DEVELOPMENT OF COST EFFECTIVE PHEROMONE MATING DISRUPTION FOR CODLING MOTH IN PEARS AND WALNUTS

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ABSTRACT

New pheromone meso-emitters were tested in 2007 that emit higher levels of pheromone per unit but are deployed at fewer dispensers per acre. Based on emission rates estimated in lab trials, the meso-emitters were deployed at lower rates of 12-60 point sources per acre compared to the traditional 180 dispensers per acre. Total pheromone emitted per acre exceeded or equaled the emission rate of the Checkmate program. Extreme codling moth pressure situations were tested in pears with mixed but positive results. Within one orchard with excessive populations, both the meso-emitters and Checkmate failed to provide adequate control. Within a second orchard, all plots with the meso-emitter improved control of codling moth, but the differences were not statistically significant. In walnut trials with more moderate pressures, the meso-emitters provided significant reductions in codling moth damage compared to the control. Within a study looking at the effects of number of point sources per acre, no significant advantage was observed when the number of point sources per acre was increased from 12 to 60 points per acre. All plots except one had total pheromone levels per acre that exceeded or approximated those of traditional pheromone programs for the duration of the trial. One treatment using emitters at 18 units per acre but the same total amount of pheromone as a traditional Checkmate program produced comparable results to Checkmate, but a statistically improved control program over the grower insecticide alone program. Finally, a new Isomate meso-emitter using a chain of Isomate twin-tube dispensers was evaluated in an unreplicated preliminary trial. Both damage and trap suppression were lower than the untreated control.

INTRODUCTION

Pheromone mating disruption continues to be the backbone of many codling moth suppression programs in pear and apple orchards. The most commonly used dispensing technology, the hand applied dispenser deployed at 150 - 400 units per acre, is a labor intensive application method for any of the codling moth associated crops. While the application continues to be relatively cost effective, increasing concerns about the cost and availability of agricultural labor has generated some apprehension. Similarly, hand-applied dispensers have not proven logistically feasible for large canopied tree crops or orchards since current recommendations suggest placement of the dispenser in the upper 1/3 of the tree canopy.

An alternative dispenser, which is a mechanical aerosol emitter commonly referred to as a “puffer”, does provide easier and less costly application given that the unit is applied at one dispenser for every 1-2 acres. Mechanical issues of the puffer units that were identified in past years have been corrected and the current puffer unit appears more reliable. However, some growers remain reluctant to invest in the puffers for two reasons: a) distrust of a mechanical device that could fail, and b) the fact that effective pheromone plume coverage is difficult with smaller, thin orchards.

Development of a reliable non-mechanical, passive pheromone dispenser that also had reduced application costs would be highly desirable for some operations. The development of a "meso-emitter", which would release codling moth pheromone at higher rates per unit than the traditional hand-applied dispensers, was hoped to be deployed at much lower application rates per acre. Initial development of meso-emitters was started two years ago in my lab using prototypes made from a wax emulsion. Positive results, as seen by trap shutdown, were observed using these emitters at only 12 units per acre. Two experimental products developed by Suterra (Suterra LLC, Bend, OR 97702) the following year included a wax formulation and an enlargement of the standard hand-applied Checkmate device. Field trials were conducted with both products in 2006 using an application rate of 12 units/acre and the assumption that these units would emit approximately 25 mg ai/day. The units fell short of the target emission rate of 25 mg ai per day with an actual rate of ca.5 to 8 mg per day. In spite of these shortcomings, we observed excellent trap suppression (>93%) in all treatment plots regardless of codling moth densities. Likewise, we observed damage suppression in all plots where the meso emitters supplemented the grower standard insecticide program compared to standard insecticide program alone until late in the growing season.

Our trials in 2007 have focused on continued development and testing of a "meso-emitter", having a higher emission rate per unit and reduced application rate (units/acre) than the traditional hand applied dispensers. Emission rate analysis of the 2006 emitters pointed to the need to improve the pheromone release rate to better match our original goal of a 25-30 mg/day release rate. Subsequent development by Suterra provided a number of units from which we selected one that better matched our criteria for use in 2007 field efficacy studies. Additionally, using other funding sources, we were able to utilize the different experimental emitters being tested by Suterra to conduct preliminary trials to evaluate optimal number of pheromone release points needed to provide trap and damage suppression. We report on the results for both pear and walnut field trials in this report as the patterns in results can sometimes be more easily seen and each crop may provide different insights into the issues around new technologies. Similarly, pears represent a much more susceptible crop to codling moth, whereas walnut typically is able to sustain higher background levels of codling moth without such dramatic economic consequences. Therefore, each crop type provides a different set of insights and hopefully, more rapid development of such an alternative approach.

