PERFORMANCE OF MEMBRANE DISPENSERS FOR COMBINED MATING DISRUPTION OF ORIENTAL FRUIT MOTH *GRAPHOLITA MOLESTA* (BUSCK) AND CODLING MOTH *CYDIA POMONELLA* L. (LEPIDOPTERA: TORTRICIDAE) IN PEARS.

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Summary

Codling moth (CM) and oriental fruit moth (OFM) are very important orchard pests both worldwide and in Australia where they severely damage pome fruit in the State of Victoria. Codling moth and OFM have been controlled by pheromone-mediated mating disruption with reasonable success, but treating pome fruit with full registered rates of separate, hand-applied dispensers for CM and OFM could be labour intensive and uneconomical for growers. Field trials were conducted to compare Disrupt CM/OFM COMBO pheromone dispensers, designed to simultaneously disrupt both CM and OFM with Disrupt CM and Disrupt OFM dispensers applied individually for the control of CM and OFM in pears. The application of combined and individual-species dispensers on pears reduced moth catches and fruit damage of both species to a similar level. The OFM control, in particular, was significantly more effective than the untreated control. These results suggest that combined control of CM and OFM in pears by applying Disrupt CM/OFM COMBO dispensers at the full-recommended rate of 500 dispensers per hectare could be reasonably effective on pears if the pest population is low, but the release characteristics of these dispensers indicate the potential for poor control under higher pest pressure situations.

Key words: Codling moth, oriental fruit moth, sex pheromone, mating disruption, pome fruit.
Short title: Combined dispenser for CM and OFM mating disruption

INTRODUCTION

Oriental fruit moth (OFM) *Grapholita molesta* (Busck) and codling moth (CM) *Cydia pomonella* L. (Lepidoptera: Tortricidae) are the most damaging pests of stone and pome fruits in Australia. CM is a pest of pome fruit such as apples and pears (Geier 1963). Although OFM was considered to primarily be a pest of stone fruit, such as peaches and nectarines (Rothschild and Vickers 1991) it has become a serious problem in pome fruit as well, especially pears in Victoria (Il'ichev *et al*. 2004). Both OFM and CM have the ability to fly substantial distances, migrate between and within orchards (Il'ichev *et al*. 2004) and quickly infest unprotected host plants (Il'ichev *et al*. 2003). Australian pome fruit growers now address both OFM and CM control in their pest management programs.

The application of pheromone-mediated mating disruption (MD) is widely used in Australia as a major part of Integrated Pest Management (IPM) programs in orchards (Williams and Il'ichev 2003). In Australian stone fruit, OFM has been successfully controlled through the use of mating disruption (MD) for more than 20 years (Vickers 1990, Sexton and Il'ichev 2000, Il'ichev *et al.* 2002). Successful control of CM in pome fruit also has been achieved with the use of MD alone (Vickers and Rothschild 1991, Il'ichev *et al.* 2007) or in conjunction with limited insecticide treatments (Vickers *et al*. 1998).

An area-wide MD program for control of OFM, when all fruit varieties were treated with MD during two consecutive seasons in 1997-99 improved the protection of 40 contiguous orchards (1,100 ha) in the Cobram region of Northern Victoria (Il'ichev *et. al*. 2002). The area-wide MD program also controlled population outbreaks, reduced border damage attributed to migration, and significantly reduced the number of insecticide treatments in the region. Significant reductions in shoot and stone fruit damage indicated that OFM can be successfully controlled by MD and support the area-wide approach to MD applications (Il'ichev *et al*. 2002).

Long-term successful control of CM with area-wide MD treatments of pome fruit was demonstrated in the western USA during five years of a government-supported program (Brunner *et al.* 2001). Incorporation of selective area-wide MD treatments of major pests into IPM programs has potential for development of cost effective strategies for controlling pests, while improving protection of the environment by reducing the amount of pesticides applied in orchards (Williams and Il'ichev 2003).

However, Il'ichev *et al*. (2004) observed increased infestation by OFM when only CM was targeted by MD applied to pome fruit. Unfortunately, separate application of MD dispensers at the full registered rate for both OFM and CM as a solution for managing these two pests in pears is expensive and laborious. Application of the half the registered rate of Isomate OFM Rosso® dispensers (Shin-Etsu Chemical Co. Ltd., Japan) could control low to medium OFM population in pears (Il'ichev and Sexton 2002). The results of field trials conducted in Victoria demonstrated that dual Isomate CM/OFM TT® dispensers (Shin-Etsu Chemical Co. Ltd., Japan), designed to disrupt both CM and OFM, reduced moth catches and fruit damage to a similar degree as Isomate CTT® and Isomate OFM Rosso® dispensers (Shin-Etsu Chemical Co. Ltd., Japan) applied individually in pears for control of CM and OFM, respectively (Il'ichev *et al*. 2007).

