

**USE OF PHEROMONES FOR MONITORING AND CONTROL
OF MAIN PESTS OF APPLE IN BULGARIA**

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Abstract

The trials were carried out in Bulgaria in the years 2006-2008. The possibilities for reducing the number of treatments with chemical insecticides against pests in apple orchards of Bulgaria, by use of synthetic sex pheromones have been studied. In some species this reduction may be due solely to an adequate monitoring strategy implemented by pheromone traps, indicating the most appropriate time for treatment, thus avoiding inappropriate sprays. The pests that may be successfully controlled using this strategy are leaf miners, apple sawfly, San Jose scale, apple clearwing and leopard moth borer. The key pest of apple – codling moth (CM), *Cydia pomonella* L., which has shown the high resistance to most chemical insecticides used, can be successfully controlled using the method of mating disruption (MD), consisting in disorientation of males, by dispersion of the synthetic pheromone over an orchard lot. A significant reduction of population density of this pest is possible through a combination of mating disruption with application of virus insecticides. The present review paper contains a summary of the selected, most important results of investigations on use of sex pheromones for management of apple pests, carried out by the authors in Bulgaria.

Keywords: apple pests, codling moth, sex pheromones, flight monitoring, mating disruption, Bulgaria

Introduction

Apple trees are infested in Bulgaria by a large number of pests. Codling moth, *Cydia pomonella* L., is undoubtedly the key pest of apple. The other ones are leaf miners, apple sawfly, San Jose scale, apple blossom weevil, aphids and red spider mite. Recently the population of leaf chewing caterpillars, apple clearwing and leopard moth borer has been also increasing. Unfortunately, most of farmers still follow conventional technologies of plant protection that imply a massive use of various chemical compounds for crop protection. However, conventional methods have shown a number of disadvantages. The great extent of chemicals used leads to a negative impact on the environment as well as on human health, if residues persist on the crop till harvest time. Moreover, repeated use of pesticides induced development of resistant strains of some pests, thus resulting in ineffectiveness of chemical control. In case of codling moth it was documented by Charmillot et al. (1999), followed by Charmillot and Pasquier (2002) in Switzerland and later in Bulgaria (Charmillot et al. 2007). For these reasons in many European countries as well as in the USA and Canada, ecologically approved methods of pest management gained a wide application. It is necessary to introduce these technologies in Bulgarian orchards as soon as possible.

Sex pheromones are harmless and effective means for monitoring and control of pests. Pheromone traps have been widely applied in the world plant protective practice as additional means or substitute to the laborious, traditional methods for monitoring of the insect pest species (Wright 1970, Giannotti and Orlando 1975). Pheromone traps have been also used in Bulgaria for determination of the date of appearance of the most important insect pests of apple and for monitoring their flight dynamics. Pheromones of different origin and traps of different shape have

been tested for monitoring of different pests in our investigations (Kutinkova et al 1997, Kutinkova and Subchev 1998, Kutinkova and Arnaoudov 2001, Kutinkova and Andreev 2001, 2002, 2002a, 2003, Kutinkova et al. 2006, 2006 a, 2008, 2009).

For the key pest of apple, codling moth, the investigations on use of pheromone traps were initiated by Kutinkova (1984). The parameters of traps for this species were established, i.e. the necessary number of traps installed per hectare, height of installation above the ground, and scheme of distribution. For monitoring flight dynamics of codling moth, the traps with pheromone dispensers and sticky bottom, type Pherocon® 1C, Pherocon® VI Delta, all of Trécé Inc. (USA) were mainly used. During the last years black “delta” traps supplied with the capsules of PheroNet Sweden were used. Satisfactory results were obtained changing lures only once per season (Kutinkova et al. 2009).

The first trial on mating disruption (MD) of codling moth in Bulgaria was conducted in the years 1998-1999 at the Experimental Field of the Agricultural University in Plovdiv. Pheromone dispensers of BASF (Germany), i.e. RAK 3+4 were used. Those experiments, provided unsatisfactory results, due to small orchard size, high initial CM population density and missing isolation from migration of codling moths from heavily infested orchards in the neighbourhood (Kutinkova and Andreev 2003).

Isomate-C dispensers, emitting synthetic CM pheromones, were released by Shin-Etsu (Japan) in 1989 and then improved and successfully applied in many countries (Veronelli and Iodice 2004). They were intensely tested by Kutinkova et al. (2009, 2010). At high codling moth pressure, indicated by high initial fruit damage and/or by high hibernating larvae population, granulosis virus products may be helpful as another biological means of control, complementary to mating disruption (Charmillot and Pasquier 2002a). Recently the combination of MD with a virus product, was tested in Bulgaria by Kutinkova et al. (2012).