PROCEDURES

Objectives:

1. Field age emitters and determine release rates through the field season.
2. Field test best available modified "meso-emitter" for control of codling moth damage (pears and walnuts).
3. Field trials to indicate optimal number of pheromone release points (at constant per acre pheromone rates) for codling moth control (walnuts only)

Emitter aging trials. Emitters were hung in a pear orchard and sampled at regular intervals in order to evaluate emission rates through time. Fifty dispensers of each of seven emitter types (Isomate C+, Checkmate CM-XL1000, and Suterra experimental units F004, F004.1x, F007M, F007MDD, and F007M.1x) were set out. Four dispensers of each type were collected at each time interval beginning at week 0 (initial deployment), and then at 2, 4, 6, 9, 12, 15, 18, 21, and 24 weeks after deployment. Dispensers were submitted to Suterra for residual analysis. Emission data was highly variable with the small sample size. Thus, data are presented as a 3-day running average to better illustrate the trends over time. Additionally, we measured the weight of each dispenser when it was hung and again when it was collected from the field.

Standardized meso-emitter application for codling moth control. Suterra continued development and lab testing of modified meso-emitters during winter 2006-7. Modifications in the polymer membrane and release surface area were made with the goal of achieving a release rate of 25-30 mg ai per day per unit. This release rate for units deployed at a density of 12 per acre would achieve a per acre release rate comparable to traditional hand applied dispensers. Emitters were aged at 30°C in the Suterra labs and emission rates calculated at different time points. Based on this data, the emitter that best matched our criteria was selected for 2007 field trials. Lab data of the selected unit suggested emission rates that exceeded our goal through day 45, after which time it appeared emissions might drop below our per unit target. To compensate for the decline in emission rates seen as emitters aged, we opted to increase the density of emitters in field trials such that our minimum target field load (per acre) was achieved throughout the entire season.

Based on the winter laboratory data, meso-emitters were deployed at the rate of 24 dispensers per acre into experimental plots using Suterra experimental emitters numbered F007MDD or F007M. These two emitters were the same membrane type and size but differed in the method by which pheromone was loaded into the reservoir. All meso-emitters were hung in the upper third of the canopy in pears or mid-canopy or higher in walnuts. They were placed in a uniform grid pattern within each 5-acre plot. Adult codling moth activity within each treatment and control plot was monitored by a set of four traps. Large plastic delta traps (Suterra) were baited with 1X or 10X Biolures (two traps of each lure) (Suterra). Traps were read weekly and lures changed on the recommended schedule. Additionally, delta traps baited with the Pherocon® CM-DA COMBO™ (Trécé, Inc, Adair, OK 74330) lure were used in some sites as a secondary monitoring system. In pears, fruit damage was assessed for first generation codling moth (all sites) and at the approximate harvest timing (Hood orchard only) by inspecting 500 or 1000 fruit in each plot. In walnuts, codling moth damage was assessed by canopy counts conducted in late June and mid August (Modesto plots) or late July (Linden), by examining 500 nuts/plot from a pruning tower. Harvest damage was assessed by crackout of 1000 nuts/plot and damage or a present worm was carefully examined to identify codling moth from navel orangeworm.

Pear sites. Replicated trials evaluated the effect of the meso-membrane emitters in two Bartlett pear orchards. Five-acre treatment plots were established in each site for the experimental emitters and untreated control plots. One of the more consistent difficulties in pear codling moth research has been locating orchards with enough codling moth pressure to have significant damage as well as a grower willing to sustain that level of damage. Two orchards were identified early in the season, but uncertainties with the management of one orchard precluded early season setup. Three replicated plots of the Suterra F007MDD emitter and three untreated control plots were established in the Hood orchard (Figure 1). Within a second orchard (Eagle Point), two replicate plots of the Suterra F007M emitter and two replicates of Checkmate CM-XL1000 (200 dsp/acre) were deployed (Figure 2). A single control plot in the Eagle Point orchard was 1.5 acres. Due to the smaller size of this control, the plot was monitored by single 1x and 10x traps. Despite plans to not farm their orchards commercially in 2007, both growers generously provided access and support of the project. Emitter applications were made on March 28 (Hood blocks 1 and 2), April 6 (Hood block 3), and May 1-2 (Eagle Point). The late application at Eagle Point resulted from the ambiguity over possible orchard management changes. Neither orchard was managed for commercial pear production in the 2007 season and thus no insecticides were applied.

