Limitation of Codling moth (*Cydia pomonella*) with different paraffin and plant oils

S. Caruso[2], C. Casera[1], M. Kelderer[1], S. Vergnani[3]

Abstract

Codling moth, Cydia pomonella, *is the major pest of pome fruit, and especially difficult to control in organic farming in Southern fruit growing areas, where this pest has two and more generations per year. Mating disruption,* Cydia pomonella *GranuloVirus (*Cp*GV) and entomopathogenic nematodes do not always provide adequate pest control. The active substance Spinosad shows high efficacy, but has also negative side effects on beneficial organisms. Furthermore residues of Spinosad remain detectable for a long time in fruits. From 2007 to 2011, several field trials with paraffin and plant oils have been conducted on apple and pear in the major Italian pome fruit growing areas, South Tyrol and Emilia Romagna. Results varied considerably: while only low efficacy levels were recorded in South Tyrol on apple, interesting and extremely promising results were obtained in Emilia Romagna on pear. Assumptions can be made to explain these differences, but none of them can be considered completely satisfactory.*

Keywords: Apple, codling moth, paraffin oil, plant oil

Introduction

Codling moth, *Cydia pomonella*, is one of the major orchard pests. Apple and pear are its major hosts, but in warmer climates it may attack also quince, apricot, peach, plum, cherry, hawthorn, chest- and walnut. The pest probably originally occurred only in the Mediterranean Countries of Europe, but is now distributed almost worldwide (Pollini *et al*., 1993). In conventional and integrated production, codling moth can be adequately controlled with the chemical synthetic plant protection products currently available on the market, but in organic farming its control is still challenging due to the sometimes limited efficacy of the available insecticides. Mating disruption of codling moth with sex pheromones is one of the most important control tools also in organic farming (Kelderer, 2007). Good efficacy levels can be achieved under conditions of low pest pressure and by applying mating disruption over large areas. To increase efficacy, these systems for population reduction are usually used in combination with insecticide sprays based on *Cydia pomonella* GranuloVirus (*Cp*GV). However, in recent years, codling moth populations resistant to *Cp*GV have been detected (Fritsch *et al.,* 2005; Jehle *et al*., 2010). Furthermore, several studies show that the insecticide can provide efficient population control, but damage reduction may not always be satisfactory. The organic plant protection product Spinosad, a mixture of metabolites of the soil-dwelling bacterium *Saccharopolyspora spinosa*, shows high efficacy against insects, but its activity is not selective and residues of the substance are detected in the production. Most of the German organic fruit grower associations therefore allow the use of Spinosad only under special conditions. Also entomopathogenic nematodes, such as *Steinernema feltiae* and *Steinernema carpocapsae*, are applied for population control against overwintering codling

[1] M. Kelderer, Research Centre Laimburg, Italy 39040 Ora, Markus.Kelderer@provinz.bz.it
[2] S. Caruso, Consorzio fitosanitario di Modena, Italy 41123 Modena, scarso@regione.emilia-romagna.it
[3] S. Vergnani, CRPV Cesena, 47522 Cesena (FC), vergnani.s@valledelreno.com

moth larvae, but in the open field their efficacy is limited (Kienzle *et al.,* 2008; Peters *et al.,* 2008).

For organic farming, finding valuable alternatives for the control of this key pest is therefore of sound importance. Single-row netting structures provided good levels of control, but they are very expensive (Kelderer *et al.,* 2010).

From 2007 to 2011, several trials with special focus on the use of oily substances for codling moth control, have been carried out in the major Italian pome fruit growing regions Emilia-Romagna and South Tyrol. In South Tyrol trials were conducted on apple, while in Emilia Romagna they were performed on pear.

Material and methods

Trials on apple in South Tyrol

In South Tyrol, trials on the efficacy of plant protection products against codling moth have been conducted from 2009 to 2011. All trials were performed in an apple cultivar Braeburn orchard (rootstock: M9), located in Auer (South Tyrol, Italy). The orchard was planted in 1997.

Details on the products tested in the trials are reported in Table 1, 2 and 3.

