

OPTIMIZING “MESO-PHEROMONE” EMITTERS FOR CODLING MOTH MANAGEMENT IN WALNUTS

Stephen Welter, Daniel Casado, and Frances Cave
Cooperators: Rachel Elkins, Joe Grant, and Carolyn Pickel

ABSTRACT

Research continued on the development of novel pheromone emitters that hopes to reduce the cost of application dramatically by reducing the number of dispensers per acre. The Sutterra meso or Pacific Biocontrol ring emitters that emit at ca. 5-20 times the rate of traditional hand-applied mating disruption devices for codling moth continue to look positive. Larger plots were used in 2009 so as to try and minimize the effect of pheromone drift between plots. Using data pooled across pears and walnuts, we were able to show suppression of codling moth flights typically ranged at 95% or more as indicated by pheromone traps baited with 1x lures. More importantly, this suppression also resulted in statistically significant damage suppression when the data were pooled across pears and walnuts. The suppression levels by the newer dispensers were equivalent to damage suppression from applications of the standard pheromone dispensers at standard application rates. No clear effect of reducing emission rates was observed on trap capture or damage levels, but these findings are still very preliminary and pending the final chemical analyses of the dispensers.

INTRODUCTION

Increasing economic pressures have continued to press on our existing programs that rely on mating disruption for control of codling moth. Overall program costs, including labor and materials, remain an important cost component of many operations, especially as concerns about labor availability arise. Both pear and walnut orchard systems face similar issues with management of codling moth, but differ significantly with regards to crop susceptibility, tree size and canopy structure, and secondary pests. In addition, variation between orchards in terms of realized codling moth pressures, orchard management, and moth phenology allows for greater insights when data are pooled across pears and walnuts. Rather than separate reports, we have pooled the studies across studies so as to provide a more robust analysis of the patterns in the data as well as to bring the relative strengths of studies in both crops to bear on a common problem.

The search for less expensive pheromone delivery approaches has driven our research to evaluate the number of dispensers per acre and more recently on the amount of pheromone required per acre. Reductions in the number of dispensers per acre would reduce application (labor) costs in pears and walnuts and would address the fact that current programs at 160 units or more per acre is not logistically feasible for most growers with the larger walnut canopies. Given that dispensers are being hung in the upper 1/3 of the canopy using pruning towers, the time and effort to place the dispensers needed to be minimized.

One alternative dispenser that has been examined for the past 3-4 years is a group of dispensers, called meso emitters, which are modifications of existing hand-applied dispensers, Checkmate or Isomate. The term meso emitter is a generic term that refers to hand-applied dispensers that emit higher levels of pheromone per unit, typically 15-25 times greater. However, in the report, the term meso emitter will refer to the products by Suterra and the term ring emitter will refer to a product by Pacific Biocontrol. The increases have resulted from either changes in release area, polymer selection, or a general increase in size of the emitters. The units are passive releasing devices with the pheromone diffusing across some type of polymer barrier (tube or membrane). The meso-membrane dispenser developed by Suterra has a release rate of ca. 15-20 times the release rate of the traditional Checkmate dispenser. The ring meso-emitter developed by Pacific Biocontrol is shaped into a hoop by modifying their existing twin-tube dispensers such that the individual units were not separated such that the two tubes are fused at the end of a much larger circular emitter. Both types of dispensers are applied at 20 units per acre, but differ in their overall emission rates per acre. The ring dispenser releases 5 times the amount of pheromone per unit compared to the Isomate twin tube. Therefore, 20 ring units would be predicted to have 50% of the total amount of pheromone released per acre (20 units * 5 times the release rate) of the 200 twin tube dispensers per acre. The membrane dispenser has been developed by Suterra to release at total release rates that are comparable to traditional programs (20 units * 16 mg per acre = 320 mg ai per day). Release rates varied between sites and during the growing season as overall temperatures varied. The Pacific Biocontrol ring dispenser has been submitted to EPA for consideration as a new pheromone product for codling moth. The commercial availability of the unit for 2010 is not clear at this time.

