Regulation of plum moth (*Cydia funebrana*) with mating disruption and entomopathogenic nematodes in organic orchards

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Abstract

As a control strategy against the plum moth (Cydia funebrana) the pheromone dispensers 'Isomate OFM Rosso' for mating disruption were field tested in different organic plum orchards from 2007 to 2009 in Germany. We found efficacies for the mating disruption of up to 70 % at moderate infestation levels but the efficacy is limited at infestation levels above 4 % infested fruits and border influences have to be considered. In 2008 the field trials were expanded by an evaluation of the efficacies of entomopathogenic nematodes against diapausing plum moth larvae in order to develop a combined control strategy for organic plum growing.

Keywords: Plum moth, mating disruption, 'Isomate OFM Rosso', entomopathogenic nematodes (EPN)

Introduction

A project titled "Evaluation und optimization of biological methods for regulation of plum moth (*C. funebrana*)" has been conducted from 2007 to 2009 in cooperation of FA Geisenheim, JKI Darmstadt, LVWO Weinsberg, DLR Rheinpfalz-KoGa and LfULG Dresden and was funded by the German Federal Agency for Agriculture and Food within the 'Bundesprogramm Ökologischer Landbau' (06OE348, 06OE057 and 06OE198).

Mating disruption with pheromones may be one way to regulate the plum moth (*C. funebrana*) in organic orchards. The dispensers release female sex pheromones which disrupt the male's sensory ability to locate and therefore mate with the females. The efficacy of 'Isomate OFM Rosso' dispensers were evaluated from 2007 to 2009 in different orchards with different plum varieties. In Germany there is no registration for the pheromone dispenser 'Isomate OFM Rosso' so far. In recent years it was only possible to use the mating disruption within a separate registration per season for each fruit grower (§ 11 PflSchG 'Gefahr in Verzug'). At the moment *Andermatt Biocontrol AG* applied for a general registration for organic plum growing in Germany.

In recent years lots of research has been done testing entomopathogenic nematodes (EPN) against the diapausing larvae of codling moth (*Cydia pomonella*). To develop another tool for a combined control strategy we started field trials using entomopathogenic nematodes against diapausing plum moth larvae in 2008 and 2009 based on the experience with EPN against codling moth.

Selected results of the field trials are reported here.

Material and Methods

Field trials: Mating disruption

From 2007 to 2009 in four orchards in Rheinland-Pfalz and in three orchards in Baden-Württemberg the pheromone dispensers 'Isomate-OFM Rosso' were placed in the trees in April or May with an application rate of 500-550 dispenser per ha. Details of selected

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testing plots are shown in Table 1. For population monitoring in each plot pheromone traps were installed and weekly controlled.

The infestation of the fruits was assessed at two times depending on flight peaks of plum moths, first in June (1st generation) and second short before harvest (2nd generation) by counting the rate of infested plums in treated und untreated plots (minimum 1000 fruits per plot). Depending of the site, there are different positions of the untreated plots. At plot 1 (Kettig) the untreated control is the western part of the testing field (placed opposite the main wind direction), at plot 2 (Fronreute) and 4 (Büchold) there was a distance of 300 m and at plot 4 (Endingen) 3 km between untreated control and treatment plots.

Table 1: Rate and date of application of pheromone dispenser Isomate-OFM Rosso in three on-farm trials in 2008 and 2009

No	Site / region	Variety	planted	Area of treated plot [ha]	Application rate	Application date
1	Kettig / near Koblenz	'Cacak's Fruchtbare', 'Auerbacher', 'Hauszwetschge'	2002	1.5	500 pcs/ha	23.05.2008
2	Fronreute / near Lake Konstanz	'Mirabelle von Nancy'	1998	2.8	500 pcs/ha	14.05.2008
3	Endingen / South Baden	'Elena'	1984	0.85	550 pcs/ha*	17.04.2009
4	Büchold / near Würzburg	'Hauszwetschge' and diverse varieties	1998	2.48	550 pcs/ha*	19.04.2007 26.04.2008 07.04.2009