Table 1: Description of the products tested in 2009

Active ingredient	Product name	Distributor	Applied rate (/100 l)
CpGV	Madex Plus	Intrachem Bio Italia	6.7 ml
CpGV + Paraffin oil	Madex Plus + UFO	Intrachem Bio Italia+ Intrachem Bio Italia	6.7 ml + 1 l
Spinosad	Spinosad	Dow Agroscience	30 ml
Untreated control	-	-	-

Table 2: Description of the products tested in 2010

Active ingredient	Product name	Distributor	Applied rate (/100 l)
Chlorpyrifos*	Pyrinex ME	Makhteshim	210 ml
Soy oil	Greenline	Organics	500 ml
Mustard oil + Cruciferous plant meal	Duofruit	Cerealtoscana	1 l + 300 g
Untreated control	-	-	-

*applied at 14-day time intervals

Table 3: Description of the products tested in 2011

Active ingredient	Product name	Distributor	Applied rate (/100 l)
Chlorpyrifos*	Dursban	Dow AgroSciences	70 g
CpGV	Madex Plus	Biofa	7 ml
Spinosad	Laser	Dow AgroSciences	30 ml
Plant oil	A1	Icas	350 ml
Soy oil	Greenline	Organics	500 ml
Mustard oil + Cruciferous plant meal	Duofruit	Cerealtoscana	500 ml + 150 g
Untreated control	-	-	-

*applied at 14-day time intervals

In each study year, to compare the different treatments, a randomized block design with 4 replicates of 10 trees each per treatment was used. To avoid biasing of data due to spray drift among plots, each study plot was isolated from the other plots by additional trees and rows of trees. All treatments were applied using a motorized sprayer (sprayer for experimental trials Waibl, Teejet blu), a spray volume of 1500l/ha, and a spray pressure of

7.0 bar. Except for chlorpyrifos, which was used at 14-day time intervals, all other treatments were applied at weekly time intervals from beginning of egg-hatching up to harvest.

Trials on pear in Emilia-Romagna

In the Emilia-Romagna region, trials on the efficacy of oily substances for codling moth control in organic farming have been conducted from 2007 to 2011. The trials were carried out in pear orchards (cultivars “Abate Fetel” and “William”), located in the surroundings of Modena, Ferrara, and Bologna. A randomized block design with 4 replicates per treatment was used.

Details on the products tested in the different study years and trials are reported in Table 4, 5, 6, 7, and 8.

Table 4: Description of the products tested in 2007

Active ingredient	Product name	Distributor	Applied rate (/100 l)
Untreated control	-	-	-
CpGV + Paraffin oil	Carpovirusine + Biolid	Scam + Sipcam	70 g + 1 kg
CpGV	Carpovirusine	Scam	70 g

Table 5: Description of the products tested in 2008

Active ingredient	Product name	Distributor	Applied rate (/100 l)
Untreated control	-	-	-
CpGV	Carpostop	Serbios	34 g
CpGV + Paraffin oil	Carpostop + Agrol	Serbios + Agrol	34 g + 1 kg
Paraffin oil	Agrol	Agrol	1 kg
Untreated control	-	-	-
CpGV	Carpovirusine	Scam	70 g
Paraffin oil	Agrol	Agrol	1 kg
CpGV + Paraffin oil (full rate)	Carpovirusine + Agrol	Scam + Agrol	70 g + 1 kg
CpGV + Paraffin oil (half rate)	Carpovirusine + Agrol	Scam + Agrol	70 g + 0.5 kg

Table 6: Description of the products tested in 2009

Active ingredient	Product name	Distributor	Applied rate (/100 l)
Untreated control	-	-	-
CpGV + Paraffin oil	Madex 100 + Agrol	Intrachem Bio Italia + Agrol	21 g
CpGV	Madex 100	Intrachem Bio Italia	21 g
Paraffin oil (full rate)	Agrol	Agrol	500 g
Paraffin oil (half rate)	Agrol	Agrol	250 g
Untreated control	-	-	-
Emamectin benzoate+ adjuvant	Affirm + Break Thru	Syngenta	300 g + 25 g
Paraffin oil	Agrol	Agrol	250 g
Soy oil	Greenline 88	Organics	250 g

