 d.	1.9	33.8
	Preharvest Prieš nuimant derlių	1.0	12.3	Preharvest Prieš nuimant derlių	1.3	26.3
	At harvest Derliaus nuėmimo metu	1.0	18.7	At harvest Derliaus nuėmimo metu	1.9	33.8
Chi-square test	Chi-square = 86.124	p = 0.0001		Chi-square = 122.57	p = 0.0001	
Larvae per tree Lervų ant medžio	After harvest Nuėmus derlių	0.250	7.97	After harvest Nuėmus derlių	0.550	9.82
t-test	t = 3.612	p = 0.0098		t = 2.988	p = 0.0136	

Then it reached 0.6 % in the second decade of July and increased slightly – to 0.8 % during the third decade of August; at harvest it reached only 1.0 %. In the reference orchard near Plovdiv, with conventional treatments, fruit damage progressed from 0.3 % on June 8 up to 18.7 % at harvest.

In 2008, damage rate in the trial plot was nil on June 3, then it reached 0.5 % in the second decade of July and increased slightly – to 1.2 % in the third decade of August; at harvest it reached 1.9 %. In the reference orchard with conventional treatments fruit damage progressed from 0.2 % on June 3 up to 33.8 % at harvest.

The overwintering population of CM in the trial plot was only 0.250 larvae per tree in the autumn of 2007. At the same time in the reference orchard located in the vicinity the overwintering population reached a very high value of 7.97 larvae per tree. In the autumn of 2008 the overwintering population in the trial plot was 0.550 larvae per tree, whereas in the reference orchard as much as 9.82 larvae per tree.

Damage rates were significantly different between trial plot and reference already in late June and thereafter until harvest (Chi-square tests, $p < 0.001$). The population sizes of diapausing larvae were significantly different between treated with LastCall™ CM plot and the reference orchard over both years of study (t-test, $P < 0.05$).

Discussion. The "attract and kill" technique using LastCall™ CM was effectively protecting apples from infestation by codling moth what was indicated by scarce flights, low fruit damage and a low level of the hibernating population in the trial plot. Albeit the overwintering population of CM evolved from 0.250 larvae per tree in the autumn of 2007 to 0.550 larvae per tree in the autumn of 2008 it still stayed relatively low. This confirmed the findings of Hofer and Brasel, 1992, Charmillot et al. 1996, 1997; Dickler et al., 1998; Lösel et al., 1998 a, b, 2000; Pluciennik, Olszak 2002, 2006. The trial orchard was isolated, so no sources of external moth infestation were present. According to Charmillot et al., 2000, this is essential for an acceptable effectiveness of the "attract and kill" strategy. The LastCall™ CM treatments nearly completely eliminated catches of male moths in pheromone traps, and this effect was noticed immediately, starting from the day of application. This indicates that pheromone droplets quickly and successfully prevent the calling activity of the CM females. Under conditions of the South-Central Bulgaria the "attract and kill" method apparently requires, on an average, five applications of LastCall™ CM per season. The first application has to be performed when first onset of CM appears in the reference lot, notwithstanding missing moths in the lot treated with the "attract and kill" agent. Considering the common beginning of flights in the region, this must be done in the second decade of April. The second treatment should be applied after four to five weeks. The dates of the next treatments depend on weather conditions, but usually should be performed at 4–5 week intervals, too. When these rules are followed, the treatments are fully effective till the end of the season. The "attract and kill" method is rather laborious, as in our study it took 3 man-hours per ha for every application.

The results of two-year experiments do confirm that the "attract and kill" method may be effective when the population level of *Cydia pomonella* is medium or low and when the fruit damage in the preceding year was below 2 % as a result of correct application of conventional control treatments. The advantage of this method consists in that

it may be applied in orchards having non-standard characteristics, as small surface or irregular shape. In view of the appearance in Bulgaria of CM resistance to pyrethroids, to which belongs permethrin (Charmillot et al. 2007), it is necessary to consider also the other alternatives as mating disruption or granulosis virus products.

Nevertheless, the method under study is fully compatible with any IPM strategy. According to Charmillot et al., 2000, the great advantage of this method is that it requires less than 1 g of the expensive codlemone per ha during the season. Therefore, it may present a valuable complement to mating disruption, especially for medium or small-size plots.

Conclusions. 1. A new "attract and kill" method is a semiochemical approach that is effective in controlling codling moth and is acceptable for integrated fruit production.

2. In the fruit region of South-Central Bulgaria, according to the length of codling moth activity, five applications per season guarantee long protection during season.

3. The "attract and kill" strategy is very suitable to small-size orchards and tot orchards of irregular shape.

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Obuolinių vaisėdžių kontrolė „priviliok ir nužudyk“ metodu Bulgarijoje

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Santrauka

Metodas „priviliok ir nužudyk“, panaudojant lipnios pastos pavidalo LastCall™ CM, kurio sudėtyje yra kodlemono, priviliojančio vyriškos lyties vaisėdžius, ir juos nužudančio permetrino, neseniai buvo pasiūlytas kaip biologinė obuolinių vaisėdžių (*Cydia pomonella* L.) naikinimo priemonė. 2007–2008 metais atlikti bandymai 0,5 ha obelų sode Pietų ir Vidurio Bulgarijoje. LastCall™ CM naudotas penkis kartus per sezoną po 3 000 lašų hektarui. Metodas „priviliok ir nužudyk“ išliko gana veiksmingas maždaug 30 dienų. Bandomajame sode nuimant derlių 2007 metais vaisiai buvo pažeisti tik 1,0 %, 2008 metais – 1,9 %, o tradiciniame sode – atitinkamai 18,7 ir 33,8 %. Buvo patvirtinta, kad LastCall™ CM yra labai veiksmingas, nesvarbu koks apdorojamo ploto dydis. „Priviliok ir nužudyk“ metodas gali būti tinkamas sprendimas naikinti obuolinius vaisėdžius mažuose ir netaisyklingos formos soduose.

Reikšminiai žodžiai: metodas „priviliok ir nužudyk“, *Cydia pomonella*, diapauzuojančios lervos, skraidymo valdymas, vaisių pažeidimas, LastCall™ CM.