Regulation of plum moth (*Cydia funebrana*) with *Cydia pomonella* granulovirus (CpGV) in organic plum orchards - first results

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Abstract

*As a further regulation strategy of plum moth (*Cydia funebrana*) CpGV isolate V15 in two different formulations was tested in different organic plum orchards in Germany in 2010 and 2011. On most plots CpGV was used in combination with mating disruption with "Isomate OFM Rosso". Various efficacies were found, they were in average not as high as in lab and ranged from 80 % to negative in worst case.*

Keywords: Plum moth, CpGV isolates, *Cydia funebrana*, organic plum growing

Introduction

The plum fruit moth, Cydia funebrana is regarded as one of the key pests of organic plum production in Europe. On higher infestation levels biological control is limited. To test if infection of plum moth larvae is principal possible, viral suspensions of ten different CpGV isolates were sprayed on mature plums in the laboratory of the Department of Phytomedicine at the Geisenheim Research Center in 2009 (Reineke et. al 2010, Rueß et. al. 2010). The results demonstrated, that an infection of C. funebrana with CpGV is principally possible with an efficacy of up to 63%. Therefore the CpGV isolate with the highest efficacy was field tested in different organic plum orchards in Germany in 2010 and 2011.

Material and Methods of the field trials

In the field trial 2010, it was the main aim to test if the promising laboratory infection experiments with the isolate CpGV V15 (Andermatt Biocontrol) could be extended to the field situation in organic orchards. In 2011, an additional attempt was directed to closer application intervals and another formulation. In 2010 and 2011 CpGV was applied in seven orchards in Rhineland-Palatinate on nine field trials in block design, as well as in one (2010) and two (2011) exact field trials with four replications. In 2010 and 2011 in Baden-Wuerttemberg, CpGV was applied in six field trials in block design in five orchards.
Weekly applications of CpGV V15 with an application rate of 150 ml per meter crown height (ml/mch) ($3x10^{10}$ occlusion bodies (OB)/ml) beginning with the flight of plum moth were compared to an untreated control. In 2010 CpGV V15 was used in a concentration of 500 ml/mch as a third treatment in an exact field trial. In further trial in 2011, a new formulation of CpGV V15, called "V42" ($1,7x10^{10}$ occlusion bodies (OB)/ml), was applied in two plots with an application rate of 261 ml/mch. 2011 in Rheinland-Pfalz in one plot CpGV V15 was applied as a third variant every 5 to 6 days and the numbers of application was increased from 12 to 23. Details of the orchards are shown in Table 1.

Details of the treatments, the numbers and the dates of start and end of applications in 2010 and 2011 are shown in Table 2.

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Table 1: Details of the orchards in Rhineland-Palatinate and Baden-Wuerttemberg where on-farm trials with CpGV V15 and V45 were done in 2010 and 2011.

Site (Province RP or BW)	Plot No.	Variety	planted	plot [ha]
Wackernheim (RP)	1.1 1.2 1.3	Top (old) Top (new) Presenta		0.5 0.5 0.9
Grafschaft (RP)	2.1 2.2 2.3	President Hauszwetschge, Ortenauer Hauszwetschge	1994 up to 1996	0.3 0.32 0.5
Kettig (RP)	3	Presenta, C. Schöne	2002	1.0
Uhlbach (BW)	4	Elena, C. Schöne, Valjevka, Katinka Presenta	1993 2003	0.75
Sulzburg-Laufen (BW)	5.1	Herman, C. Schöne, Ersinger, Valjevka	1996	0.42
	5.2	Herman, C. Frühe, C. Schöne, Elena Valjevka Presenta	1994 / '96' 2001	0.25
Backnang (BW)	6	Felsina, Hanita, Elena	1999	0.25

Table 2: Treatments, type of field trail, amount of water, numbers and dates of application of CpGV V15 and V42 in 2010 and 2011