Table 7: Description of the products tested in 2010

Active ingredient	Product name	Distributor	Applied rate (/100 l)
Untreated control	-	-	-
Rape oil	Edible oil	-	250 g
Soy oil	Greenline 88	Organics	250 g
Mustard oil + Cruciferous plant meal	Duofruit	Cerealtoscana	1 kg + 300 g
CpGV	Carpovirusine plus	Scam	70 g

Table 8: Description of the products tested in 2011

Active ingredient	Product name	Distributor	Applied rate (/100 l)
Untreated control	-	-	-
Paraffin oil (full rate)	Oleoter	Scam	250 g
Paraffin oil (half rate)	Oleoter	Scam	125 g
Rape oil	Edible oil	-	250 g
Mustard oil + Cruciferous plant meal (full rate)	Duofruit	Cerealtoscana	1 kg + 300 g
Mustard oil + Cruciferous plant meal (half rate)	Duofruit	Cerealtoscana	500 g + 150 g
Soy oil	Edible oil	-	250 g
Soy oil	Greenline 88	Organics	250 g
Corn oil	Edible oil	-	250 g
CpGV	Carpostop	Serbios	34 g

For each study year and trial, data were compared across treatments using 1-way ANOVA followed by Tukey's HSD test for *posthoc* comparisons of means (P<0.05). To improve homoschedasticity, data expressed in percentages were lg10-transformed. All analyses were performed with the statistics programme PASW 17.

Results

Trials on apple in South Tyrol

Table 9: Percentage of fruits damaged by *C. pomonella* in the different treatments in 2009

	06/07/2009			24/09/2009		
Treatment	**% damaged fruits**	**Std. Error of Mean**	**Tukey HSD**	**% damaged fruits**	**Std. Error of Mean**	**Tukey HSD**
Madex Plus	11.3	1.8	a	46.4	1.4	b
Madex Plus + UFO	10.5	1.9	a	41.8	1.8	ab
Spinosad	7.8	0.5	a	38.0	1.9	a
Untreated control	11.8	1.7	a	49.0	3.3	b

No significant increase in the efficacy of *Cp*GV was achieved by adding paraffin oil to the tank mixture.

Table 10: Percentage of fruits damaged by *C. pomonella* in the different treatments in 2010

	12/07/2010			07/10/2010		
Treatment	**% damaged fruits**	**Std. Error of Mean**	**Tukey HSD**	**% damaged fruits**	**Std. Error of Mean**	**Tukey HSD**
Pyrinex ME	2.2	0.4	a	13.1	1.4	a
Greenline	3.6	0.7	a	17.8	2.0	a
Duofruit*	3.7	1.4	a	15.9	1.9	a
Untreated control	5.0	1.4	a	29.0	2.2	b

*slight leaf burn was observed

The products Greenline and Duofruit showed a certain level of efficacy against both 1st and 2nd generation larvae, statistically comparable to that of the conventional standard insecticide Pyrinex ME (chlorpyrifos), applied at 14-day time intervals.

Table 11: Percentage of fruits damaged by *C. pomonella* in the different treatments in 2011

	01/07/2011			19/09/2011		
Treatment	**% damaged fruits**	**Std. Error of Mean**	**Tukey HSD**	**% damaged fruits**	**Std. Error of Mean**	**Tukey HSD**
Pyrinex ME	6.4	1.6	ab	32.3	2.8	ab
Madex Plus	9.8	2.4	b	44.4	2.8	c
Spinosad	3.9	1.6	a	27.5	1.9	a
A1	10.5	3.2	b	47.3	2.1	c
Greenline	9.9	0.8	b	36.3	2.4	b
Duofruit*	8.3	1.1	b	34.9	2.2	b
Untreated control	14.3	2.4	b	45.1	2.8	c

*slight leaf burn was observed

Even though at the 2nd assessment fruit damage in some of the oil-based treatments was significantly lower than in the untreated control, the oil-based products showed generally low efficacy in reducing fruit damage caused by both 1st and 2nd generation larvae.