The most important results of trials on application of pheromones for management of apple pests have been summarized in the present paper.

Material and methods

Trials on mating disruption

Mating disruption, as alternative method for control of codling moth was tested in different regions of Bulgaria. Locations of particular trials as well as area of trial (MD) plots are indicated in the table 2, in the section of RESULTS. For trial plots isolated apple orchards were selected. As reference, served some commercial, conventionally treated orchards, located in the vicinity. Isomate C Plus dispensers, product of Shin Etsu (Japan), each loaded with a minimum of 190 mg of the codling moth pheromone mixture, were applied at the density of 1000 pieces per ha. The dispensers were installed in the upper third of the canopy, before the start of CM flights (at the beginning of April). No insecticides against CM were employed in the trial plots. Occasionally 1-2 treatments of acaricides or aphicides were applied.

Similar, though conventionally treated orchards, located in the vicinity served as reference. In these orchards from 12 to 15 treatments with different chemical pesticides were applied.

The trial on MD, combined with application of the virus product for controlling CM

In an orchard, located at Samuilovo, Sliven District, South-East Bulgaria, the CM pressure was extremely high, as indicated by initial fruit damage (see Table 3). Under these conditions Madex®, the preparation containing the granulosis virus of codling moth (CpGV), product of Andermatt Biocontrol (Switzerland), was applied as complementary measure, ten times per season (at 10-14-day intervals), at a full recommended dosage of 100 ml/ha ($3 \cdot 10^{12}$ granules/ha) every time. The Madex treatments were combined with fungicide treatments till the end of June, then applied alone, without fungicides, from July on. As in the trials on mating disruption alone, the appropriate reference orchard was used as conventional reference.

Monitoring of CM flights by use of pheromone traps

In the reference as well as in trial plots two triangular traps with a standard capsule (Pheronet OP-72-T1-01), containing 1 mg codlemone were placed every year. The traps were always installed prior to the beginning of flight of CM, then checked twice a week; the caught male moths were

counted and removed. In trial plots catches were scarce or nil. Hence flight dynamics of codling moth in different regions was followed in conventionally treated orchards, serving as reference.

Evaluation of fruit damage

The final damage by CM was evaluated by inspection of 3000 or 2000 apples just before harvest or after harvest. The rate of fruit damage was expressed in percentages.

Evaluation of hibernating population of CM

In June, corrugated cardboard band traps were placed on the trunks of 40 trees in every trial plot and in every reference orchard, 8 at the border and 32 inside the each plot. They were recovered in autumn, after harvest and the found hibernating CM larvae were counted. The CM population density was expressed as number of hibernating larvae per tree.

Results and discussion

Flight dynamics of codling moth

It was found that in Bulgaria codling moth (CM), develops at least two full generations that usually overlap each other. Only in the hilly area, at higher altitudes, the second generation may be less numerous. In relatively warmer regions, like South-East Bulgaria, a partial third generation was recorded in the second half of August and in September of the warm years (Fig. 1).