Walnut sites. Replicated trials using the F007M emitter (24 dsp/acre) were conducted across two walnut orchards. Two treatment plots and two grower standard plots of five acres each were located in a 100-acre block of mature Ashley variety walnuts in the Modesto orchard (Figure 3). Two five-acre plots were treated with Checkmate CM-XL1000 for a standard pheromone treatment comparison. A single treatment of five acres and untreated control of 1 acre were located in an 18-acre organic block of mature Payne variety nuts in the Linden orchard (Figure 4). Two additional experimental treatments were included at the Linden site. Five-acre treatment plots were treated with the Suterra F007.1x emitter applied at 48 dsp/acre or with the Isomate twin-tube “chain” (Pacific Biocontrol Corporation, Vancouver, WA). The Isomate “chain” was made of two five-dispenser CTT units joined together to make a 10-CTT chain that was placed into the upper canopy. Twenty of the “chains” were dispensed across the 5-acre plot for a total of 200 CTT equivalent units. . Due to the small size of the control, moth activity was monitored by single 1x and 10x traps. Pheromone applications were made April 25-27 in the Modesto site and on April 26-27 in the Linden plot. The Modesto block was treated by the grower with Asana (16 oz rate on alternate rows (8oz/ac), ca. April 27-29 and May 3-5,), Lorsban (4 pts/acre rate, alternate rows (2 pts/ac), ca. May 26-28), and Penncap-M (6 pts/acre, every row, ca. August17-19). The Linden organic block received no supplemental insecticide treatments.

Optimized Point Source Number Trial. We set our initial target emission rate at approximately 320 mg ai /day/acre based on standard programs using 200-400 ties per acre. While some programs may use fewer points (ca. 100), the 200-400 tie programs appear to provide the most robust treatment option for varied situations. Suterra had developed a range of products during winter 2006-7 that differed by emission surface area and membrane type. Emission rate data generated by Suterra from lab aging trials was used to develop an experimental protocol that would permit us to use the different emitter types at different application rates (numbers/acre) but maintain similar per acre pheromone rates (Table 1). Thus, we could vary the number of pheromone point sources while keeping the per acre pheromone emissions similar. Six pheromone point source rates were compared in replicated 5-acre plots. One of these treatments was designed as a half pheromone load treatment (target rate 160 mg/day/acre) to provide at least an initial trial examining the quantity of pheromone needed per acre. Checkmate CM-XL1000 applied at180 dispensers/acre was included as a pheromone standard and two 5-acre grower standard plots were included as controls. Application of the pheromone products were made April 24-27 by placing dispensers approximately mid-canopy or higher with the use of pruning towers and extension poles. The trial was conducted in a single 100 acre block of mature Ashley variety walnuts near Modesto (Figure 3). Given that Ashleys are a susceptible variety and this block would generally have codling moth damage at harvest, our pheromone treatments were tested as a supplement to the grower spray program. The grower program included insecticide treatments of Asana (16 oz rate on alternate rows (8oz/ac), ca. April 27-29 and May 3-5), Lorsban (4 pts/acre rate, alternate rows (2 pts/ac), ca. May 26-28), and Penncap-M (6 pts/acre, every row, ca. August17-19). Given the size of the walnut trees, the study was predicated on the assumption that the pheromone supplements would have a measurable positive impact over the grower's insecticide control programs Codling moth flight and damage assessments were made as described earlier.

Table 1. Point source application rates and treatment identifications.

Treatment	# dispensers / acre	Target pheromone load mg/day/acre*
F007M	12 (2 dsp/point)	320
F007M	24	320
F004	36	320
F004.1x	60	320
F004	18**	160*
Checkmate CM-XL1000	180	320
Grower standard	0	0

* Target levels were based on estimates generated under laboratory conditions
** Half-rate application.

RESULTS AND DISCUSSION

Emitter aging trials. Residual pheromone analysis for emitters aged up to 169 days has been completed. Based on this data, we projected the per acre pheromone load rates used in our point source optimization trial (Figure 5). The target emission rate is shown by the dotted line. The data indicate an initial "blow off" of pheromone after field application which stabilizes for relatively consistent emission rates for most emitters through day 169. Our target emission rate of 320 mg/ac/day is met by only by applications of the F007 and F004 emitters. The intended half-rate application of F004 (at 18 dispensers/acre) fell below target beginning by day 107, though emission rates appeared to match the Checkmate CM-XL1000 rates at days 145 and 169. All treatments matched or exceeded the Checkmate CM-XL1000 application for except the F004.1x which fell below expectations by day 127.