Trials on pear in Emilia-Romagna

Table 12: Percentage of fruits damaged by *C. pomonella* in the different treatments in 2007

Treatment	**% damaged fruits**	**Std. Error of Mean**	**Tukey HSD**
Untreated control	12.0	2.0	b
Carpovirusine + Biolid	4.0	1.8	a
Carpovirusine	8.0	0.4	ab

A considerable, although not statistically significant increase in the efficacy of the CpGV-based product in reducing codling moth fruit damage was obtained by adding paraffin oil to the tank mixture.

Table 13: percentage of fruits damaged by *C. pomonella* in the different treatments in 2008

Treatment	**% damaged fruits**	**Std. Error of Mean**	**Tukey HSD**
Untreated control	23.5	5.1	a
Carpostop	13.5	4.7	a
Carpostop + Agrol	11.8	2.6	a
Agrol	8.5	2.5	a
Untreated control	62.0	2.4	a
Carpovirusine	43.8	3.4	ab
Agrol	29.8	7.0	b
Carpovirusine + Agrol (full rate)	26.0	5.9	b
Carpovirusine + Agrol (half rate)	26.3	2.4	b

In both trials, an increased efficacy of CpGV in reducing fruit damage was observed, when paraffin oil was added to the tank mixture, but differences among treatments failed significance. In one out of the two trials, even paraffin oil applied alone significantly reduced codling moth fruit damage in comparison to the untreated control.

Table 14: Percentage of fruits damaged by *C. pomonella* in the different treatments in 2009

Treatment	**% damaged fruits**	**Std. Error of Mean**	**Tukey HSD**
Untreated control	17.8	3.2	c
Madex 100 + Agrol	0.5	0.5	a
Madex 100	3.0	0.7	b
Agrol (full rate)	6.3	1.5	b
Agrol (half rate)	5.3	1.3	b
Untreated control	8.3	2.1	a
Affirm + Break Thru	1.5	0.7	a
Agrol	4.3	2.0	a
Greenline 88	2.5	1.3	a

Also in 2009, the addition of paraffin oil increased the efficacy of CpGV against codling moth, and paraffin oil applied alone again resulted in a significant fruit damage reduction in comparison to the untreated control in one out of the two trials.

Table 15: Percentage of fruits damaged by *C. pomonella* in the different treatments in 2010

Treatment	**% damaged fruits**	**Std. Error of Mean**	**Tukey HSD**
Untreated control	18.5	3.1	c
Edible rape oil	10.3	2.3	b
Greenline 88	5.5	0.9	ab
Duofruit	6.5	0.9	ab
Carpovirusine plus	1.3	0.6	a

All tested plant oils significantly reduced fruit damage in comparison to the untreated control, with differences among the different formulated and not formulated oils not being significant. Slightly, though not always significantly lower fruit damage levels were recorded for the *Cp*GV-based product than for the plant oils.

Table 16: Percentage of fruits damaged by *C. pomonella* in the different treatments in 2011

Treatment	**% damaged fruits**	**Std. Error of Mean**	**Tukey HSD**
Untreated control	16.5	1.9	b
Oleoter (full rate)	5.0	1.1	a
Oleoter (half rate)	5.5	3.0	a
Edible rape oil	4.0	1.4	a
Duofruit (full rate)	3.8	2.1	a
Duofruit (half rate)	4.5	1.2	a
Edible soy oil	6.3	3.6	a
Greenline	4.8	1.7	a
Edible corn oil	2.5	0.9	a
Carpostop	0.5	0.3	a

Codling moth fruit damage was always significantly lower in treated than in untreated control plots, with differences among treated plots not being significant. The *Cp*GV-based product showed slightly, though not significantly higher efficacy than the oil-based products in controlling the target pest.

