COMBINED CONTROL OF CODLING MOTH *CYDIA POMONELLA* L. AND ORIENTAL FRUIT MOTH *GRAPHOLITA MOLESTA* BUSCK (LEPIDOPTERA: TORTRICIDAE) BY MATING DISRUPTION ON PEARS IN AUSTRALIA

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Summary

Codling moth (CM) and oriental fruit moth (OFM) are both very important pests of pome fruit in Victoria, Australia. Successful control of OFM in stone fruit and CM in pome fruit has been achieved by the use of pheromone-mediated mating disruption in Victorian orchards. However, mating disruption can be costly for growers when applied at the full registered rates for both of these pests on pome fruit. Field trials conducted over three seasons consistently demonstrated that the effectiveness of the half rate of Isomate OFM Rosso for OFM control combined with the full rate of Isomate CTT for CM control was comparable with the full registered rates of both these dispensers applied in pears. During three consecutive seasons of the trial, both treatments reduced moth catches and fruit damage to a similar degree. The results suggest that the cost of controlling OFM and CM together in pears by mating disruption could be reduced by applying half the registered rate of Isomate OFM Rosso (one dispenser tree^{-1}or 250 dispensers hectare^{-1}) combined with the full rate of Isomate CTT (two dispensers tree^{-1}or 500 dispensers hectare^{-1}).

Keywords: Oriental fruit moth, codling moth, sex pheromone, mating disruption, pome fruit

INTRODUCTION

Codling moth (CM) *Cydia pomonella* L. and oriental fruit moth (OFM) *Grapholita molesta* Busck (Lepidoptera: Tortricidae) are the most important pests in Australian orchards. OFM was considered the primary pest of stone fruit such as peaches and nectarines (Rothschild and Vickers 1991), while CM mostly damage pome fruit like apples and pears (Geier 1963). OFM was known to attack apples in the United States of America (USA) (Chapman and Lienk 1971) with recent increases of severe damage (Kovanci *et al*. 2004). In recent years OFM has become a serious problem on pome fruit, especially pears in Victoria (Il'ichev *et al.* 2004). Both these pests have the ability to migrate and quickly invade new host-plants and Australian growers now need to address both OFM and CM control in their pest management programs.

OFM has been successfully controlled using pheromone-mediated mating disruption (MD) as a major part of Integrated Pest Management (IPM) programs in Australian orchards (Vickers 1990, Brown and Il'ichev 2000, Sexton and Il'ichev 2000, Williams and Il'ichev 2003). Control of CM in pome fruit also has been achieved with the use of MD alone or in conjunction with limited insecticide treatments (Vickers *et al*. 1998).

Area-wide MD treatments applied to 1100 ha of stone and pome fruit in Victorian orchards during two consecutive seasons led to a significant reduction in the OFM population level and damage to stone fruit in the MD treated area (Il'ichev *et al*. 2002). The area-wide MD program also controlled OFM outbreaks and reduced edge damage attributed to migration of OFM. These significant reductions in shoot and stone fruit damage indicated that OFM is vulnerable to MD and support the area-wide approach to MD applications (Il'ichev *et al*. 2002).

Area-wide MD treatments of pome fruit during five years of a government-supported program had demonstrated a successful control of CM in the western USA (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).

If Victorian fruit growers applied MD on pome fruit for control of CM only, it is possible that infestation of OFM on pome fruit might increase (Il'ichev *et al.* 2003, 2004). The separate application of MD dispensers at the full registered rate for both OFM and CM as a solution for managing the two pests in pears is expensive and laborious. Il'ichev and Sexton (2002) demonstrated that a low OFM infestation level in pears neighbouring MD treated peach blocks, could be controlled by extending the MD treated area through application of half the registered rate of Isomate OFM Rosso (Shin-Etsu Chemical Co. Ltd., Japan for Biocontrol Ltd., Australia) to the pears. They did not test the technique on pear blocks without surrounding MD treated peach blocks.

Area-wide MD treatments for combined control of CM and OFM on pears were supported by Victorian fruit growers, but growers continued to raise concerns about the high costs of labour and materials associated with the need to apply two MD dispensers. The aim of this study was to determine whether half of the registered rate of Isomate OFM Rosso applied together with the full registered rate of Isomate CTT (Shin-Etsu Chemical Co. Ltd., Japan for Biocontrol Ltd., Australia) would control both OFM and CM effectively on pears.

MATERIALS AND METHODS

Dispensers for OFM and CM mating disruption

The Isomate OFM Rosso dispenser (Shin-Etsu Chemical Co. Ltd., Japan for Biocontrol Ltd., Australia) is a controlled release formulation of polyethylene tubing that is 1.2 mm in diameter with 0.9 mm wall thickness. The dispenser is filled with a three-component blend of OFM sex pheromone: (Z)-8-dodecenyl acetate (223 mg dispenser^{-1}), (E)-8-dodecenyl acetate (14.5 mg dispenser^{-1}) and (Z)-8-dodecenol (2.5 mg dispenser^{-1}). The polyethylene used in Isomate OFM Rosso contains a red pigment to protect the active ingredient from degradation in sunlight. The average loading is above the nominal figure of 240 mg of active ingredient dispenser^{-1}. The registered application rate for Isomate OFM Rosso is 500 dispensers ha^{-1}, which approximates two dispensers tree^{-1}.