*incl. intensive application at the borders of the orchards

Field trials: Entomopathogenic nematodes (EPN)

The nematodes were applied in two orchards in October and November 2008 (application details see table 2). The application was made with a conventional sprayer onto the whole trees and in plot 6 the nematodes were applied additionally to the ground in the tree rows. We used Injector-nozzles (ID 90-06) and applied a water amount of 750 l per ha and meters tree high with a pressure of eight bar. The strainers of the sprayer were removed. The infestation was assessed after egg laying phase of the first and second generation of plum moth in the next season (2009) by counting the rate of infested plums in treated and untreated plots. For population monitoring pheromone traps were installed.

Table 2: Rate and date of application of nematods in two on-farm trials in 2008

Plot	Variety	Species	Application rate	Application date	Area [ha]
5 (Gelsdorf)	diverse varieties	*Steinernema feltiae*	750 Mio EPN plus 2,5l TS forte per ha and m tree height	27.10.2008	1.0
6 (Kettig)	'Presenta' 'Cacaks Schöne'	*Steinernema feltiae*	750 Mio EPN plus 2,5l TS forte per ha and m tree height	10.11.2008	1.5

Results and Discussion

Field trials: Mating disruption

Table 3 shows the infestation levels for first and second generation and efficacies of mating disruption in all testing plots.

Table 3: Rates of infested plums by 1st and 2nd generation in three testing plots, results 2008 and 2009

				Infestation [%]			
No	**Site**	**Year**	**Generation**	**Untreated control**	**Mating disruption**	**Fruit load**	**Efficacy [%] (ABOTT)**
1	Kettig	2008	1st	0.47	0.18	medium	**61,5**
			2nd	3.13	0	medium	**100**
2	Fronreute	2008	1st	6.6	0.1	high	**98**
			2nd	2.9	0.2	high	**93**
3	Endingen	2009	1st	4.32	261	medium	**39,6**
			2nd	6.07	3.98	medium	**34,4**

The population density of the first generation was low in field experiment 1 (Kettig). It changed at end of July with a high peak for the second generation (see figure 1). In total an amount of 1386 moths have been caught in the untreated plot during the season 2008. Not more than 10 moths have been caught in all three pheromone traps in the treated plot. In spite of high catching rates the infestation levels in trial 1 (Kettig) were low (0.5 % infestation by the first generation and 3 % infestation by the second generation in untreated plot) and the mating disruption was a very effective method (see table 3).