Standardized meso-emitter application for codling moth control. Based on lab-generated emission data on emitters aged at 30°C, we selected the F007 experimental emitter for standardized trials across pear and walnut sites. Though our application rate of 24 dsp/acre was above our initial target rate, we wanted to assure that adequate pheromone product was released into orchard plots such that we could evaluate the concept of a reduced point source application rate.

Application efforts were only documented in the pear plots which were applied using traditional pole setups from the ground. Application took our crew approximately 12 minutes per acre to apply the dispensers (5 acres per hour) whereas more experienced field crews would be expected to be even faster. Applications were made to the walnut orchards using hydraulic lifts, which took much longer, but the time was not documented.

Pears-trap data. The pheromone application in two Hood plots was made at biofix, with the third site added about a week later. Uncertainty about management and the potential for experimental conflict delayed implementation of our program in the Eagle Point site until early May. Pears sites demonstrated very high codling moth pressure across all treatment plots (Figure 6). Moth capture in 10x traps ranged from season totals of 284 to 1561 per trap (average) in the Eagle Point orchard and 411 and 645 in the Hood orchard. Totals in the Hood plots were capped when the orchard was removed in mid July, thus terminating our project. Given the historic codling moth pressure from 2006 and the counts from 2007, neither orchard would be considered a good candidate for a stand-alone pheromone program, but both provided 2 excellent examples for testing extreme conditions.

Despite the extreme moth pressure, trap suppression of the 1x traps was observed in treatment plots of both orchards (Figure 7). In the Eagle Point site, trap suppression in the meso plots (98.8%) was comparable to that of the standard Checkmate application (99.2% suppression). Results in Hood were less dramatic, averaging 85% suppression across the three replicates.

As seen in the flight curve generated by10x trap data for the Eagle Point orchard, the moth population was raging through the entire season with initial capture of 75 moths per week and consistent capture of 50 to 140moths per week in the control (Figure 8). Despite this pressure, 1x traps in the meso and Checkmate treatment plots were essentially, but unexpectedly, shut down through the entire season (Figure 9). In Hood, the 10x trap data for treatments and controls track well and show a very strong 1st generation flight beginning late June and peaking with an average trap capture of 100 moths / week (Fig. 10). While the 1x traps are suppressed early on, no treatment plots remained shut down through the late June-July flight with the 1x traps averaging 20/week (range 5-73 moths) at the flight peak (Figure 11).

Pear Damage suppression. First generation codling moth damage assessed in the Eagle Point site averaged about 22.8% and 20.3% in the meso-emitter and Checkmate treated blocks respectively (Fig. 12). None of the treatments including the control were statistically different from each other (P>0.05). Damage in the control block was estimated at 37.4%. Given the severe damage in this orchard, further assessments at harvest time were not conducted. Clearly, the late application of pheromone and large codling moth population predisposed this orchard to control failure. The lack of acceptable control in the Checkmate plot supports this notion, given that this product has been used commercially on a large scale for many years.

Damage estimates in the Hood plots were variable, though all meso-treated plots indicated reduced infestation levels both at 1st generation and harvest (Figs. 13-14). First generation damage averaged 2.4% compared to 7.5% in the controls, but no statistical difference was detectable (P>0.05). In fact, infestation in treatment blocks 1 and 2 was only 0.8 and 1.2%, respectively, while block 3 infestation was 5.2%. Control plots indicated damage levels of 0.8%, 10.8% and 11% and for blocks 1, 2, and 3. Reasons for control 1 to indicate low infestation remain unclear. The meso-emitter aging study reported elsewhere in this report was placed in an upwind block and may have produced a pheromone plume that impacted the site. However, such impact was not indicated by suppression of the 1x traps in this control block. Damage patterns remained similar by standard harvest timing, though the magnitude of infestation had increased in response to the large first summer flight (Fig. 14). Infestation in the control blocks now averaged 28.2% compared to the average of 11.7% in the treatment blocks. Meso-emitter treated blocks indicated damage levels of 2.2%, 3.4%, and 29.6% while control plots had damage levels of 2.8%, 40.6% and 41.2%. High plot variability rendered treatment effects statistically insignificant (P >0.05).