Disrupt-OFM® and Disrupt-CM® [Colin Campbell (Chemicals) Pty. Ltd., Australia] dispensers were recently registered in Australia for mating disruption of OFM and CM, respectively. But fruit growers continued to raise concerns about the high costs of labour and materials associated with the need to apply two dispenser types in pears. The aim of this study was to assess the effectiveness of a new hand-applied dual dispenser, Disrupt CM/OFM COMBO® [Colin Campbell (Chemicals) Pty. Ltd., Australia], designed for simultaneous control of both CM and OFM, in comparison with Disrupt-OFM® and Disrupt-CM® applied individually for control of these two key internal feeding pests of pome fruit.

MATERIALS AND METHODS

Dispensers for mating disruption of codling moth and oriental fruit moth

The Disrupt-CM® registered in Australia for mating disruption of CM in apples and pears consists of a white plastic membrane dispenser 75 X 50 mm attached to a coloured plastic clip. Each dispenser membrane is filled with the major component of CM sex pheromone (codlemone): (*E, E*)-8,10-dodecadien-1-ol (160 mg/dispenser). The colour of the plastic clip used to hang the dispenser membrane on the tree branch is changed every year by the manufacturer to distinguish between old and new dispensers in the field. The registered application rate for Disrupt-CM® in all states in Australia is 500 dispensers per hectare.

The Disrupt-OFM® registered in Australia for mating disruption of OFM in apple, pear, cherry, nashi, apricot, peach, nectarine, plum and quince also consists of a white plastic membrane dispenser 75 X 50 mm attached to coloured plastic clip. Each dispenser membrane is filled with a 3-component blend of OFM sex pheromone: (*Z*)-8-dodecenyl acetate (232.5 mg/dispenser), (*E*)-8-dodecenyl acetate (15 mg/dispenser) and (*Z*)-8-dodecenol (2.5 mg/dispenser). The colour of the plastic clip used to hang and hold the dispenser on the tree branch is changed every year by the manufacturer. The registered application rate for Disrupt-OFM® in all states in Australia is 270 dispensers per hectare.

Recently the distributor of these products introduced a combined dispenser named Disrupt CM/OFM COMBO®. The Disrupt CM/OFM COMBO® dispenser is the mechanical combination of half-size dispensers of Disrupt OFM® and Disrupt CM®, both attached to one coloured plastic clip, with recommended application rate of 500 dispensers per hectare on pears. This combined dispenser became available in Victoria, Australia for field trials in 2008. It thought that the sex pheromone loading rate for the combined dispenser would be half of the loading rate for individual dispensers for OFM and CM, but the manufacturer did not provide details of the loading rates for this product.

Experimental sites and treatments

Field trials were established in 2008-09 growing season to assess the effectiveness of the new combined dispenser of Disrupt CM/OFM COMBO® (500 dispensers per hectare) for MD control of both CM and OFM for comparison with Disrupt CM® (500 dispensers per hectare) and Disrupt OFM® (270 dispensers per hectare) applied together and individually to orchard blocks. The field experiments were conducted in large commercial pear blocks at the same property in Victoria, Australia.

Replicated trials using a randomised block design were established in a pear orchard with a history of OFM and CM infestation. All experimental plots contained both Packham's Triumph (PKT) and Williams Bon Chretien (WBC) pear varieties. Treatments applied to the experimental plots were either Disrupt CM/OFM COMBO® at recommended rate of 500 dispensers per hectare (D-C/O); Disrupt CM® at recommended rate of 500 dispensers per hectare (D-C); Disrupt OFM® at recommended rate of 270 dispensers per hectare (D-O); and Disrupt CM® (500 dispensers per hectare) together with Disrupt OFM® (270 dispensers per hectare) applied as 2 dispensers of Disrupt CM® and 1 dispenser of Disrupt OFM® per tree (D-C+O) to the opposite sides of the tree canopy. Each treatment was replicated 3 times, including 3 replications of no-MD treatment control (control). There were no chemical sprays applied against CM and/or OFM in any experimental plots including control. Each experimental plot was 0.2 hectare in size with 7 trees by 7 rows treated area (total 49 trees planted 6 by 6 m). Treatments were randomly allocated to experimental plots using

GENSTAT 8 (Lawes Agricultural Trust, Rothamsted Experimental Station) for randomisation.