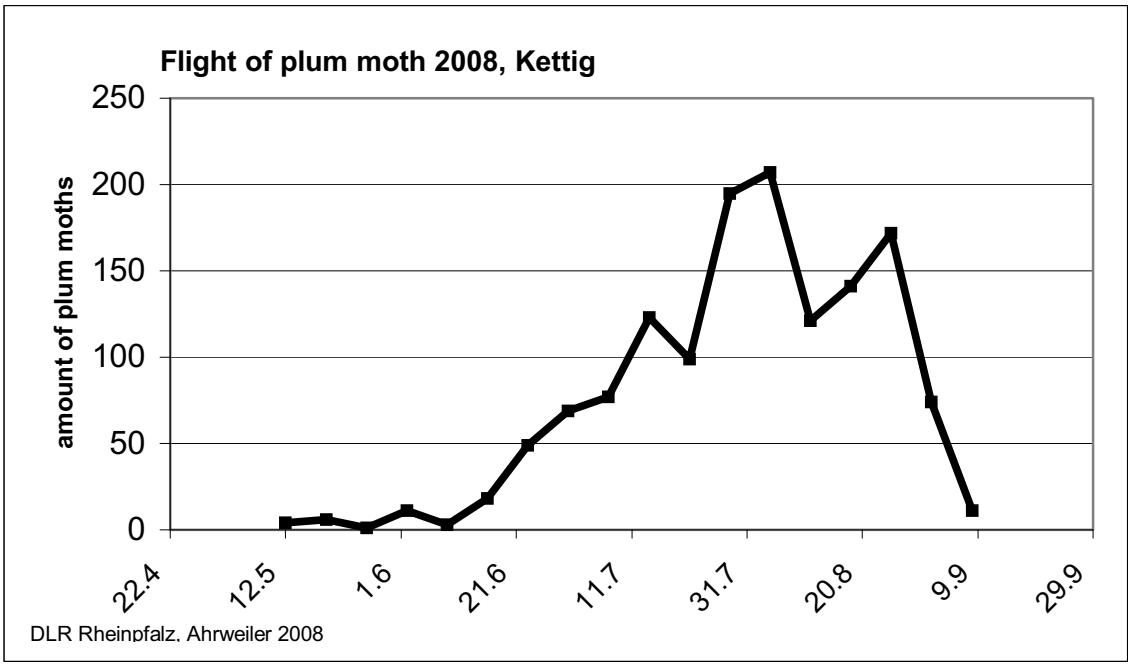

Figure 1: Plum moth flight 2008, plot 1, Kettig

In field experiment 2 (Fronreute) the population density of the first generation was low in 2008 and increased with the second generation (see figure 2). The amount of catches in 2008 was only 81 moths in the untreated plot. In the untreated plot 6.6 % of the fruits were infested by the first and about 3 % by the second generation. In the trial plot with mating disruption only 0.1 % (first generation) and 0.2 % (second generation) infested fruits were found and therefore the efficacies were high (98 % and 93 % respectively).