The Isomate CTT dispenser (Shin-Etsu Chemical Co. Ltd., Japan for Biocontrol Ltd., Australia) used for MD of CM is similar to Isomate OFM Rosso but has a double tube capillary with smaller internal diameter. Isomate CTT is loaded with the following three-component blend of CM sex pheromone: (E, E)-8,10-dodecadienol (215 mg dispenser^{-1}), dodecanol (120 mg dispenser^{-1}) and tetradecanol (27.5 mg dispenser^{-1}). The polyethylene used in Isomate CTT also contains a red pigment to protect the active ingredient from degradation in sunlight. The average loading is above the nominal figure of 362.5 mg of active ingredient dispenser^{-1}. The registered application rate for Isomate CTT is 500 dispensers ha^{-1} or about two dispensers tree^{-1}.

Experimental sites and treatments

Field trials were established to compare the effectiveness of the half registered rate of Isomate OFM Rosso (one dispenser tree^{-1} or 250 dispensers ha^{-1}) applied on pears together with the full registered rate of Isomate CTT (two dispensers tree^{-1} or 500 dispensers ha^{-1}) and the effectiveness of the full registered rates of both dispensers. The field experiments were conducted in pears in Victoria, Australia at the same locations for three consecutive seasons from 2001 to 2004.

A replicated trial using a randomised complete block design was established in a large commercial pome fruit orchard with a history of OFM and CM infestation. The orchard was subdivided into three uniform six ha blocks. Each of the three blocks was divided into three, two ha plots, allowing for three treatments to be replicated three times. Treatments consisted of half the registered rate of Isomate OFM Rosso plus the full registered rate of Isomate CTT (1Rosso+2CTT), the full registered rates of Isomate OFM Rosso and Isomate CTT (2Rosso+2CTT), and no MD treatment (control).

The experiment was conducted on a single farm to ensure that management practices, including spraying, were consistent across all treatments, plots and replicates. Commercial pear blocks in Victoria, if not treated with MD, are generally treated with parathion-methyl and/or azinphos-methyl applied up to seven times for control of both CM and OFM. Since all of the experimental plots were within a larger MD area, the grower was uncomfortable leaving control blocks totally untreated. Our ability to assess efficacy of the MD treatments would have been compromised if chemical sprays were only applied to the control area without MD therefore all plots in the entire experimental area were over-sprayed with the same chemical at the same time. This allowed us to directly compare all three treatments without worrying about the confounding effects of insecticide sprays on some treatments. All MD treatments with dispensers of Isomate OFM Rosso and Isomate CTT were applied in the experimental blocks by the middle of September (early spring) of each growing season. Pest population level and fruit damage over a period of three growing seasons was used to compare treatment efficacy.

Monitoring of OFM population

OFM was monitored weekly with food and sex pheromone traps using standard Efecto-fly traps (Avond Pty. Ltd., Narrogin, Australia) placed at a height of 1.5-2.0 m in the tree canopy. Three food traps were placed in a line through the middle of each experimental plot. Each food trap was placed in a tree row at a distance of approximately 36 m away from each other (five pear trees between food traps). Food traps consisted of about one litre of 100 g L^{-1} dark brown sugar solution with 12 drops of terpinyl acetate solution (48.5 mL of terpinyl acetate with 1.5 mL of non-ionic wetting agent and 50 mL of warm water). The sugar and terpinyl acetate solutions were changed at weekly intervals after the trapped moths had been identified and removed.

One sex pheromone trap for OFM monitoring was placed within each treatment plot. These sex pheromone traps are very species specific and catch OFM males only. Each sex pheromone trap was placed at a distance of about 54 m away from the nearest food trap to minimise interference between traps. Dispensers with one mg of OFM sex pheromone (Trécé Ltd., Salinas, CA, USA) were replaced every six weeks. The sex pheromone traps were also monitored weekly for OFM numbers. The monitoring of OFM normally began at the end of August or beginning of September before the first OFM flight had started. The monitoring usually finished in the middle of April, two weeks after the last flight of OFM had ended. The data collected from each week of monitoring (except for weeks where no catches were recorded) were accumulated as seasonal totals and used for statistical analyses.

Monitoring of CM population

Pherocon Delta VI traps with sticky inserts baited with high-dosage pheromone lures (CM Mega Lure, Trécé Ltd., Salinas, CA, USA), were used for CM monitoring under mating disruption. Pheromone traps were placed on poles and suspended as high as possible within the tree canopy. One Pherocon Delta VI trap was placed within each treatment plot in a location that was about 72 m away from the nearest CM sex pheromone trap to minimise interference. Pheromone traps were inspected weekly to count and remove captured moths. Pheromone lures were replaced every six weeks. In northern Victoria, CM normally begin to fly about a month later than OFM so CM monitoring usually started at the middle of September before the first CM flight had started. Monitoring usually finished in the middle of April, two weeks after the last flight of CM had ended.