Testing of pheromone mating disruption products has proven difficult over the years for several reasons: a) the lack of complete independence of plots as the pheromone drifts into non-treated areas, b) the need to have just the right amount of codling moth pressure such that damage can be detected, but populations do not overwhelm the treatments. Regardless of the pheromone treatment, most programs have struggled to maintain control if codling moth pressures are high. Given that most commercial operations have very low codling moth populations, we tried several approaches in 2010 to find appropriate orchards. In pears, we targeted orchards that were either in the first year of relaxed management (e.g. no insecticides, sometimes no water, and limited weed management) or were organic. This allowed us in 2 large orchards to set up large pheromone blocks plus relatively large completely untreated controls for contrast. In addition, standard pheromone plots (Checkmate or Isomate) were included in all orchards as a benchmark to determine how well the standard would have performed. In walnuts, we tried to work with orchards that had documented problems with “worm damage” of ca. 3-6% from historical crack-out data over the past 3-4 years. Unfortunately, these data do not distinguish between navel orangeworm and codling moth damage. Given that these farms were under traditional management, the contrasts were between the conventional insecticide treated plots and plots treated with the same insecticide program plus a pheromone treatment. Given the historical damage levels, the contribution of the pheromone program would be measured as the difference.

Finally, our earlier work had shown no clear benefit for the higher number of dispensers per acre, but we had not been able to successfully target the amount of pheromone per acre. Given that the walnuts are intrinsically less susceptible to codling moth, different amounts of pheromone per acre were replicated and compared within a series of orchards. If the total amount of

pheromone could be reduced, overall program costs should be reduced as well given that the pheromone is an important contributor to the cost of the product. Rather than trying to develop the best pheromone program, this effort is trying to produce the most cost-effective pheromone program given our existing understanding and products. Rather than focus primarily on this program as a pesticide free program, we are focusing on developing a management program that optimizes overall costs with minimal insecticide intervention. In part this stems from both the recognition that high densities of codling moth have required insecticides in the past, but also the recognition that other lepidopterous pests may require treatments as well, e.g. leafrollers or the navel orangeworm.

PROCEDURES

Objectives:

1. Large block testing of meso-emitter treatment strategies using application rates of 18 to 20 dispensers per acre across multiple orchards. (pears and walnuts)
 - a. Suterra G037 dispenser applied at 18 units per acre
 - b. Isomate “rope” dispenser applied at 20 units per acre (pears and walnuts)
2. Repeat the 2008 evaluation of the effect of total pheromone emissions per acre at a fixed number of dispensing units per acre (18 units per acre) targeting sites with greater codling moth pressure (walnuts, unfunded)
3. Field aging study of Suterra membrane dispensers

Meso-emitter variants being developed and tested by two companies were evaluated in large block trials in 2009. These included 1) large membrane dispensers developed by Suterra referred to as “meso” emitters in this report and 2) five-unit lengths of uncut Isomate-C TT twin-tube dispensers that form a single large circular dispenser and are referred to as a “ring” for this report. Both dispenser types were evaluated in pear and walnut orchards (Table 1). These experimental programs were compared against a standard pheromone mating disruption program of 200 Checkmate CM XL1000 or 200 Isomate®-C TT per acre. Insecticide applications were applied across all treatments at the grower’s discretion in actively managed sites. Our trials were conducted orchards with conventional insecticide management programs (six walnut sites), an organic/pheromone program (one pear site), and unsprayed sites (one walnut and two pear sites). Codling moth pheromone programs have traditionally assumed that a greater number of point sources are necessary for program success. This belief was challenged in trials comparing the efficacy of experimental meso or ring dispensers applied at rates of 18 or 20 emitters per acre to the traditional pheromone applications of 200 dispensers per acre.

We included a standard pheromone treatment for all treatment sites this year. Any grower applied insecticides were sprayed across all treatments within a site. Thus, our treatment contrasts were between the grower standard only, the grower treatment plus a standard rate pheromone, and the grower standard plus experimental meso or ring dispensers. Suppression of codling moth in any treatment compared to the grower’s insecticide only or untreated plots would be attributed to the addition of the meso or ring emitters. A total of 18 walnut and 16 pear treatment plots were monitored and evaluated in efficacy trials.