The experiment was conducted in a single orchard to ensure that all management practices were consistent across all treatments, plots and replicates. This allowed us to directly compare all four treatments and the untreated control without worrying about the confounding effects of insecticide sprays on some treatments. No chemical treatments were applied to any treatment. All mating disruption dispensers were applied in the experimental plots by the end of September (spring). The treatments were assessed by comparison of the pest population levels as indicated by the number of moths captured in sex pheromone traps, and fruit damage over a period of full growing season.

Monitoring of codling moth population

Two Pherocon Delta VI traps with sticky inserts, one baited with high-dosage pheromone lure (CM L2) and the other baited with low-dosage pheromone lure (TRE 8579) (Trécé Ltd., Salinas, CA, USA) were used for weekly monitoring of CM in control plots without MD and in experimental plots under MD. Pheromone traps were placed on the top of bamboo poles and suspended as high as possible within the tree canopy. Two Pherocon Delta VI traps were placed in the next row from OFM traps and spaced by ca. 24 m (3 pear trees between traps) to minimise interference. High-dosage (CM L2) sex pheromone lures were replaced every 8 weeks, but low-dosage lures were replaced fortnightly. The monitoring of both species started at the beginning of October 2008 and finished at the beginning of April 2009.

Monitoring of oriental fruit moth population

The population of OFM was monitored weekly with two sex pheromone traps per each control and experimental plot. Pherocon Delta VI traps with sticky inserts baited with 1 mg sex pheromone lures (OFM 3102, Trécé Ltd., Salinas, CA, USA), were used for OFM monitoring in all plots. Sex pheromone traps were placed at a height of 1.5-2.0 m in the tree canopy in the middle row of the plot and spaced by ca. 24 m (3 pear trees between traps). Standard red rubber septa with 1 mg of OFM sex pheromone was replaced in traps every 8 weeks.

Pear fruit damage assessments

The effectiveness of treatments in preventing damage was assessed by inspecting pear fruit at harvest for OFM and CM larval infestation. OFM damage to pear fruit, but not shoot tips, was assessed because larval feeding in shoot tips in pear is extremely difficult to detect and it would occur only at a very high level of OFM infestation in the pear orchard.

Damage to pear fruit was assessed with a random sample of 100 fruit collected about one week prior to harvest from 5 trees per plot including the trees in which monitoring traps were deployed. It is difficult to distinguish between CM and OFM damage from external examination of pome fruit. Therefore all damaged fruit were cut open for identification of OFM and CM larvae by determining presence (for OFM larvae) or absence (for CM larvae) of the anal comb. The number of fruit damaged by each species was recorded and used for analyses.

Measurements of pheromone release rates from dispensers

The release rate characteristics, over time, of sex pheromone active ingredient (a.i.) for CM and OFM from the Disrupt CM/OFM COMBO® dispenser, Disrupt CM® and Disrupt OFM® individually were determined using volatile collection and gas chromatography (GC) analysis. Samples of ten new unexposed dispensers of Disrupt CM®, Disrupt OFM® and Disrupt CM/OFM COMBO® were sealed in foil bags. Samples of ten exposed dispensers were removed after 60 and 145 days of exposure in the orchards throughout the season, and sealed in foil bags. New and exposed dispensers were sent to Michigan State University (USA) for analysis. The release rate of sex pheromone from combined and individual Disrupt dispensers was calculated in micrograms per hour and plotted in a graph.