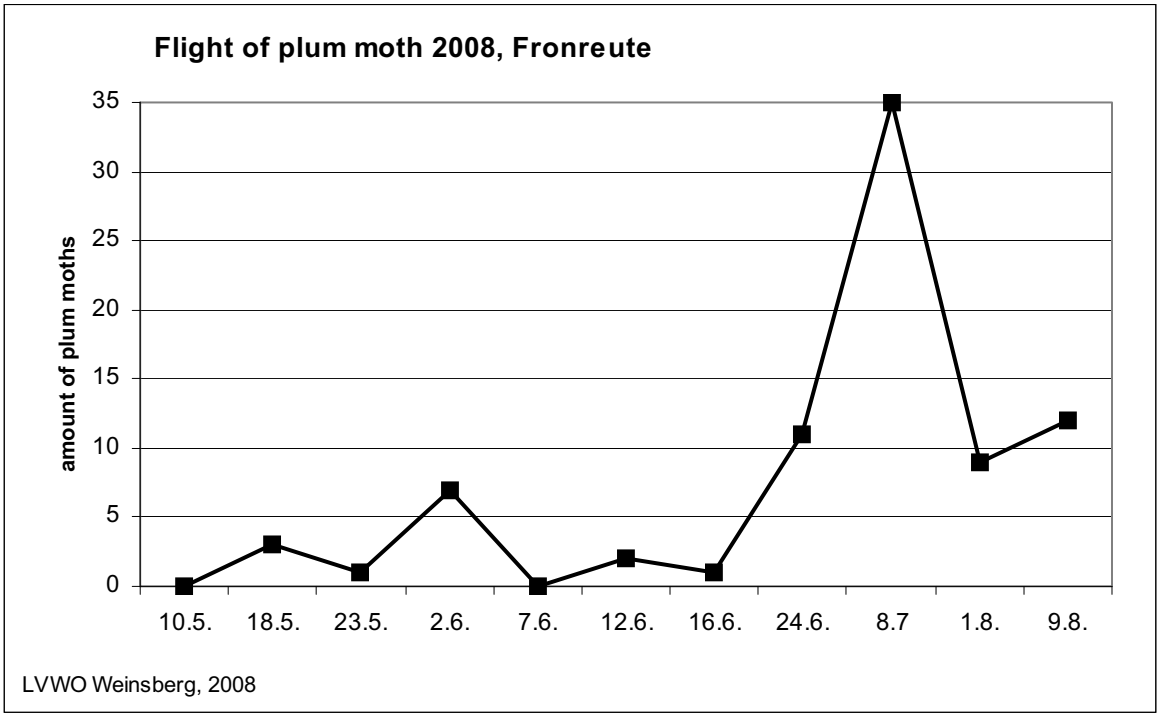

Figure 2: Plum moth flight 2008, plot 2, Fronreute

In the field experiment 3 (Endingen, 2009) the population density of the first generation was on a low level and did not increase very much within the second generation (see figure 3). The trap located at the border of the treated plot catches 47 moths during the season, more than the trap in the untreated plot. In untreated plot 4.3 % of the fruits were infested by the first generation and 6 % by the second generation. In the mating disruption plot the infestation of 2.6 % (first generation) and 4 % (second generation) was high and the efficacies were only 40 % and 34 %, respectively (see table 3). One site of the testing orchard 3 (Endingen) is neighboured by hedges of *Prunus spinosa* and some extensively cultivated meadow orchards, where we found the highest infestation levels. On the opposite side with bordering agricultural cropland only half the infestation rates were found. At this plot the neighbouring structure influenced the efficacy of the mating disruption.