Walnuts-trap data. Codling moth pressure indicated by moth capture in 10x traps indicated variable pressure across orchards and treatment plots in the standardized meso-emitter (Suterra, F007 emitter) trials (Figure 15). Only light to moderate pressure was indicated in the Modesto orchard sites with season total capture ranging from <5 up to 70 moths per plot. The Linden orchard indicated a much greater pressure (>170 moths) in the control plot compared to the meso-treatment plot (<4 moths). However, a significant moth population was present in the meso plot as indicated by season total capture of 108 moths in a CM-DA combo trap. Suppression of 1x traps in the meso-treated walnuts plots was 100% as no codling moths were captured in these traps (Figure 16). Codling moth flight behavior is shown in Figure 17 for the Modesto orchard site and indicates similar patterns across the plots.

Walnuts-damage suppression. Late season canopy samples performed in all treatment areas found greatest infestation levels in control plots (Fig. 18) which experienced 1.2% and 4% damage in the Modesto and Linden orchards respectively. On average, infestation was reduced by about 60 to 80% in the meso-emitter treated plots, compared to the grower treatments.

Patterns of infestation remained similar through harvest with significantly less damage (P<0.01) observed in the meso-emitter treated plots (Fig. 19). Infestation in the grower treatment sites averaged 2.9% compared to 0.6% in the meso-emitter treatments. Control provided by the meso-emitters was comparable to the Checkmate treatment at 180 dispensers per acre (see point source treatments 24 and 180 in Fig. 24). One important point to note again is that the meso treated plots also were treated with the same insecticide sprays as the “grower control”. In a separate trial at the Modesto orchard, plots operated by the same grower with the same varieties, age, and management practices averaged 6.3% damage in plots treated with 3 applications of Intrepid for codling moth control (range 5.2% to 7.7%). Thus, the orchard did have the codling moth pressure to produce significant damage levels.

Walnuts-Multiple meso-emitter comparisons in the Linden orchard. Alternative meso-emitter treatments applied in the Linden orchard included the Suterra F007.1x at 48 dsp/acre and the Isomate chain at 20 dsp/acre in addition to the Suterra F007 reported above. We assume codling moth pressure was similar throughout this small (18 acre) orchard block as 10x baited traps averaged a season total of 24 and 27 moths in the Isomate and F007.1x treatments, respectively, and the CM-DA combo traps collected season totals of 108 and 122 moths in the F007 and F007.1x treatments. Suppression of 1x baited traps was nearly 100% in all three treatments with only a single moth captured the entire season in one of the Isomate treatment. At harvest, all pheromone treatments suppressed damage levels compared to the control (Fig. 20).

Optimized Point Source Number Trial.

Point source trial. Codling moth capture in 10x baited traps was low to moderate in all treatment blocks with large variation between plots (Fig. 21). Season total trap catch ranged from an average of 2.5 to 69 moths depending on site location. All pheromone applications impacted moth behavior to the extent that 1x baited traps were suppressed almost 100% throughout the season (Fig. 22). The first generation canopy sample conducted in June found little damage in any treatment plot and are not shown here. Maximum damage of 0.2% was observed in three plots (control, F004.1x at 60 dsp/ac, F007 at 24 dsp/ac), and no damage was observed in the remaining eleven plots.

In August, following a late season codling moth flight, we did detected damage rates ranging from 0 to 1.2% in the late canopy evaluation. Observed infestation levels for each treatment plot are shown in Figure 23. Much of this was detected as new, early instar infestation. The first shake for harvest was completed in mid September and the impact of the late season moth flight was expressed in the nut samples as late instar worms or exits. All pheromone treatments significantly reduced codling moth damage in contrast to the grower treatment (Fig. 24). There was no apparent trend with increasing the number of point sources from 12 to 180 per acre. The highest level of damage at 0.8% was observed in plots with 12 point sources per acre, but this damage level was not statistically significant.

One important point to stress is that the plots treated with 18 dispensers per acre using the F4 emitter had a total pheromone emission rate per acre that was comparable to the Checkmate plots. Damage levels were comparable across these two treatments.

Similar to conventional pheromone mating disruption programs, the meso-emitter approach provided significant reductions in trap counts and codling moth damage for orchards with more moderate population levels. The emitters were able to provide intermediate emission rates that exceeded target levels for the entire growing season. The lack of any strong response to increasing the number of point sources per acre for emitters releasing at higher pheromone release rates supports the meso-emitter concept. The cost advantages and reduced labor requirements for this hand-applied dispenser should prove attractive to growers.   Additional testing in multiple orchards with a range of codling moth pressures in 2008 will need to be conducted in 2008 as part of the validation process. Similarly, the effect of the total amount of pheromone per acre will need to be considered as well as part of a cost-reducing strategy.