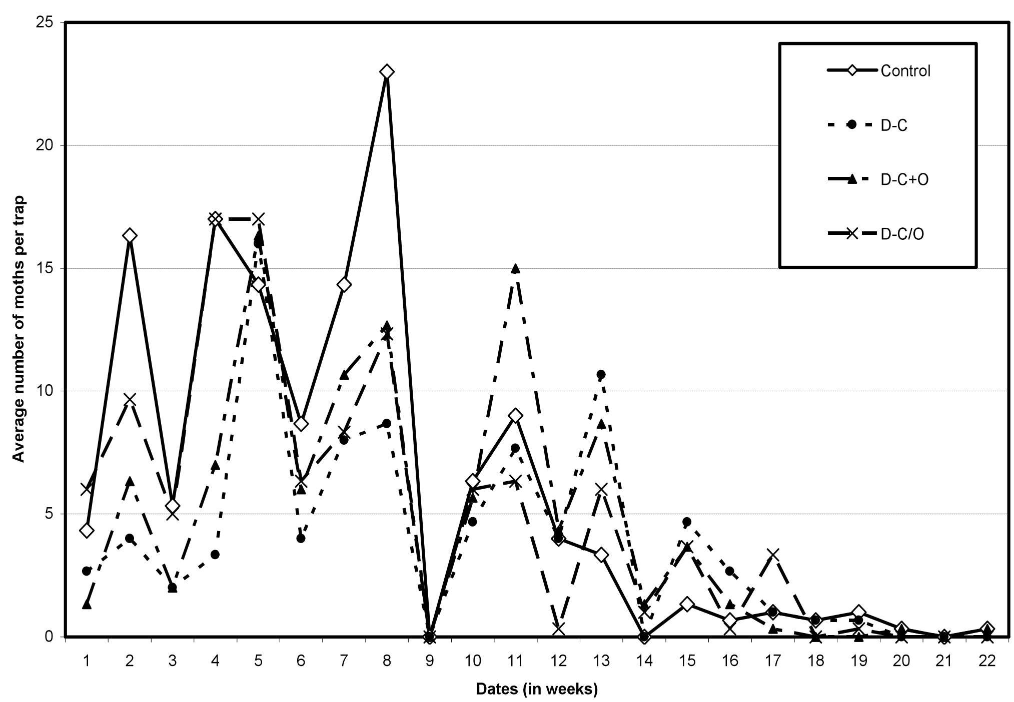
Dispensers were stored at -10^{o}C until analysed via volatile collection. Volatile collections were made under standardised laboratory conditions (Tomaszewska *et al.* 2005). All dispensers were allowed to equilibrate to room temperature for 24 h prior to volatile collection. The volatile collection apparatus consisted of compressed air flowing through Teflon tubing connected to a Teflon collection jar. A glass tube containing an adsorbent polyurethane foam cartridge (Supelco, Bellefonte, PA) was attached to the jar outlet. Individual dispensers were suspended within the collection jar. Volatile collections were made for 2 h at 20 ^{o}C with a flow rate of 10 L per min. Pheromone was extracted from the foam cartridges by three 150mL acetone rinses. Extracts were then appropriately diluted for analysis using an Agilent 6890N Gas Chromatograph with 5973N Mass Selective Detector (MSD) and an Agilent 7683 auto sampler. Operating procedures and GC conditions have been previously detailed in Tomaszewska *et al*. (2005). The quantification of residues in the extract was performed by electronic peak area measurement and comparison to an internal standard.

Statistical analysis

To compare the performance of four treatments (D-C/O; D-C; D-O; D-C+O) and no-treatment control (Control), the end-of-season data on total number of OFM and CM catches (cumulative count) were analysed using both the analysis of variance (ANOVA) and a Poisson-based generalised linear model as appropriate for a completely randomised design. Statistical program GENSTAT 8 (Lawes Agricultural Trust, Rothamsted Experimental Station) was used to perform the analysis. The original data satisfied the ANOVA assumptions of constant variance and normality of residuals. The significance of the difference between the mean total catch of any treatments and control was tested using protected and unprotected least significant difference (LSD) approach at 5% level of significance. The results obtained from ANOVA on the original data are reported here, because a Poisson-based generalised linear model produced similar results.

RESULTS

Figure 1. Mean of codling moth weekly catches in traps baited with high-dosage sex pheromone lure (CM L2) under no-MD treatment (control) and different Disrupt treatments: Disrupt CM (D-C), Disrupt CM and Disrupt OFM (D-C+O), and Disrupt CM/OFM COMBO (D-C/O).



Codling moth catches under Disrupt treatments

The mean weekly capture of CM in Pherocon traps baited with high-dosage sex pheromone lure (CM L2) placed in each experimental plot are shown in Figure 1. The mean catches varied from 3 to 23 per week per trap and suggested the presence of CM infestation at medium to high population densities in our experimental blocks at the beginning of the experiment. The highest peak of CM catches was recorded during the first flight at the beginning of December (week 8) in the control blocks and during November (weeks 4 and 5) under combined D-C/O and D-C+O treatments. Mean catches under D-C treatment also peaked in November (week 5) and was very similar to catches under combined treatments. This could indicate that the initial level of CM population during the peak of the first generation flight was similar in all blocks before the treatments started to affect subsequent generations of CM. Average catches in all traps demonstrated a similar pattern during the whole season. Closer to the end of the growing season (weeks 14-18), mean CM catches under all treatments had decreased to less than 5 moths per trap. By the end of the season (weeks 20-22), catches of CM in all traps were very small under all treatments including no-treatment control (Fig.1).