We conducted a rate trial to investigate the range of pheromone emission needed to impact codling moth when applied at these low density (number) deployment rates of 18 dispensers per acre. This repeated our 2008 trial which failed when membrane seals broke and either released the pheromone containing pad or altered the release rate. In 2009, we again used four different types of meso membrane dispensers that varied in their release rates. These combinations allowed us to evaluate a range of total emission rates per acre on codling moth control. The meso membrane dispensers in 2009 retained their integrity through the period of the study. Rate trials were conducted across four orchard sites with a total of 24 treatment plots.

Table 1. Summary of 2009 codling moth pheromone field trials.

			Treatment Plots (number of acres)			
	Crop	Site	Meso	Ring	Pheromone Std	Conventional Grower Std
Efficacy Trials	Pears	Isleton	1 (14)		1(10)	
		Walnut Grove	2 (10,20)		2 (5,5)	2 (UTC) (5,5)
		Ukiah	2 (18,18)	1 (16)	2 (6,6)	3 (UTC) (3,5,5)
	Walnuts	Colusa		1 (7)	1 (5)	1(5)
		Gustine	1 (16)		1(5)	1(10)
		Knight's Landing	1 (18)		1 (5)	1 (5)
		Linden	1 (20)		1 (5)	1 (5)
		Tracy		1 (20)	1 (5)	1 (5)
		Yuba City	1 (5)		1 (5)	1 (8)
	Total number of plots = 34 (306 acres)			9 (139)	3 (43)	11 (62)
Rate Trials	Walnuts	Colusa	4 (all 5)		1 (5)	1 (5)
		Knight's Landing	4 (all 5)		1 (5)	1 (5)
		Tracy	4 (all 5)		1 (5)	1 (5)
		Woodland	4 (all 5)		1 (5)	1 (UTC) (5)
	Total number of plots = 24 (120 acres)			16 (80)		4 (20)

Large block field trials of standardized meso-emitter for codling moth control. We again conducted efficacy trials to further challenge the reduced point source strategy in larger plots and increase replication across years, locations, and different codling moth pressures. Meso-emitters utilized were the Suterra G037 used in 2008 (Suterra LLC, Bend, OR 97702) and the Isomate “ring” dispenser (Pacific Biocontrol Corporation, Vancouver, WA). Based on residual analysis of several Suterra unit variants in dispenser aging studies (2007), the G037 appeared have the best release profile through the season and released at a rate that matched or exceeded a traditional Checkmate XL application. The Isomate ring is made of five Isomate-C TT dispensers

in a single long unit that form a single tube ring when the twin tubes are separated. Deployment of the Isomate product at the rate of 20 per acre is equivalent to a 100 Isomate-C TT per acre application which is half the full standard rate.

Deployment rates were 18 per acre for G037 (Suterra) and 20 per acre for the “ring” (Isomate). Units were placed in a uniform grid pattern through treatment plots of five to twenty acres. All emitters were placed in the upper third of the tree canopy in pears. Placement in walnuts was made as high as possible (mid to upper canopy) from pruning towers in tall canopy sites or only by an extension pole in shorter walnuts. Codling moth flight activity was monitored by four large plastic delta traps (Suterra) for five acre treatment and control plots or up to 12 traps for larger 20 acre plots. Traps were baited with 1X or 10X Biolures (Suterra) or Pherocon® CM-DA COMBO™ lures (Trécé, Inc., Adair, OK 74330). Traps baited with 1x lures were hung low, and those with 10x or combo lures were placed high in the canopy. Traps were read weekly and lures changed on the recommended schedule. Damage assessments were made at two time points for each cropping system. In pears, inspection of 1000 fruit per treatment was conducted after 1st generation (1100dd) and at harvest. In walnuts, canopy samples were conducted from pruning towers in all rate trial sites and two efficacy sites between July 16 and August 4th by inspecting 600 to 900 nuts per treatment plot. Harvest samples of 1000 walnuts were collected immediately after shaking from all treatment plots. Collections were made from the central region of each plot (from within a perimeter defined by the trap placement). Nuts were returned to the lab to be cracked and internal damage or worms were identified as codling moth or navel orangeworm.