Damage assessments

Inspection of pear fruit at harvest for OFM and CM larval infestation assessed the effectiveness of treatments in preventing damage. OFM damage to pear fruit, but not shoot tips, was assessed because larval feeding in shoot tips in pear is extremely difficult to detect. To assess damage to pear fruit a random sample of 100 fruit was taken about one week prior to harvest from each of the trees in which food traps were placed. Another 100 fruit from each of three bins per plot were sampled during harvest. 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 and to determine the cause of damage. The number of fruit damaged by each species was recorded and used for analyses.

Measurements of pheromone release rates from dispensers

The pheromone release rates of Isomate CTT and Isomate OFM Rosso dispensers were determined using weight loss measurements. Ten dispensers of each kind were individually suspended on a wire rack in partial shade within the tree canopy in Tatura, northern Victoria, and weighed (±0.1 mg) individually at weekly intervals between 19 September 2003 and 30 April 2004. Similar weight measurements conducted in Tatura from 6 September 2001 to 6 May 2002 were used for background information. The release rates were estimated using the slope of a trend line of the absolute weights of the dispensers and calculating the difference in individual dispenser weights at each successive measurement.

Statistical analysis

The numbers of OFM caught in each food and sex pheromone trap were recorded and analysed for three consecutive seasons in 2001-02, 2002-03 and 2003-04. To compare the performance of the three treatments, the end-of-season data on total number of OFM and CM catches were analysed using a randomised-complete-block-design-based analysis of variance (ANOVA) in each of the three seasons using GENSTAT 8 (Lawes Agricultural Trust, Rothamsted Experimental Station). The original data x was transformed to the $\log_e(x+1)$ scale for analysis as this more reasonably satisfied the ANOVA assumptions of homogeneity of error variance and normal distribution of errors. The significance of the difference between the mean total catch of any two treatments was tested using the Fisher's unprotected least significant difference (LSD) test at 5% level of significance.

RESULTS

2001-2002 field season

The average weekly catches per food trap (OFM trap^{-1}) for each treatment, from three replicates and three traps per replicate (nine traps), during the 2001-02 season are shown in Figure 1. The highest peak of OFM catches was recorded during the first flight under the half rate of Isomate OFM Rosso and the control treatments. However, in the full rate of Isomate OFM Rosso treatment, the highest peak of OFM catches was recorded during the last flight. By the end of the season OFM populations, as indicated by trapping results, had decreased in the half rate and control treatments whereas populations in the full rate treatment had increased slightly. For the majority of the season, the catches in the reduced and full rate treatments were lower compared with those in the control. During this season, the highest weekly average number of OFM recorded in the peak of the first flight was 20.9, 6.3 and

25.9 OFM trap^{-1} in the half rate, the full rate and the control respectively. By the end of the season, catches of OFM under the half rate treatment had decreased to about half of those at the beginning of the season.

The mean total (back-transformed) number of OFM caught in food traps under the 1Rosso+2CTT, the 2Rosso+2CTT and the control treatments were 390.9, 234.1 and 496.7 respectively. There were no significant differences between these three treatments (P=0.116). In contrast to food traps, sex pheromone traps placed in control blocks without MD caught significantly more OFM males (P=0.017) than sex pheromone traps placed in either of the two MD treated blocks, but the difference between OFM catches in the two MD treatments was not statistically significant.

The mean total (back-transformed) number of OFM caught in sex pheromone traps under the half rate, the full registered rate and the control treatments were 15.5, 7.9 and 193.4 respectively. Sex pheromone traps placed in MD treated blocks caught OFM males in only the two weeks before, and the first week after MD treatment had been applied and then did not catch OFM males at all until the end of the season. These results indicated that experimental blocks had high level of initial OFM population. The sex pheromone trap catches were not unexpected. Sex pheromone traps (one mg dispenser^{-1}) placed in MD-treated blocks have to compete with the sex pheromone emitted from MD dispensers (240 mg dispenser^{-1}). The catches in the MD-treated blocks mostly occurred before the MD treatment was applied and in the first week of its deployment, before significant sex pheromone emission would have occurred.

2002-2003 field season

Catches of OFM were generally low during the whole 2002-03 season (Figure 2) compared with the previous season. Mean weekly individual trap counts did not exceed 12 OFM trap^{-1}. In this case, the highest peak of OFM catches was recorded during the first flight in all three treatments. The numbers of OFM caught generally decreased during this season under all three treatments with one exception under the half rate treatment when catches peaked at the end of January. For the first half of the season, the catches in the half and full rate treatments of Isomate OFM Rosso were slightly lower compared with that in the control. During the second half of the season, the OFM catches in pears under all treatments were similar in general with slight increase at the end of January and end of February. During this season, the highest weekly average number of OFM recorded in the peak of the first flight was 7.8, 7.8 and 11.7 OFM trap^{-1} in the half rate, the full registered rate and the control respectively.