Oriental fruit moth catches under Disrupt treatments

The mean catches of OFM were substantially lower than catches of CM in the same plots and varied from 0 to 3 moths per week per trap indicating a very low OFM infestation. The highest peak of OFM catches was recorded during the first flight at the middle of October in the control blocks with maximum catches of 5 moths per trap. There were no OFM captured in any of the pheromone treatments closer to the end of the season in February-March and only under the no treatment control were single moths caught late in the season.

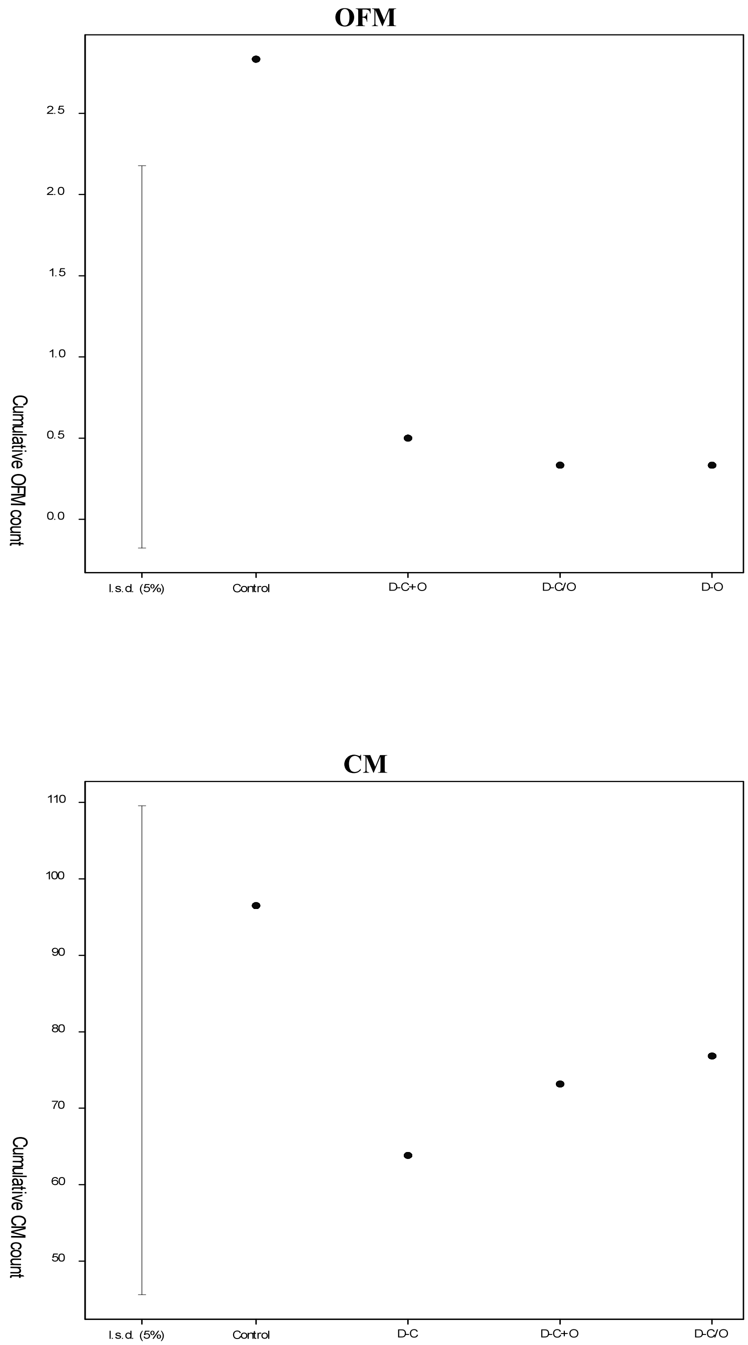
Analysis of cumulative moth catches under different treatments

The overall difference among the four treatments were observed to be non-significant for both CM and OFM (F Prob = 0.698 for CM, F Prob = 0.103 for OFM) using protected LSD approach (Table 1 and Figure 2). The no-treatment control was observed to have the highest mean value of cumulative catches for both CM and OFM compared to the other four treatments. The mean value for CM under no-treatment control was 96.0 when the MD treatments produced values between 64.0-77.0. The mean values for OFM under D-C/O and only D-O treatments were the same (0.33), and D-C+O was slightly higher (0.50) (Table 1). Considering the substantial variation in the results produced by this study and a very low level of initial OFM population in the experimental plots it would be reasonable to make an attempts to analyse the available results further. Therefore using unprotected LSD approach it was demonstrated that the control in this exploratory study differed significantly from the other three treatments in the case of OFM, but not in the case of CM (Fig. 2).