All plots within an orchard were treated the same with regard to pesticide applications. Observed differences between plots thus could be attributed to the differences in the pheromone programs. The grower applied treatments are shown in Table 2 (pears) and Table 3 (walnuts). Two pear orchards were abandoned for 2009 and the certified organic Isleton orchard applied a traditional pheromone application as the grower standard in the non-experimental area. Two walnut orchards received no insecticide spray applications – in one site this was the grower option in 2009 and the other site has a history of no sprays.

Table 2. Pear site efficacy trial locations and grower applied insecticide treatments.

Site	Grower Standard Treatments
Isleton (organic)	Isomate-C TT 200dsp/ac Omni oil 3 gal/ac 4/29, 5/6 Cyd-X 3 oz/ac 5/15, 5/22, 5/28, 6/3 Entrust 2 oz/ac + 440 spray Oil 1 gal/ac 6/17
Talmage (Ukiah)	Delegate 7 oz/ac + Slither 2 Oz/ac, 7/5
Walnut Grove	No sprays / Unmanaged site
Ukiah	No sprays / Unmanaged site

Efficacy trials: Pears. Efficacy of the low deployment rate meso-emitters was evaluated in replicated plots of three Bartlett pear orchards located in the Sacramento River delta region and Ukiah. The Suterra G037 meso-emitter was deployed across five plots in the three orchards and the Isomate ring was deployed in a single site. We applied a standard pheromone treatment of

200 dpa of Suterra CM XL1000 in two five-acre plots at each of the Walnut Grove and Ukiah orchards. These orchards were otherwise unmanaged, thus, untreated controls were an additional treatment plot. The organic Isleton orchard was treated by the grower with 200 dpa Isomate-C TT except for our experimental plot. Isleton was the only pear site to receive supplemental insecticide treatments as indicated in Table 2.

An additional managed site, Talmage, was also located in Ukiah. This trial site was run by R. Elkins and consisted of five acre treatments of both the G037 Suterra meso and the Isomate ring dispensers. The pheromone standard consisted of Isomate-C TT applied by the grower at 200 dispensers per acre to the remainder of the site. Insecticide treatments were applied at the grower discretion across all treatment plots.

All pheromone applications were completed April 3-6, 2009 in the delta and April 9-13, 2009 in Ukiah. First generation codling moth damage assessments were conducted at approximately 1100 dd on June 12 and 15 in the delta, June 23 at Talmage, and July 2 in Ukiah. Harvest samples were completed July 9-11 in the delta, July 31 at Talmage, and August 13 in Ukiah. A final post harvest sample was made September 23 at Talmage only.

Table 3. Walnut site locations and grower applied insecticide treatments.

Trial	Experimental Product	Site / Variety	Grower Standard Treatments (2009)
Efficacy Trial	Suterra G037	Bogue / Vina	Lorsban 4E ½ gal/ac, 7/9 Lorsban 4E ½ gal/ac, 8/10 Ethrel ½ gal/ac + Lambda-star 5 oz/ac, 9/1
	Suterra G037	Knight's Landing/Serr	Nufos 4E ½ gal/ac, 5/21 Brigade WSB 1-lb/ac + Onager miticide 19.2 floz/ac + Pro 90 12.8 floz/ac, 6/26 <i>Nufos 4E 4 pt/ac, 8/16</i>
	Suterra G037	Linden/ Vina	Guthion 3lb/ac + Dibrom 1-1/2 pt/ac + Omite 3 pt/ac, 8/1
	Suterra G037	Gustine/Payne	Warhawk 2 qt/ac, 4/28 Asana 12.8 oz/ac + Agrimek 10 oz/ac, 6/29
	Isomate "ring"	Colusa / Vina	Lorsban 4E ½ gal/ac, 6/29 Ethrel ½ gal/ac + Lorsban 4E ½ gal/ac, 8/28
	Isomate "ring"	Tracy / Tulare	No insecticide
Emission Rate Trial		Colusa / Vina	Lorsban ½ gal/ac, 6/29 Ethrel ½ gal/ac + Lorsban 4E ½ gal/ac, 8/28
		Knight's Landing/Serr	Nufos 4E ½ gal/ac, 5/21 Brigade WSB 1/lb/ac + Onager miticide 19.2 floz/ac + Pro 90 12.8 floz/ac, 6/26 <i>Nufos 4E 4 pt/ac, 8/16</i>
		Tracy / Tulare	No insecticide sprays
		Woodland / Chandler	No insecticide sprays