Plot	Variants	Type of trial exact / field [1)]	Water l/ha	Year	Applications		
					numbers	start	end
1.1 1.2 / 1.3	1. Control 2. 150 ml V15	field	500	2010	11	03.06.	13.08.
1.1 1.2 / 1.3	1. + 2.	field	400	2011	12	31.05.	17.08.
2.1	1. + 2. 3. 500 ml V15	exact	500	2010	14	25.05.	31.08.
2.1	1. + 2. 3. 261 ml GV V42	exact	400	2011	13	13.05.	05.08.
2.2 / 2.3	1. + 2.	field	500	2010	14	25.05.	31.08.
2.2	1. + 2. 3. 150 ml V15 all 5-6 days	exact	400	2011	13/23	13.05.	05.08.
2.3	1. + 2.	field	400	2011	13	13.05.	05.08.
3	1. + 2.	field	500	2010	6	09.06.	14.07
4	1. + 2.	field	600	2010	7	04.06.	24.08.
5.1	1. + 2. 3. 261 ml V42	field	360	2011	12	11.05.	26.07.
5.2	1. + 2.	field	360	2011	13	11.05	03.08.
6	1. + 2.	field	900	2011	14	14.05.	08.08.

[1)] field trail in block design or exact field trail with 4 replications (exact)

In all plots, except plot 4 in Baden-Württemberg 2010, application of CpGV was used in combination with mating disruption with "Isomate OFM Rosso".

For population monitoring pheromone traps were installed and controlled weekly (data not shown, Rueß et. al 2011, 2012).

The infestation of the fruits was assessed at two times depending on flight peaks of plum moths; the assessment was made in June or at beginning of July (1st generation), the second shortly before harvest (2nd generation) by counting the rate of infested plums in treated and untreated plots (minimum 1000 fruits per plot). For the 1st generation the

infested fruits were counted on the trees. For the infestation assessment of the 2nd generation the fruits were cut open.

CpGV infection of cadavers and living larvae from field trails were tested by PCR amplification at the Geisenheim Reasearch Center (Reineke 2010, Rueß et al 2010).

Results

The results of the field trials with CpGV V15 in comparison to untreated control are reported here. In the trials 1.1 - 1.3 (Table 3) the infestation rate of the 2nd generation 2010 raised up to more than 10% in all three plots, in untreated and treated plot, except for treated plot 'Presenta' (plot 1.3), where the infestation was 5.2%.

First generation 2011 started with low infestation levels and did not increase in the 2nd generation. The efficacies ranged from negative to 53%, except for the plot 1.2. (2nd gen.) with 84% efficacy. The low efficacy was partly caused by very low infestation levels. An exception was the negative efficacy in plot 1.2 at 2nd generation 2010 in general very high infestation level.

Table 3: Infested plums (%) of the 1st and 2nd generation and efficacies (ABBOTT) at Wackernheim, 2010 and 2011

1. Wackernheim				Infestation in %		
No	**variety**	**Year**	**Generation / Date**	**Untreated control**	**CpGV V15**	**Efficacy [%])**
1.1	Top (old).	2010	1st	5.2	3.5	**32**
			2nd	13.6	12.1	**11**
1.1		2011	1st (29.06.)	2.9	2.0	**29**
			2nd (25.08.)	0.9	0.6	**31**
1.2	Top (new)	2010	1st	8.2	6.0	**26**
			2nd	12.8	15.2	**-19**
1.2		2011	1st (29.06.)	3.0	2.3	**24**
			2nd (25.08.)	0.8	0.1	**84**
1.3	Presenta	2010	1st	0.5	0.3	**50**
			2nd	11.1	5.2	**53**
1.3		2011	1st (29.06.)	0.1	0.1	**1**
			2nd (25.08.)	0.0	0.1	**-**

Nearly the same situation was found in Grafschaft (Table 4). After moderate infestation rates in the 1st generation 2010 infestation increased to more than 10% (trial 2.3.) and up to 37% (trial 2.2) in 2nd generation. The efficacies ranged from 10 to 74%. In 2011 Grafschaft (trial 2.3) both generations caused in both treatments very low infestation levels of about 1%, resulting in low or even negative efficacies.