Table 1. Least squares mean cumulative counts of codling moth (CM) and oriental fruit moth (OFM) under no-treatment (control) and different Disrupt treatments.

Treatment	CM	OFM
Control	96.0	2.83a
D-C+O	64.0	0.50ab
D-C/O	73.0	0.33b
D-C or D-O	77.0	0.33b
F Prob	0.698	0.103
LSD (5%)	63.9	2.354

Figure. 2. Model-based plots with cumulative counts of codling moth (CM) and oriental fruit moth (OFM) under no-MD treatment (control) and different Disrupt treatments (LSD 5%)



Analysis of pear fruit damage assessments under different treatments

The trial site, a large commercial pear fruit orchard, had a history of OFM and CM infestation recorded by monitoring using pheromone traps during the previous season and observing a low level of pear fruit damage. No significant differences were observed in pear fruit damage between no-MD treatment control plots and the Disrupt treated plots. Therefore, comparison of combined percentage of damaged fruit collected from all three replications together may demonstrate some numerical (but not statistically significant) differences, despite an apparent numerical trend suggesting an increasing numerical trend between D-C+O, D-C, D-O, D-C/O and the untreated control consecutively (Table 2).

Table 2. Least squares mean combined damage (%) of codling moth (CM) and oriental fruit moth (OFM) larvae under no-MD treatment (control) and different Disrupt treatments.

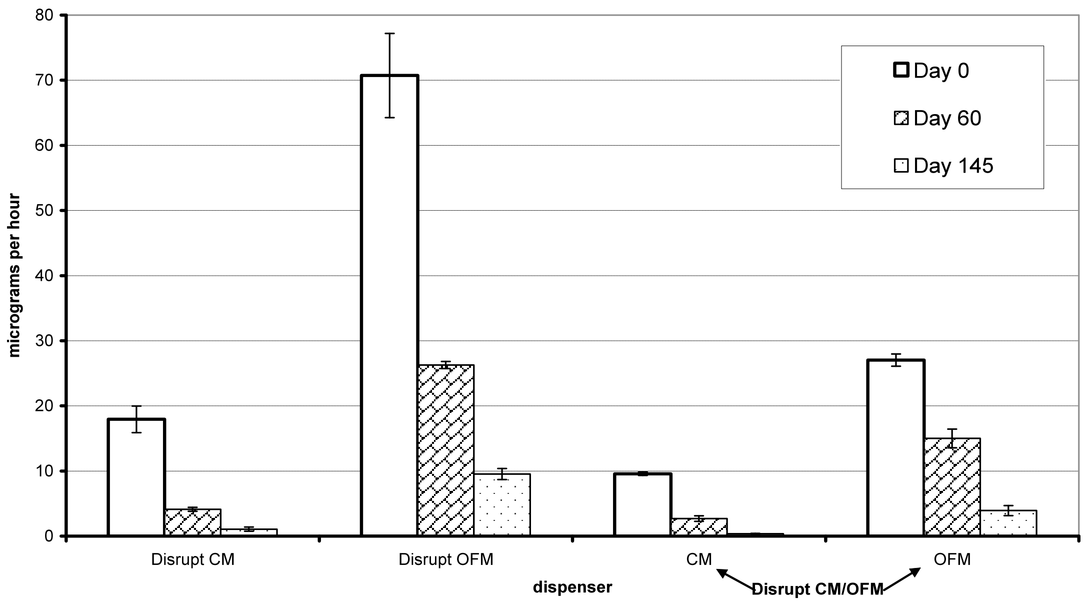
Treatment	Mean damage (%)	SE means
Control	0.67b	0.257
D-C+O	0.13a	0.115
D-C/O	0.40ab	0.199
D-C	0.20a	0.141
D-O	0.27ab	0.163
F Prob	0.373	