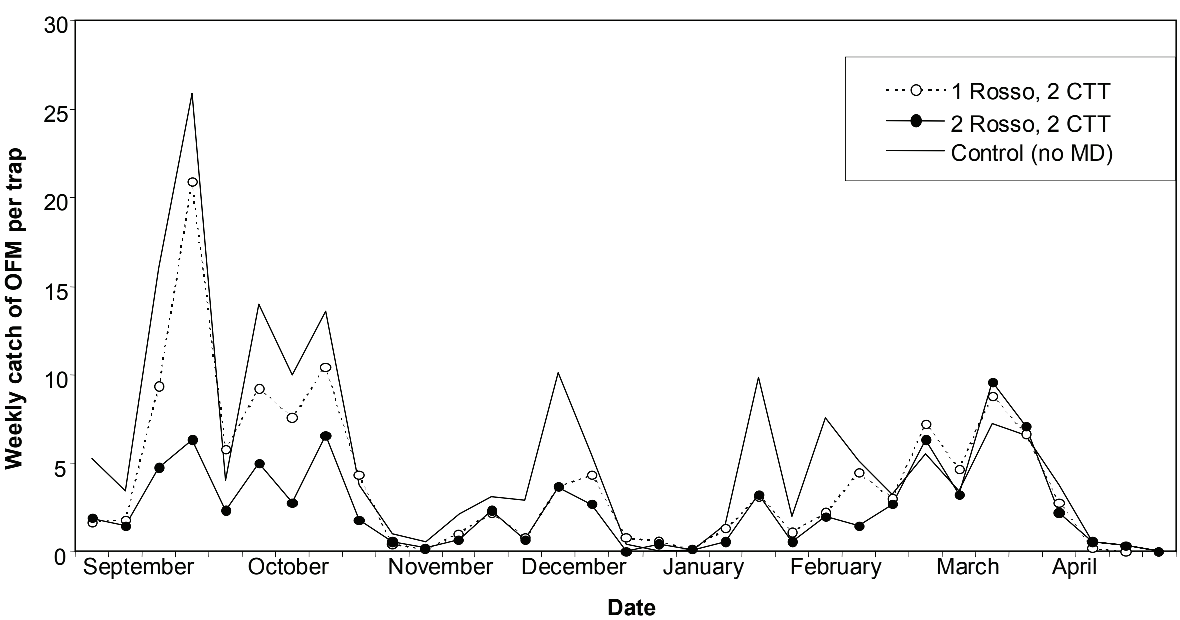

Figure 1. Catches of OFM in food traps pooled from three replications (average of 9 traps) under MD treatments with half-registered rates of Isomate OFM Rosso and Isomate CTT (1Rosso+2CTT), full-registered rates (2Rosso+2CTT), and no MD (control) on pears (2001-02).

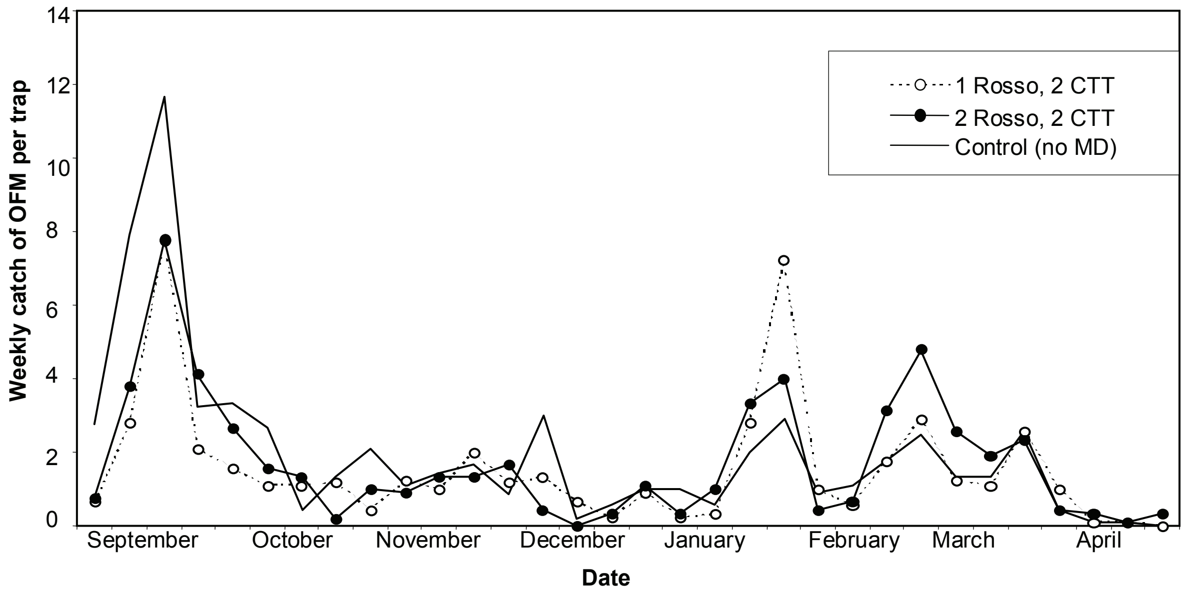

Figure 2. Catches of OFM in food traps pooled from three replications (average of 9 traps) under MD treatments with half-registered rates of Isomate OFM Rosso and Isomate CTT (1Rosso+2CTT), full-registered rates (2Rosso+2CTT), and no MD (control) on pears (2002-03).