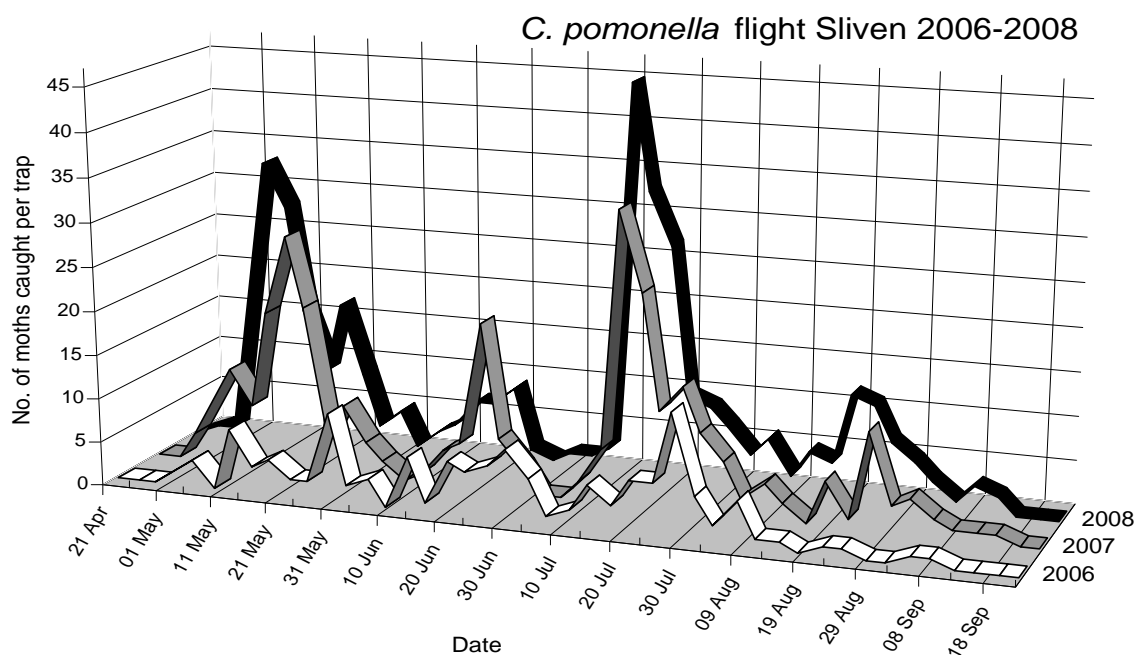


Fig. 1. Dynamics of CM flights in Sliven district, South-East Bulgaria in the years 2006-2008

In the plain land areas of Bulgaria, CM flights usually started at the end of April and lasted with varying intensity till about mid-September; the earliest and the latest flights over the passed years were noted in South-Central Bulgaria, beginning from April 10, (in the Plovdiv district in 2007) and ending as late as on October 3 (in the Stara Zagora district in 2006) – Table 1. It is worth noting that the number of moths caught in the reference orchards, treated with conventional pesticides was, in general, increasing during three years of study.

The results obtained in this study, were confronted with those obtained by Kutinkova (1984) in early 80'ies of the 20th century. At that time the CM flights in the Central-South Bulgaria started later and finished earlier; no signs of the third generation was noted. The apparent acceleration and intensification of the development of codling in Bulgaria over the period of more than 30 years may be attributed to the phenomenon of global warming.

Table 1. Dates of the first and last flight and total catches of CM in different regions and different seasons

Region of Bulgaria	Latitude North	Altitude above sea level	Year	Dates of:		Total catches per trap
				first flight	last flight	
Stara Zagora district South-Central	42°32'	~240 m	2006	April 24	October 3	260
			2007	April 20	September 28	288
			2008	April 23	September 16	311
Plovdiv district South-Central	42°22'	~150 m	2006	April 26	September 17	73
			2007	April 10	September 19	145
			2008	April 12	September 15	195
Sliven district South-East	42°40'	~250 m	2006	May 2	September 9	64
			2007	April 30	September 14	141
			2008	April 25	September 14	179
Bourgas district South-East (Pomorie)	42°64'	~30 m	2006	May 3	September 4	40
			2007	April 27	September 18	126
			2008	April 25	September 15	153
Pleven district North-Central	43°25'	~75 m	2007	May 1	September 18	103
			2008	April 24	September 11	82

Incidence of codling moth in conventional orchards and resistance to pesticides

Under conditions of Bulgaria fruit damage by codling moth, without any control, may exceed 80%. To avoid losses of crop, apple growers routinely apply different insecticides targeted this pest, 12-15 times during the season. Commonly used pesticides against CM are mainly organophosphates and pyrethroids. In spite of numerous treatments, rate of fruit damage by CM was in the studied conventional orchards high and progressively increased in successive years (Fig. 2A). The records of hibernating larvae population in these orchards also indicated at the increasing pressure of the pest (Fig. 2B). Apparently the populations of CM in conventionally treated orchards under study were already resistant to the pesticides used. This interpretation of the noted trends seems reasonable in view of the report of Charmillot et al. (2007), who detected populations of CM resistant to organophosphates and pyrethroids by testing diapausing CM larvae from some apple orchards of South Bulgaria. In that study, efficacy below 20% was found in case of indoxacarb, imidacloprid, azinphos-methyl, phosalone and deltamethrine.