The pear fruit damage in three randomly distributed no-treatment control plots ranged from 0.2% to 0.5%, but combined damage in all three plots was 0.67 ±0.257%. Combined damage under different Disrupt treatments was as follows: treatment D-C/O had 0.40 ±0.199% damage; treatment D-C+O had 0.13 ±0.115% damage; treatments D-O and D-C had 0.27 ±0.163% and 0.20 ±0.141% damage respectively (Table 2). Comparison of the numerical damage indicators between D-C/O (0.40%) and D-C+O (0.13%) treatments may indicate some difference and such results may be interpreted as better performance of D-C+O treatment in pear damage control. Comparison of the combined damage under D-C+O (0.13%) treatment and no-treatment control (0.67%) may look more pronounced, but the difference between such low damage indicators was not significant.

Release rates of sex pheromone active ingredients from Disrupt dispensers

The release rate characteristics in micrograms per hour (µg/h) of sex pheromone active ingredients (a.i.) emitted from the Disrupt CM®, Disrupt OFM® and Disrupt CM/OFM COMBO® dispensers, calculated from the results of gas chromatography (GC) analysis of residual a.i. of CM and OFM sex pheromone in the sampled dispensers are presented in Figure 3. The initial (day 0) calculated emission rate of the main component of OFM sex pheromone a.i. from Disrupt OFM® and Disrupt CM/OFM COMBO® dispensers was 70 and 27 µg/h, respectively. Pheromone emission rates for both dispensers dropped substantially by day 60 and again by day 145 to 10 and 4 µg/h, respectively. Codlemone [major component of the sex pheromone (*E, E*)-8,10-dodecadien-1-ol] emission from Disrupt CM® and Disrupt CM/OFM COMBO® dispensers at day 0 was approximately 18 and 10 µg/h, respectively. As with the OFM pheromone, codlemone emission rates decreased significantly at each sampling with rates below 1 µg/h for both dispenser types.

Figure. 3. Release rate characteristics of sex pheromone active ingredient (in micrograms per hour) for Disrupt CM/OFM COMBO (D-C/O), Disrupt CM (D-C), and Disrupt OFM (D-O) dispensers after 0, 60, and 145 days of field life.



Emission ratios of OFM pheromone components remained constant from both Disrupt OFM® and Disrupt CM/OFM COMBO® dispensers throughout the study (Table 3), with greater than 90% of pheromone consisting of the major component (*Z*)-8-dodecenyl acetate. Codling moth pheromone emission compositions varied dramatically with sampling period. At day 0, the pheromone from both Disrupt CM® and Disrupt CM/OFM COMBO® dispensers consisted of 95% codlemone. By day 60, the percentage of codlemone in the emitted pheromone dropped to approximately 67%, with all isomers increasing in release rate. On day 145, codlemone ratio decreased again to 50 and 57% for Disrupt CM® and Disrupt CM/OFM COMBO® dispensers, respectively.

Table 3. Proportion of pheromone components from Disrupt membrane dispensers after 0, 60, and 145 days of field life: Proportion of total (standard error).

	CM isomers of Disrupt CM/OFM				OFM pheromone components of Disrupt CM/OFM		
Day	(Z,E)8,10-12OH	(E,E)8,10-12OH	(E,Z)8,10-12OH	(Z,Z)8,10-12OH	(Z)8-12OH	(E)8-12Ac	(Z)8-12Ac
0	0.03 (0.0005)	0.95 (0.001)	0.03 (0.001)	0 (0)	0.01 (0.0001)	0.06 (0.0002)	0.93 (0.0002)
60	0.13 (0.01)	0.68 (0.03)	0.13 (0.01)	0.06 (0.01)	0 (0)	0.07 (0.0004)	0.93 (0.0004)
145	0.17 (0.03)	0.57 (0.06)	0.18 (0.02)	0.09 (0.01)	0 (0)	0.09 (0.01)	0.91 (0.01)
	CM isomers of Disrupt CM						
	(Z,E)8,10-12OH	(E,E)8,10-12OH	(E,Z)8,10-12OH	(Z,Z)8,10-12OH			
0	0.02 (0.01)	0.95 (0.01)	0.03 (0.001)	0 (0)			
60	0.14 (0.01)	0.67 (0.03)	0.14 (0.01)	0.06 (0.01)			
145	0.20 (0.02)	0.50 (0.06)	0.20 (0.02)	0.09 (0.01)			
					OFM pheromone components of Disrupt OFM		
					(Z)8-12OH	(E)8-12Ac	(Z)8-12Ac
0					0.005 (0.0002)	0.06 (0.0001)	0.93 (0.0001)
60					0 (0)	0.08 (0.001)	0.92 (0.001)
145					0 (0)	0.10 (0.003)	0.90 (0.003)