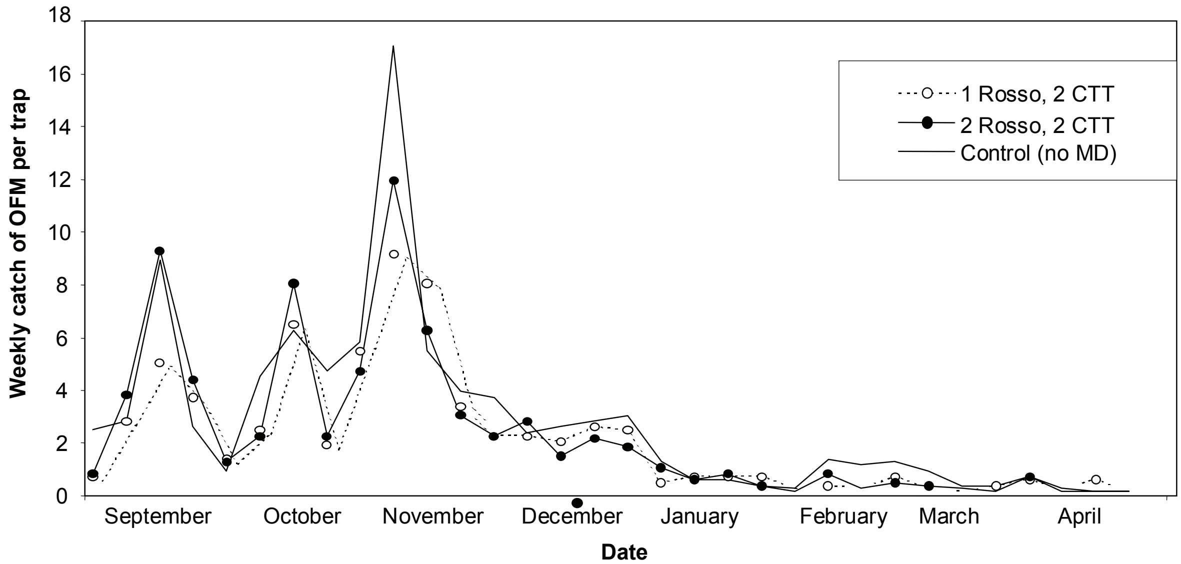

Figure 3. Catches of OFM in food traps pooled from three replications (average of 9 traps) under MD treatments with half-registered rates of Isomate OFM Rosso and Isomate CTT (1Rosso+2CTT), full-registered rates (2Rosso+2CTT), and no MD (control) on pears (2003-04).

Over the entire sampling period for food traps, the mean total (back-transformed) OFM catch was 135.8 for the half rate treatment (1Rosso+2CTT), 158.3 for the full rate treatment (2Rosso+2CTT) and 204.0 for control treatment. Once again, the difference in mean total food trap catches in the three treatments was not significant (P=0.242). Mean total OFM catch in sex pheromone traps under the 1Rosso+2CTT, the 2Rosso+2CTT and the control treatments were 0.8, 2.3 and 114.6 respectively. Like the season before, sex pheromone traps placed in control blocks without MD caught significantly more OFM males (P=0.011) than sex pheromone traps placed in both MD treated blocks which caught OFM males only within the first three weeks of the season. There was no significant difference between mean total catch in 1Rosso+2CTT and 2Rosso+2CTT treatments.

2003-2004 field season

Weekly catches of OFM in food traps during the 2003-04 season (Figure 3) started slightly higher compared with the previous season, but then after November, dramatically decreased to the low level of around 2 OFM trap^{-1}. Mean weekly individual trap counts did not exceed 18 OFM trap^{-1} during the season. The highest peak of OFM catches was recorded around November under all three treatments. The highest weekly average number of OFM recorded in the highest peak was 9.0, 11.8 and 16.9 OFM trap^{-1} in the half rate, the full registered rate and the control respectively. At the end of the season, catches of OFM under all treatments had greatly decreased when compared with those at the beginning of the season.