In Plot 3 (Table 4) in 2010, the cultivar 'Cacaks Schöne' had moderate infestation levels of 5.8% (1st gen. control) and 3.3% (1st gen. V15) with 42% efficacy, and of 6.5% (2nd gen. control) to 2.4% (2nd gen. V15) with an efficacy of 64%.

In the late variety 'Presenta' (plot 3, Table 4), the infestation levels were 4.6% (1st gen., control) and 3.9% (1st gen. V15) as well as 17.5% (2nd gen., control) and 16.4% (2nd gen. V15) with efficacies of 16 and 6%, respectively.

Table 4: Infested plums (%) of the 1st and 2nd generation and efficacies (ABBOTT) at Grafschaft and Kettig, 2010 and 2011

				Infestation [%]		
No	**Site**	**Year**	**Generation**	**Untreated control**	**CpGV V15**	**Efficacy [%] (ABBOTT)**
2.2	Grafschaft	2010	1st	4.4	2.3	**48**
			2nd	37.3	22.9	**39**
2.3	Grafschaft	2010	1st	3.0	0.8	**74**
			2nd	13.0	11.7	**10**
2.3	Grafschaft	2011	1st (04.07.)	0.7	0.7	**3**
			2nd (30.08.)	1.2	1.3	**-4**
3	Kettig / C. Schöne	2010	1st	5.8	3.3	**42**
			2nd	6.5	2.4	**64**
3	Kettig / Presenta	2010	1st	4.6	3.9	**16**
			2nd	17.5	16.4	**6**

In the plot 4 (Table 5) in 2010, the infestation of variety 'Katinka' was 4.8% (control) and 4.7% (treated) in 1st generation (efficacy 2%). In the 2nd generation, the infestation level was 0.6% (control) and 0.3% (treatment). The infestation of the varieties 'Elena' and 'Presenta' was low in 1st generation. It increased in the 2nd generation to moderate level (4.1%) for the variety 'Elena' and to 8.9% for 'Presenta'. Efficacies were found to be 9% to 40% (Table 5). The early ripening cultivars 'Ruth Gerstetter', 'Cacaks Schöne', 'Valjevka' and 'Cacaks Fruchtbare' were only assessed for the 1st generation. The infestation levels were moderate and the efficacies were 17%, 3% and 23%, respectively. Only for 'Cacaks Fruchtbare' a negative efficacy was assessed.

Table 5: Infested plums (%) of the 1st and 2nd generation and efficacies (ABBOTT) plot 4, Uhlbach, 2010

4. Uhlbach		**Infestation [%]**			
Variety	**Generation Date of harvest**	**Untreated control**	**CpGV V15**	**Efficacy [%]**	**Fruit load**
Ruth Gerstetter [1)]	1st (08.07.)	2.3	1.9	**17**	low
C. Schöne [1)]	1st	2.1	2.0	**3**	low-medium
Valjevka [1)]	1st	3.5	2.7	**23**	low-medium
C. Fruchtbare [1)]	1st	2.7	3.2	**-19**	low-medium
Katinka	1st (08.07.)	4.8	4.7	**2**	low-medium
	2nd (29.07.)	0.6	0.3	**48**	
Elena	1st (08.07.)	1.2	0.8	**34**	medium-high
	2nd (16.09.)	4.1	2.9	**29**	
Presenta	1st (08.07.)	1.1	1.0	**9**	low
	2nd (16.09.)	8.9	5.3	**40**	

[1)] early varieties, no 2nd assessment

In the plot 5.2 (Table 6) the early variety 'Herman' (1st gen.) and the latest variety 'Presenta' (2nd gen.) caused high rates of damaged fruits with 10.4 and 12.3% in the control. The rate of damaged fruits in the treatment with V15 was 2% at the variety 'Herman' and 20.1% at the variety 'Presenta'. The efficacies were 80 and -63%. All other efficacies obtained in this plot are between these two numbers.