Discussion

In Southern areas, codling moth, *Cydia pomonella*, is the major pest in organic pome fruit production. Mating disruption, entomopathogenic nematodes and *Cydia pomonella* GranuloVirus (*Cp*GV) frequently do not provide satisfactory levels of control of this pest. Even though Spinosad has recently been included into Annex II of EU Regulation 889/2008, many grower associations are disinclined to recommend the use of Spinosad because of its negative side effects on beneficials and its long-lasting detectable residue levels. From 2007 to 2011, several field trials aiming at evaluating the efficacy of oily substances against codling moth, have been conducted in South Tyrol on apple and in Emilia Romagna on pear. Several paraffin oil-based products, differing in their origin and manufacturing, and various plant oils, obtained from different plant species, have been tested.

No satisfactory results were obtained in the trials carried out on apple in South Tyrol. Efficacy levels against codling moth of the oil-based products were low, and almost no significant damage reduction in comparison to the untreated control was recorded. In addition, the plant oil-based product Duofruit, which showed highest efficacy, caused considerable leaf and fruit burn.

In the trials conducted on pear in Emilia Romagna, instead, the same active substances showed efficacy values ranging from 50 to 80%. These substances thus seem to be promising tools to be included into currently commonly used control strategies of codling moth.

Doubts on the mode of action of oily substances may arise, and an acceptable explanation for the observed differences in efficacy is warranted. In the past it was assumed that oily substances may act as ovicides, and contradictory studies, reporting from low up to excellent efficacy levels, can be found also in literature. Riedl *et al.* (2002) investigated the mode of action of oily substances in laboratory studies, and concluded that their efficacy depends on the likelihood of interrupting egg respiration. Egg respiration, and thus the efficacy of oils, seems to be strongly influenced by the location of the oviposition site: eggs deposited on the lower leaf surface are hardly affected by the oil, while eggs deposited on the upper leaf surface and on fruits may be killed. Literature does not provide a definite answer whether differences exist in the oviposition sites of codling moth between apple and pear.

References

Fritsch, E., Undorf-Spahn, K., Kienzle, J., Zebitz, C. P. W. & Huber, J. (2005) Apfelwickler-Granulovirus: Erste Hinweise auf Unterschiede in der Empfindlichkeit lokaler Apfelwickler-Populationen. Nachrichtenbl. Deut. Pflanzenschutzd. Vol. 57(2), 29-34.

Jehle J. A., Asser-Kaiser S., Fritsch E., Gund N. A., Heckel D., Huber J., Kienzle J., Reineke A., Schulze-Bopp S., Undorf-Spahn K. und Zebitz C. P.W. (2010). Management der Minderempfindlichkeit von Apfelwicklerstämmen gegenüber dem Apfelwicklergranulovirus. Dienstleistungszentrum Ländlicher Raum Rheinpfalz, D-Neustadt an der Weinstraße und Universität Hohenheim, Institut für Phytomedizin, D-Stuttgart, Phytomedizin.

Kelderer M. (2007). La difesa delle colture in agricoltura biologica. PETRIA Giornale di Pathologia delle Piante. Vol 17(2), 356-357.

Kelderer M., Casera C., Lardschneider E., Rainer A. (2010). Controlling codling moth with different netting structures and their influence on crop yield and quality. In: Boos, Markus (Hrsg.) Ecofruit - 14th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit-Growing: Proceedings to the Conference 2010 at Weinsberg/Germany, S. 183-190.

Kienzle J., Zimmer J., Volk F. und Zebitz C.P.W. (2008): Experiences with entomopathogenic nematodes for the control of overwintering codling moth larvae in Germany. In: Boos, Markus (Hrsg.) Ecofruit - 13th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit-Growing: Proceedings to the Conference 2008 at Weinsberg/Germany, S. 277-283.

Peters A., Katz P. und Elias E. (2008): Entomopathogenic nematodes for biological control of codling moth. In: Boos, Markus (Hrsg.) Ecofruit - 13th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit-Growing: Proceedings to the Conference 2008 at Weinsberg/Germany, S. 284-286.

Pollini A., Ponti I., Laffi F. (1993). Insetti dannosi alle piante da frutto. Edizione L'informatore Agrario. 85-88.

Riedl H., Marti S., Pons S., Hilton R., VanBuskirk P. (2002). Spray Oils beyond 2000 – Sustainable pest and disease management. University of Western Sidney, 457.