The mean total (back-transformed) OFM catches over the 2003-04 season were 166.9 for the half rate treatment, 161.8 for the full rate treatment and 229.7 for the control treatment. Although numerically these differences appeared substantial, as in the previous two seasons, there were no significant differences between the three treatments (P=0.068) but these results were more close towards approaching significance. Also for this season there was no significant difference (P=0.068) between OFM male catches in sex pheromone traps placed in control blocks without MD treatment and sex pheromone traps placed in MD treated blocks. It is important to mention that during three consecutive seasons, sex pheromone traps placed in MD treated blocks caught OFM males only during the two weeks before and the first week after MD treatment had been applied, and then did not catch OFM males at all during the rest of the season. Mean total OFM catches in sex pheromone traps under 1Rosso+2CTT, 2Rosso+2CTT and control treatments were 0, 0.9 and 9.9 respectively. The mean total OFM numbers caught in sex pheromone traps under 1Rosso+2CTT declined from 15.5 to 0 throughout the three consecutive seasons.

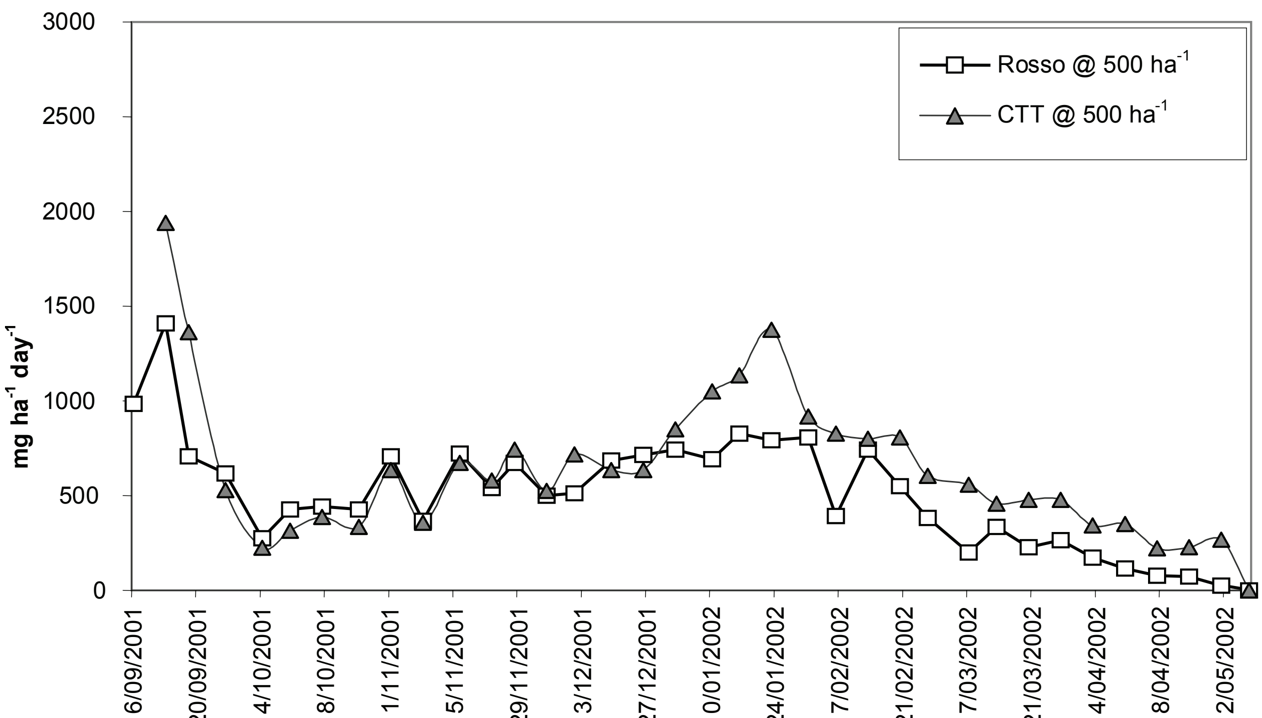

Figure 4. Release rates of Isomate OFM Rosso and Isomate CTT calculated from weight loss measurements in Tatura, Victoria (2001-02). NB. Threshold for disruption of CM average 372 (144 - 600) mg ha^{-1} day^{-1}; Threshold for disruption of OFM 120 - 144 mg ha^{-1} day^{-1}

During all three seasons from 2001 to 2004, the numbers of OFM caught under both MD treatments declined over time. The difference between treatments with half and full registered rates of Isomate OFM Rosso was not significant. The weather conditions recorded during these three seasons were similar and are unlikely to have influenced the level of OFM population.

Codling moth catches during three seasons (2001-2004)

There were no CM captured in two of the three replicates under all treatments during the first two seasons. However, in the third season in these two replicates, two and 28 CM males were caught in the control treatments only, indicating the beginning of CM infestation in blocks without MD treatment. CM males were captured in the third replicate under all treatments in the first season (2001-02), when mean total (back-transformed) CM catches in sex pheromone traps under the 1Rosso+2CTT, the 2Rosso+2CTT and the control treatments were 1.1, 0.9 and 2.3 respectively. The difference between both MD treatments and control was not significant (P=0.444) during first two seasons, but in the third season of consecutive treatments the difference achieved significance (P=0.041). There were no CM caught in any of MD treated plots throughout 2002-03 and 2003-04, although mean total CM numbers in the control plots increased from 3.5 in 2002-03 to 22.1 in 2003-04. There was a dramatic increase in mean total numbers of CM caught under control (no MD) treatment from 2.3 to 22.1 throughout three consecutive seasons.