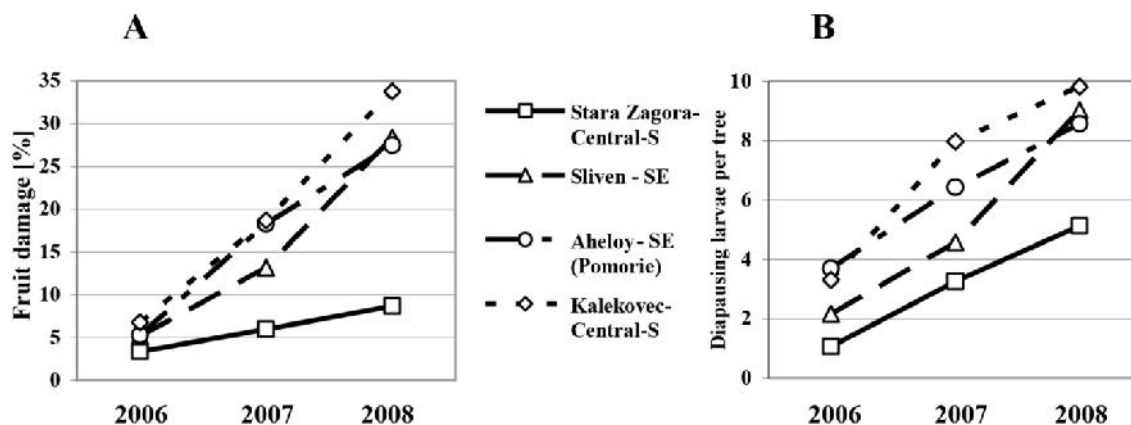


Fig. 2. Fruit damage by CM at harvest (A) and diapausing larvae per tree in corrugated paper bands (B) in four conventionally treated apple orchards in successive years

Effectiveness of mating disruption in control of codling moth

During the three years of study positive results were obtained in different orchards of the South-Central Bulgaria and South-East Bulgaria. The most important results of these trials are summarized in the Table 2.

Table 2. Results of trials on control of codling moth, by mating disruption, with use of Isomate C plus dispensers applied once per season

Location & altitude	Region of Bulgaria	Trial area [ha]	Initial fruit damage [%]	Year	Fruit damage at harvest [%]		Diapausing larvae per tree in autumn	
					trial	reference	trial	reference
Bogomilovo ~240 m ^{1,2}	Stara Zagora distr. South-Central	4.0	~2.0	2006	0.06	3.40	0.075	1.075
				2007	2.10 ¹	6.00	1.271	3.263
				2008	1.30	8.70	1.800	5.133
Glufishevo ~145 m ³	Sliven distr. South-East	1.0	~5.0	2006	0.35	5.20	0.125	2.175
				2007	0.40	13.20	0.225	4.575
				2008	0.70	28.40	0.425	9.025
Malka Vereya ~300 m ⁴	Stara Zagora distr. South-Central	1.7	~2.0	2007	0.03	5.20	0.225	3.263
				2008	0.60	5.70	0.325	5.133

¹ The neighbouring pear trees were not treated and were probably a source of CM infestation at the end of the season

² Kutinkova et al. 2009a; ³ Kutinkova et al. 2010; ⁴ Own unpublished data

Virus products as complementary measures to control codling moth

Trials, carried out for two years in the orchard where initial damage rate exceeded 30% (according to the grower), has shown a high efficiency of mating disruption with Isomate C plus, combined with 10 applications of the virus product Madex[®] (Andermatt Biocontrol AG, Switzerland) per season at the rate of 100 ml per ha. Fruit damage in the trial plot was considerably reduced and the population of diapausing larvae successively decreased. In the reference orchard damage rate and the hibernating CM population dramatically increased, in spite of numerous conventional insecticide treatments.

Table 3. Results of trials on control of codling moth, by mating disruption, with use of Isomate C Plus dispensers, combined with applications of the virus product Madex[®]

Location & altitude	Region of Bulgaria	Trial area [ha]	Initial fruit damage in trial [%]	Year	Fruit damage at harvest [%]		Diapausing larvae per tree	
					trial	reference	trial	reference
Samuilovo 140-160 m ¹	Sliven district South-East	0.8	>30	2006	d.m. ²	6.1	d.m. ²	2.16
				2007	2.5	14.8	1.05	4.58
				2008	2.2	28.4	1.65	9.03

¹ Kutinkova et al. 2012; ² d.m. – data missing for the trial plot

Conclusions

Considering demand of the market for fruits free of chemical residues and concerns about pollution of the environment, the use of chemical pesticides in Bulgarian fruit production should be reduced or eliminated wherever possible.

Decreasing efficiency of conventional fruit protection – due to development of resistance of key pests to most of the insecticides used – is an additional argument for the search of alternative, non-chemical means of control.

Monitoring of pests may be helpful in reducing the number of treatments, by more precisely timing them.

Mating disruption may be an effective method of pest control, provided that the specific principles are followed: adequate size and shape of an orchard lot, isolation of the orchard as well as proper timing of treatments and right installation of dispensers. Under these conditions Isomate C plus dispensers of Shin-Etsu may be very effective in control of codling moth in apple orchards with a low or moderate population density of CM.

In the orchards with a high initial population density, a combination of MD with application of products containing CM granulosis virus may be a perspective method. Installation of Isomate C dispensers combined with application of Madex[®] leads to decrease of the fruit damage by codling moth. To reduce substantially CM population in that kind of orchards, this method should be applied consequently in successive years.

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