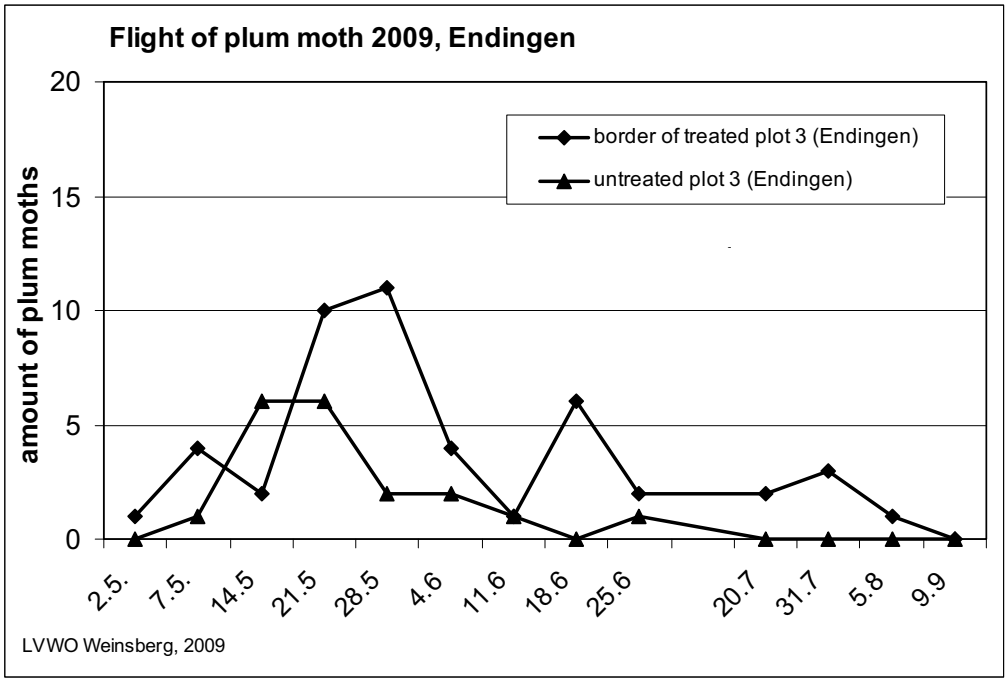

Figure 3: Plum moth flight 2009, plot 3 Endingen

Figure 4 shows the plum moth flight in 2008 and 2009 for testing plot 4 (Büchold). In 2008 the population density had a peak in early June and then remained at a low level until end of flight. In 2009 it was just the opposite situation with a low flight from April until end of June and a peak in July. In both years 151 moths were caught in the traps in the untreated control during the season. Table 4 shows the development of infestation at testing plot 4 (Büchold) for a period of three years. A correlation between the fruit load and the infestation rates and resulting differences of efficacies were determined. In 2007 the infestation level for the second generation in the treated plot was only 0.5 % but reached an infestation level of 51 % for the first generation in 2008. The very low crop load in the plum trees in 2008 and approximately no fruits in the blackthorn hedges nearby leaves rare possibilities for copulated females to oviposite and thus leads to high infestation rates. With medium to high crop load in 2009 the efficacy of mating disruption was again sufficient with 80 % and 92 % for first and second generation, respectively.

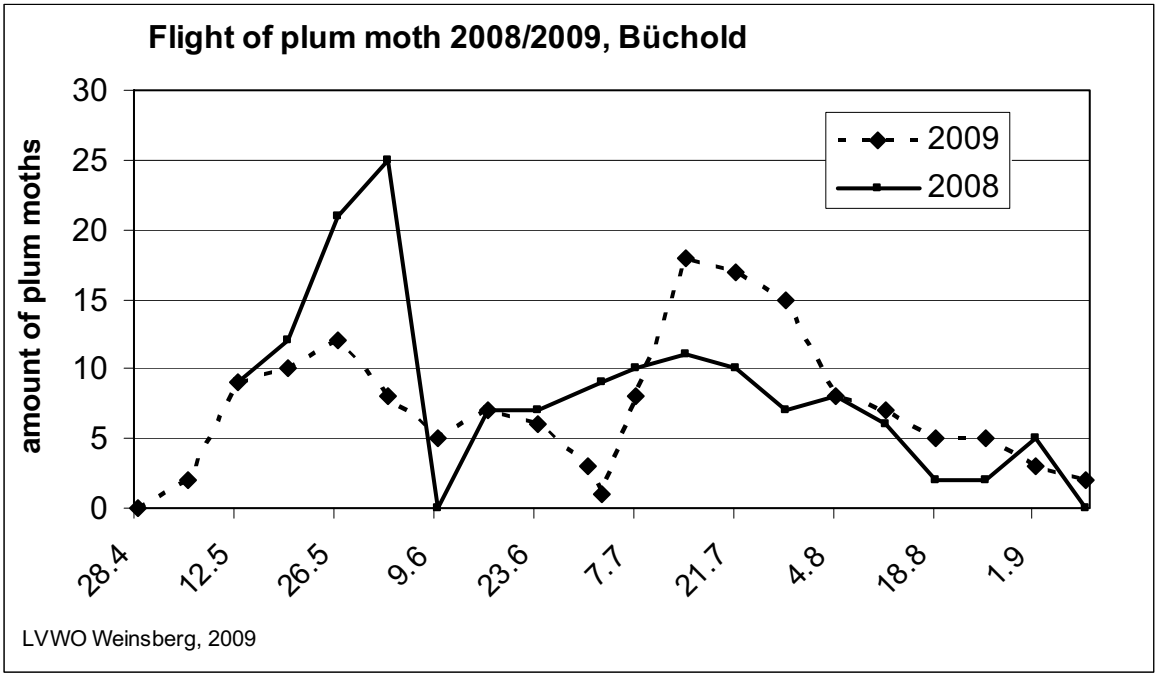

Figure 4: Flight of plum moth 2008 and 2009 at plot 4 (Büchold)

Table 4: Rate of infestation at testing plot 4 (Büchold) in 2007 to 2009

	2007		2008		2009	
	1st gen.	2nd gen.	1st gen.	2nd gen.	1st gen.	2nd gen.
Untreated control infestation [%]	14.9	3.2	86.8	assessment useless	15.7	13.3
Mating disruption infestation [%]	3.4	0.5	51.2		3.3	1.1
Efficacy [%] (ABOTT)	77.2	84.4	41		80	92
Crop load	medium	medium	very low	very low	medium-high	medium-high

Field trials with entomopathogenic nematodes (EPN)