Fruit damage assessments during three seasons

There was no fruit damage prior to the 2002 harvest in the MD treated plots, while in the control plots (no MD) fruit damage ranged from 0.2-0.9%. Bin damage assessments conducted during harvest in early February 2002 confirmed the results of the pre-harvest sample from trees. No CM damage was found in bins harvested from MD plots, but OFM damage ranged from 0.1-0.2%. OFM damage found in bins from control plots ranged between 0.2-0.8%.

Prior to harvest in 2003, no damaged pears were found in the MD treated plots, but in the control plots fruit damage averaged 0.2%. Subsequent assessments of fruit damage in bins during harvest were consistent with the on-tree samples conducted prior to harvest. Levels of 0.1-0.2% OFM damage were observed in bins harvested from control plots while no fruit damage was recorded in any MD treated plots.

There were no damaged pears found in any of the treatments prior to harvest in the 2003-04 season. Fruit bin counts during harvest uncovered an average of

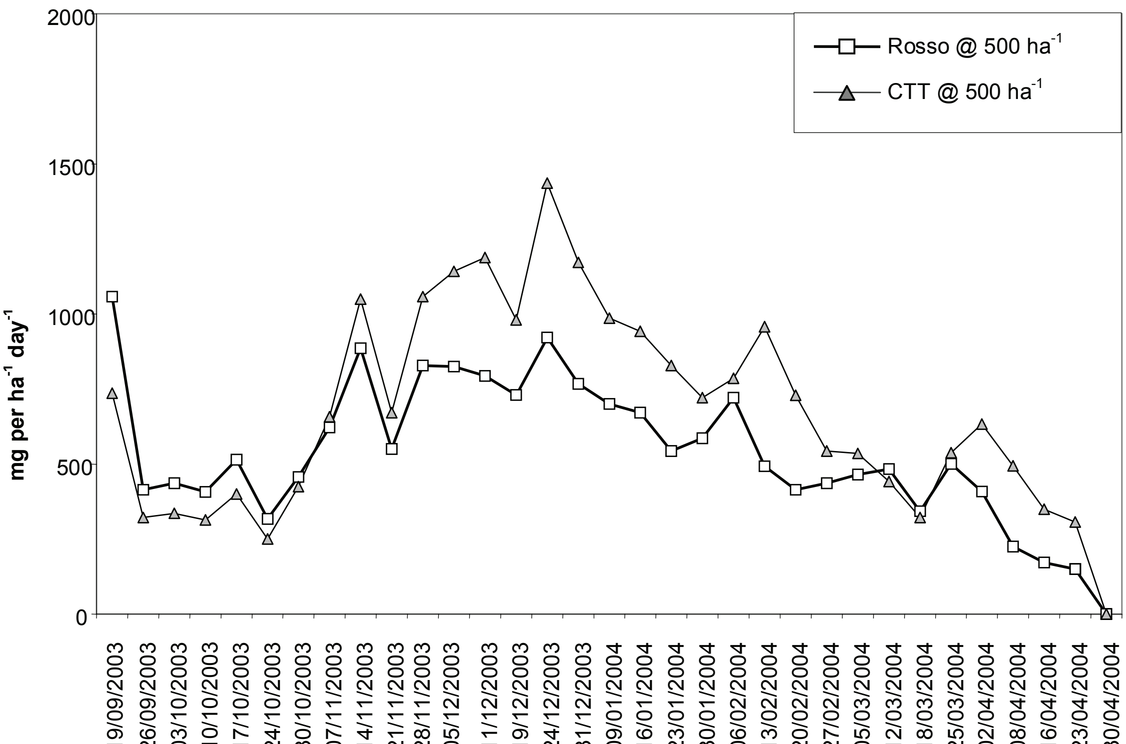

Figure 5. Release rates of Isomate OFM Rosso and Isomate CTT calculated from weight loss measurements in Tatura, Victoria (2003-04). NB. Threshold for disruption of CM average 372 (120 - 144) mg ha^{-1} day^{-1}; Threshold for disruption of OFM 120 - 144 mg ha^{-1} day^{-1}

0.2% OFM damage in the control plots. There were no damaged fruit detected in the MD treated plots.