**Walnut scale treatment with potential effects on codling moth populations if timed during flights.*

Efficacy trials: Walnuts. Efficacy trials for Suterra G037 and Isomate ring emitters were conducted in six walnut orchards. The G037 dispenser was deployed in four orchard plots of five to twenty acres. The Isomate ring dispenser was applied in two trial plots of seven and twenty acres. Walnut varieties included Payne, Serr, Vina, and Tulare. Grower standard programs were all insecticide based and applications were made across all treatment plots based on grower determined need (Table 3). Applications targeting other walnuts pests are shown in italics as they can impact codling moth if timing coincides with a moth flight. We applied a five-acre pheromone standard of Checkmate XL1000 in each orchard. Trap and damage evaluations were

conducted in all three treatments at each site. Pheromone applications for membrane emitters (Suterra) were completed April 14 through 25 in three sites, May 4-5 in Gustine, and May 12-15 in Linden, and the Isomate ring application was completed April 15 in Tracy and April 28 in Colusa. The May applications were generally a result of pruning tower availability or other logistic conflicts in the particular sites. Dispensers were applied from the ground in three sites where small tree stature permitted or lack of a pruning tower necessitated this method. Canopy samples for codling moth damage were conducted in one membrane and both ring treatments. Harvest samples were taken from all sites as described earlier.

Effect of total pheromone emissions per acre at a fixed number of dispensing units. In 2007 we conducted field trials that varied the number of pheromone dispensers per acre while holding the total pheromone load within a certain range. Our data suggested effective control could be achieved with deployment rates of 18 point sources per acre. In 2008 we conducted a trial using a deployment rate of 18 dispensers per acre but attempted to vary the total emissions per acre by using dispensers with different emission rates. However, the high pheromone load rates used in the membrane meso-emitters resulted in problems sealing the membrane margins during manufacturing. The outcome of this was that the edge seals would open, and thus, emission rates were altered or the pad containing the pheromone would fall from the dispenser. Dispenser unit types had different failure rates depending on the membrane combinations used, though the G037 used in the efficacy trials had the lowest failure rate. Thus, we were unable to make a reliable estimate of actual emission rates per acre and the number of units per acre essentially changed as dispensers dropped the pheromone pads. The problems of sealing the large membrane dispensers were addressed and we ran the emission rate trial again in 2009 (unfunded).

Four experimental dispensers from Suterra were tested in replicated 5-acre plots and compared to a standard Checkmate XL1000 application and the grower standard control (no pheromone). The trial was replicated in four commercial walnut orchards located near Tracy, Woodland, Knight's Landing, and Colusa. Pheromone applications for these rate trials were completed between April 14 and 24, 2009. Three sites have been managed in a conventional spray program (though one of these went untreated in 2009) and the fourth site has followed a "relaxed" management strategy with no sprays. All treatment plots in an orchard replicate received the same insecticide treatments. Thus, observed differences between treatments could be attributed to the additional pheromone component. The five-acre treatment plots were each monitored with a set of four traps baited with 1X Biolures or Pherocon® CM-DA COMBO™ lures. Canopy samples for codling moth damage were conducted July 16 through August 5th from pruning towers and harvest samples collected as described above.

Dispenser aging trial. Field aging studies were conducted for the Suterra membrane dispensers by placing 48 dispensers of each type (G037, H035, H042, H043, XL1000) in a pear orchard (Sacramento delta) canopy in a pattern approximate to a field rate. Eight dispensers of each type were collected at days 0, 30, 56, 84, 112 and 137 following placement. Residual analysis of the dispensers is being conducted by Suterra and emission rates will be calculated from these data when analysis is completed. Additionally, a set of eight units of each of the five emitter types was collected from one rate trial site (Tracy) to evaluate residual status after a full season deployment (216 days).

RESULTS AND DISCUSSION

Application of meso-emitters in field plots.