DISCUSSION

The overall difference among the four Disrupt treatments was not significant in cumulative moth counts for combined control of both CM and OFM. The no-treatment control was observed to have the highest mean value of cumulative catches for both CM and OFM compared to the other four treatments. The cumulative moth counts in no-treatment control differed significantly from the other three Disrupt treatments in the case of OFM, but not in the case of CM. The release rate characteristics of Disrupt dispensers for OFM sex pheromone were also much higher better than for CM sex pheromone. All four MD treatments with different Disrupt dispensers applied individually or in combination provided similar levels of fruit protection in experimental plots. The results of our trials were able to determine the contribution of MD treatments to OFM and CM control without the confusing impact of insecticide treatments because the entire experimental area was not sprayed with any insecticides at all. In USA and Canada (Kovanci *et al*. 2004, Trimble *et al*. 2001, 2004) it was recommended to use insecticide sprays against OFM and CM first generations and then apply mating disruption for successful control of the following generations during the growing season. Our study was conducted under the condition that no insecticide sprays would be applied at all in the experimental pear block. Such a unique opportunity permitted us to observe only the effects of mating disruption on control of OFM and CM in pears without complicating factors.

The efficacy of all Disrupt dispensers to protect pears against OFM and CM damage was very similar and slightly but not significantly better than no-treatment control. Probably, the application of Disrupt CM/OFM COMBO® dispensers in concert with companion insecticide sprays against OFM and CM would provide more improved control of both species than the application of Disrupt CM/OFM COMBO® dispensers only. Such combination of Disrupt CM/OFM COMBO® treatment supplemented with insecticides holds the promise as a control strategy to meet considerably low fruit damage thresholds.

The Disrupt CM/OFM COMBO® dispenser has the potential advantages of disrupting both OFM and CM with similar effectiveness as the combined application of individual dispensers of Disrupt CM® and Disrupt OFM®, without the associated costs of extra labour time required to apply the products separately at each application. However our results suggest that since the release rate of sex pheromones in the COMBO dispenser was nearly half that of the two single component dispensers, the COMBO dispenser may not provide the same level of control for CM and OFM as the single species dispensers.

The reduced release rate of the main pheromone components for both species from the Disrupt CM/OFM COMBO® dispensers (Figure 3) is likely due to lower load rates of the corresponding pheromones compared to the Disrupt dispensers that contain the pheromone of only one pest species. This could be due to a limited amount of pheromone each dispenser is capable of containing. Dividing that volume to accommodate more pheromones necessarily dictates a lower amount of each pheromone that can be loaded. Another possibility is that each dispenser was loaded with less pheromone to make the product more economical. This is especially the case for the Disrupt CM/OFM COMBO® dispensers which are applied at approximately twice the dispenser rate as Disrupt OFM®. Halving the load rate of the OFM pheromone components would maintain the same pheromone load per hectare and keep the cost per dispenser very similar.

Codlemone is sensitive to degradation when exposed to ultraviolet light (Brown *et al* 1992). It commonly degrades into its various isomers. El-Sayed *et al* (1998) reported reduced attractiveness to male codling moths when codlemone was combined with its various isomers. Here we report significant isomerization of codlemone throughout the course of the study in both the Disrupt CM® and Disrupt CM/OFM COMBO® dispensers (Table 3). This likely contributed to the low (17-31%) reduction in codling moth male captures in monitoring traps compared to the control (Table 1). A similar study using a combo dispenser more effective at protecting codlemone from isomerization was more successful at reducing male codling moth capture (Stelinski *et al.* 2009).

The interference between active ingredients of two (OFM and CM) sex pheromone formulations was reported when OFM male response to a combined sex pheromone-based attracticide formulation designed for both OFM and CM demonstrated the increased attractiveness of this formulation for OFM and decreased attractiveness for CM males (Evenden and McClaughlin 2005). These data suggest interference between sex pheromone formulations designed for CM and OFM similar to that demonstrated for other tortricid species (Judd and Gardiner 2004).

Overall, if the codlemone protection from ultraviolet light in the Disrupt CM/OFM COMBO® dispenser would be substantially improved, the advantages of the COMBO dispenser would be more pronounced with the convenience of reduced labour associated with hand application.

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