Table 6: Infested plums (%) of the 1st and 2nd generation and efficacies (ABBOTT) at plot 5.2, Sulzburg, 2011

5.2 Sulzburg		**Infestation** [%]			
Variety	**Generation Date of harvest**	**Untreated control**	**CpGV V15**	**Efficacy [%] (ABBOTT)**	**Fruit load**
Herman [1)]	1st (16.06.)	10.4	2.0	**81**	medium
C. Frühe [1)]	1st (16.06.)	7.7	4.8	**37**	medium
C. Schöne	1st (16.06.)	1.7	1.4	**20**	medium
	2nd (07.07.)	1.3	1.8	**-38**	
Valjevka	1st (16.06.)	3.7	3.4	**7**	medium
	2nd (01.08.)	5.6	6.9	**-23**	
Elena	1st (16.06.)	1.3	1.5	**-9**	very high
	2nd (12.08.)	5.3	6.5	**-24**	
Presenta	1st (16.06.)	0.9	0.5	**46**	medium-high
	2nd (12.08.)	12.3	20.1	**-63**	

[1)] early varieties, no 2nd assessment

In 2011 trial 6 (Table 7) the 1st generation caused in both treatments very low infestation levels of about 1%, resulting in efficacies of 50 and 44%. The rate of infested plums at the variety 'Hanita' in 2nd generation was very low with 0,3% control and 0,4% V15. The efficacy was a negative one. The latest variety in this trial 'Elena' with rates of damaged fruits of 9% control and 4.8% V15 of 2nd generation had an efficacy of 47%.

Table 7: Infested plums (%) of the 1st and 2nd generation and efficacies (ABBOTT) at plot 6, Backnang, 2011

6 Backnang			**Infestation** [%]			
Variety	**Year**	**Generation Date of harvest**	**Untreated control**	**CpGV V15**	**Efficacy** [%] (**ABBOTT**)	**Fruit load**
Hanita	2011	1st (21.06.)	2.0	1.0	**50**	high
		2nd (05.08.)	0.3	0.4	**-33**	
Elena	2011	1st (21.06.)	1.0	0.6	**44**	very high
		2nd (24.08.)	9.0	4.8	**47**	

The application of CpGV V15 as an additional treatment (2010, plot 2.1) at a concentration of 500 ml/ha/mch did not show a higher efficacy in any case (Table 8). The numbers of damaged plums was very high in general in the 2nd generation.

Table 8: Infested plums (%) of the 1st and 2nd generation and efficacies (ABBOTT) at plot 2.1, Grafschaft, 2010 (exact)

			Infestation [%]				
No	**Site**	**Generation**	**Untreated control**	**V15 150 ml**	**Efficacy [%]**	**V15 500 ml**	**Efficacy [%] (ABBOTT)**
2.1	Grafschaft	1st	6.9	6.3	**9**	5.9	**14**
		2nd	29.8	19.5	**35**	22.5	**25**

In 2011 another formulation of CpGV (termed V42) was used in plots 2.1 and 5.1 (Tables 9 and 10). In plot 2.1 an efficacy of 47% was obtained in 1st generation, but in 2nd generation it was negative.

Table 9: Infested plums (%) of the 1st and 2nd generation. and efficacies (ABBOTT) at plot 2.1, Grafschaft, 2011 (exact)

			Infestation [%]				
No	**Site**	**Generation**	**Untreated control**	**V15**	**Efficacy [%]**	**V42**	**Efficacy [%]**
2.1	Grafschaft	1st (04.07.)	4.6	4.7	**-3**	2.4	**47**
		2nd (30.08.)	3.8	1.8	**52**	4.4	**-14**

On plot 5.1 (Table 10) V42 showed higher efficacies than V15 at the varieties 'Herman' with 58% and 'Cacaks Schöne' with 80% (both at 1st generation).