In field experiment 1 (plot 5, Gelsdorf) the population density was on a moderate level with only slight peaks at first and second moth generation flight (Fig. 5). Thus the infestation level in the untreated plot remained at low levels of 2 % (1st generation) and 1.4 % (2nd generation) infested fruits, respectively. The application of nematodes in the previous autumn (2008) decreased the infestation to 0.56 % in both generations and thus showed good efficacies (Tab. 5). In the other experimental orchard (plot 6) the trap catches reached numbers of up to 200 moths per trap in one week. Two clear peaks of first and second generation's flight were monitored in May and July. In addition to a high population density another factor compromising the efficacy was that the application was made at non-optimal weather condition. In this plot the efficacy of the nematode treatment was only 54 % for the first generation and the infestation level was equalized at harvest.

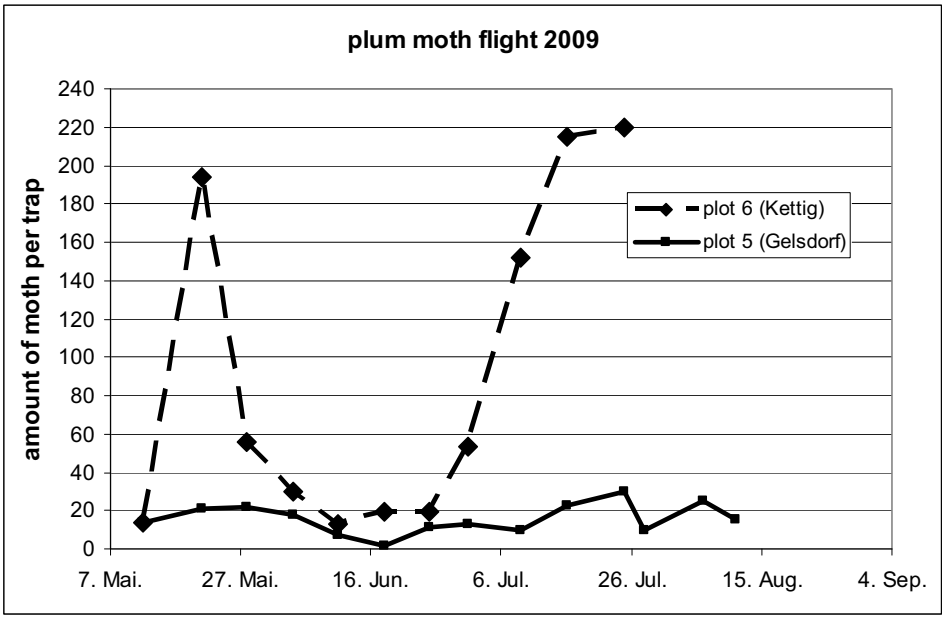

Figure 5: Plum moth flight in both EPN field trials, 2009

Table 5: Rates of infested plums for 1st and 2nd generation in both testing plots, results 2009

		Infestation untreated control [%]	Infestation treatment with nematodes [%]	Efficacy [%] (Abbott)
Plot 5 (Gelsdorf)	1st generation	2.05	0.56	73
	2nd generation	1.41	0.56	60
Plot 6 (Kettig)	1st generation	3.02	1.38	54
	2nd generation	8.5	7.98	6.1

Conclusion

At medium to high crop loads and infestation levels less than 4 % infested fruits, the mating disruption proved to be a sufficient control strategy against the plum moth (*C. funebrana*). In orchards with a small-structured neighbourhood (housegarden, not cultivated percels) and occurrence of *Prunus spinosa* border influences can be an efficacy limiting factor as well as low crop load. Additional treatments seem to be useful especially at the borders of an orchard. Mating disruption will be an important element of a regulation strategy in organic plum production, but needs an additional control part. First results showed promising results with entomophatogenic nematodes against the diapausing larvae of the plum moth and might be a building stone in a control strategy. Regarding to that further research will be done the next years.