Pheromone release rates from Isomate OFM Rosso and Isomate CTT dispensers

The release rate characteristics of Isomate OFM Rosso and Isomate CTT dispensers derived from weight loss data during the 2001-02 season are presented in Figure 4. The distinctive low release period in the first three weeks of exposure was exhibited in both dispensers but this was more pronounced in Isomate CTT, where release rate dropped slightly below the CM mating disruption daily threshold level of 372 mg ha^{-1} (Vickers and Rothschild 1991, Vickers *et al*. 1998) briefly on 4 October 2001. After the first month of exposure, the release rates of both dispensers were very similar until December. During the hottest period in January-February 2002 the release rate of Isomate CTT was higher than Isomate OFM Rosso and reached a peak on 24 January 2002 (Figure 4). The release rate of Isomate CTT dispensers started to decline in February and crossed the threshold level at the end of April 2002. The release rate of Isomate OFM Rosso dispensers during the same period was low, but well above the threshold for effective mating disruption of OFM (Rothschild 1975) and crossed the threshold level about a month earlier than Isomate CTT.

The release rate characteristics of Isomate OFM Rosso and Isomate CTT dispensers, derived from the weight loss data measured during 2003-04, demonstrated that both dispensers released a considerable amount of pheromone in the first week in the field, but then the release rate dropped (Figure 5). Both dispensers exhibited a very distinctive low release period during the five weeks of exposure but this was more pronounced in Isomate CTT, where the release rate dropped slightly below threshold for CM mating disruption on 24 October 2003. This early season pattern was similar to that observed in 2001-02.

The increase in the release rate of both dispensers that began in early November corresponded to an increase in maximum daily temperatures. From 7 November 2003 through 12 March 2004, the release rate from Isomate CTT was higher than from Isomate OFM Rosso, but followed a similar pattern. This would be expected given the higher loading rate of Isomate CTT. However, the pheromone release rate for this dual dispenser peaked on 24 December 2003, and then declined dramatically over the next four weeks. The emission of sex pheromone from Isomate OFM Rosso and Isomate CTT showed similar patterns of decline in release rates over this period, however Isomate CTT maintained higher release rates for a longer period (Figure 5). The release rate of Isomate OFM Rosso was low, but above the threshold for effective mating disruption of OFM until 24 April 2004. In general both dispensers of Isomate OFM Rosso and Isomate CTT released active ingredient above the mating disruption threshold for effective disruption during about 200 days.

Both dispensers emitted sufficient rates of pheromone for the whole season and provided effective MD control of OFM and CM together on pears. These results suggest that the cost of MD on pears can be reduced by applying half the registered rate of Isomate OFM Rosso together with the full rate of Isomate CTT for combined control of OFM and CM.

DISCUSSION

The reduction of moth numbers in food and sex pheromone traps supported by a decrease of fruit damage throughout three consecutive growing seasons indicated reasonable control of OFM. It is important to underline that all plots in the entire experimental area were over-sprayed with the same chemicals at the same time, which allowed comparison of all treatments.

The results of field trials during 2001-04 seasons demonstrated that the half rate of Isomate OFM Rosso combined with the full rate of Isomate CTT was comparable to the Isomate OFM Rosso and Isomate CTT applied in the full registered rates. At the end of three consecutive seasons, both treatments had reduced moth catches and fruit damage to a similar degree.

Evenden and McClaughlin (2005) found that capture of OFM males was significantly increased when CM pheromone was either combined with OFM pheromone in baits or when baits containing the individual pheromones were placed in close proximity. They found that the attractiveness was not due to increased flight activity or orientation towards the pheromone plume but was related to the amount of time OFM males spent at the baits. These data suggest interactions between sex pheromone formulations designed for these two species as occurs in other tortricid species (Judd and Gardiner 2004).

Both MD treatments, with half rate and full registered rates of Isomate OFM Rosso and Isomate CTT dispensers provided equal levels of fruit protection during three consecutive seasons. Since the entire experimental area was sprayed with the same insecticides at the same time, we were able to determine the contribution of MD treatments to OFM and CM control as well as assess the impact of the insecticide treatments. It is a common practice in the USA and Canada to use insecticide sprays against the first OFM generation and then mating disruption for successful control of the following OFM generations (Trimble *et al.* 2001, 2004). The use of half rate of Isomate OFM Rosso and full rate of Isomate CTT in concert with companion insecticide sprays in our experiments provided improved control in comparison to using only insecticides. Our results strongly suggest that the insecticide-only program was not sufficient for CM control, and the MD program supplemented by insecticides was highly effective.

Our results suggest that the cost of mating disruption of OFM and CM on pears could be reduced by applying half the registered rate (one dispenser tree^{-1} or 250 dispensers hectare^{-1}) of Isomate OFM Rosso together with the full rate of Isomate CTT (two dispensers tree^{-1} or 500 dispensers hectare^{-1}).

ACKNOWLEDGMENTS

This research was funded by the Department of Primary Industries (DPI), Victoria and Horticulture Australia Ltd. We thank the following people from DPI, Tatura: Mr. Chris Sheehan, Ms. Elizabeth Alsop and Mr. Neil Penfold for monitoring and assistance with data preparation for analysis, Dr. Alvin Milner and Dr. Subhash Chandra for experimental design discussions and for statistical analysis. Also we thank Mr. Stephen Sexton (Biocontrol Ltd. Qld., Australia) for supplying the mating disruption dispensers.

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