In the 1st generation the infestation rates of the middle-early ripening variety 'Valjevka' were 4.2% (treatment V42), 3% (untreated plot) and 2.3% (V15). The infestation rates of the 2nd generation from 'Valjevka' raised up to a very high level of 17% in untreated plot. So efficacies of 21% (V15) and 23% (V42) were realized, but the damage in both treated plots was unacceptable high considering the fact, that 12 applications were done. 'Ersinger' (2nd gen.) treated with V15 as well as 'Cacaks Schöne' (2nd gen.) and 'Ersinger' (1st and 2nd gen.) treated with V42 showed on low infestation levels negative efficacies.

Table 10: Infested plums (%) of the 1st and 2nd generation and efficacies (ABBOTT) at plot 5.1, Sulzburg, 2011

5.1 Sulzburg		**Infestation [%]**					
variety	**Generation**	**Untreated control**	**V15**	**Efficacy [%]**	**V42**	**Efficacy [%])**	**Fruit load**
Herman	1st (16.06.)	5.0	4.2	**17**	2.1	**58**	Medium-high
	2nd	Fruits still harvested				**--**	
C. Schöne	1st (16.06.)	2.7	0.8	**71**	0.6	**80**	High
	2nd (06.07.)	0.5	0.1	**80**	0.9	**-80**	
Ersinger	1st (16.06.)	2.2	1.4	**35**	2.3	**-5**	Very high
	2nd (06.07.)	0.1	0.5	**-400**	0.3	**-200**	
Valjevka	1st (16.06.)	3.0	2.3	**25**	4.4	**-47**	high
	2nd (08.08.)	17.0	13.5	**21**	13.1	**23**	

Another treatment with narrow application intervals of 5 to 6 days between the applications of V15 was tested in comparison to the normal interval of 8 to 10 days (Table 11). For the variety 'Ortenauer' in 1st generation the efficacy of V15 sprayed every 5-6 days was higher than V15 sprayed every 8-10 days. In 2nd generation the opposite results were observed: Applications every 8-10 days showed a higher efficacy. At variety 'Hauszwetschge' (2nd gen.) a similar efficacy of both treatments of 32 and 28% was observed.

Table 11: Infested plums (%) of the 1st and 2nd generation and efficacies (ABBOTT) at plot 2.2, Grafschaft, 2011 (exact)

2.2 Grafschaft		**Infestation [%]**				
Variety	**Generation**	**Untreated control**	**V15 5-6 d**	**Efficacy [%]**	**V15 8-10 d**	**Efficacy [%])**
Ortenauer	1st (04.07.)	2.8	2.0	**29**	2.5	**11**
	2nd (22.08.)	4.2	2.8	**34**	2.2	**48**
Hauszwetschge	2nd (22.08.)	3.6	2.4	**32**	2.6	**28**

Discussion and Conclusion

The field trials with CpGV V15 showed heterogeneous results with efficacies up to 50% and exemptions up to 80% on low infestation levels, mainly during 1st generation. Also on moderate to high infestation levels efficacies of 50% could be reached in 1st and 2nd generation. But there are also negative efficacies in both generations. The average efficacy over all results in both years is 10%.One reason for various efficacies could be the short time, larvae of plum moths are crawling on the surface of the plum fruit and the behaviour to penetrate the fruit through the egg, so that the uptake of CpGV maybe is not high enough for a lethal dose. In case of abundant fruiting, the wetting of the single fruit with virus maybe not sufficient. A higher concentration with 500 ml/ha/mch did increase the efficacy for 1st generation, but not for the 2nd generation. It has to be considered that the used concentration of 150 ml/mch is higher than in the regulation of Codling moth. Also the use of CpGV V42 did not show a clear better result than V15. To set the applications closer (all 5-6 days) intervals did not raise the efficacies in all cases, but raised the amounts of application from 12 to 23. As a consequence CpGV is not recommended for the use of plum moths control

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