Ground applications. The membrane meso-emitter deployments were completed quickly with the use of a pole applicator. The Suterra mesos are manufactured with an attached clip (like the Checkmate XL 1000 product) that facilitated a quick application. In pears, we completed the meso applications (18 dsp/acre) in 10 minutes/acre/person compared to 60 minutes/acre/person for a 200 dsp/acre Checkmate application. Clearly, different operations with different levels of experience will vary in their rate of application, but the time is provided as a relative comparison using University crews. A ground application of the mesos in walnuts was made at 8.4 minutes per acre into moderate sized trees averaging about 25 feet with the use of a fully extended 16-foot pole. The differences between pears and walnuts are presumed to have arisen from the fact that the walnuts were applied later and we had gained additional experience with the application.

Tower applications - Walnuts. An extension pole was also used from a pruning tower to place the mesos into the mid to upper canopy of larger trees (up to 45 foot size). Average application rate was 19 minutes per acre (range 15 – 24 minutes). Application time with a tower would be expected to vary due to tower speed and mobility, tree size, spacing, and experience of the applicator.

Efficacy trials using a standardized meso-emitter for codling moth control.

By working in both pears and walnuts, we were able to increase the functional size of our trial so as to increase our ability to distinguish statistical differences. Considerable variation was observed across systems and orchards and is shown in detailed figures in the crop specific discussions. Similarly, the contrast also varied across the 2 cropping systems: 1) for pears, the most highly replicated contrast was with an untreated control given that 2 orchards were no longer be aggressively managed and 2) for walnuts, the contrast was the standard spray program for plots with and without the addition of a pheromone treatment. Using the appropriate contrast in each system, the results are summarized for the most replicated treatment across the 2 systems, the Suterra meso G037 dispenser (N=8). Codling moth damage was first significant depressed by the meso pheromone dispensing treatment ($P=0.03$), but no statistical difference was observed between the meso and pheromone standard program (Fig. 1). Orchards which did not have all of these contrasts nor any damage in the plots were not included. Because of the relative larger size of these plots and the limited number of replicates that fit these criteria (4 in each cropping system), the differences are not statistically significant despite the consistency of the trends within each crop. Pooling of the effort and data across the crop types allowed for a much more robust evaluation. A similar device, the Pacific Biocontrol ring, also worked well, but the combined analyses was not possible due to the more limited number of replicates.

Pears: codling moth flight curves. The Suterra G037 meso-emitter was used for the standardized efficacy trials. Total codling moth counts for all treatments are shown in Fig 2. The pattern of counts is similar to patterns from 2007 and 2008. The untreated areas caught the greatest number of moths, but no statistical differences could be discerned. Despite the relatively large size of the plots at ca. 15-20 acres, the plots are not completely independent as evidenced by the

low counts in the 1x lures in the untreated controls. The untreated controls have higher counts with a 10X trap which normally would not perform as well in a non-pheromone permeated area. However, the lowest counts were always lowest in the meso treated plots (87% trap suppression) versus 95% suppression in the standard pheromone programs. Examples of codling moth flights as monitored by three lure types are shown for the organic Isleton orchard (Fig 3-5), and as averages for two replicates in the unmanaged Walnut Grove site (Fig 6-8). Detailed flight data for the Ukiah plots are not shown as codling moth populations remained extremely low throughout the season.

The Walnut Grove orchard has had a history of high moth populations and in 2009 received no insecticide sprays. The flight patterns shown with the 1X traps (Fig 8) appear to indicate the population in the untreated controls may have been suppressed by the adjacent pheromone treatments, especially during the early part of the season. This is a frequent problem with pheromone field research programs. Controls need to be located near the treatment plots to standardize the moth pressure and grower treatment variables, but because the pheromone is dispersed by air currents, it becomes difficult to locate an isolated yet meaningful “untreated” control.

Average season total trap capture in all four efficacy sites are shown for the CM/DA combo, 10X and 1X baited traps (Fig 9-11). The combo trap catch (Fig 9) indicates the variation in codling moth pressure across the trial sites. Trap totals ranged from 80 (Ukiah) to more than 500 (Walnut Grove 2) in the untreated controls and from 13 (Ukiah) to more than 380 (Walnut Grove 2) in meso-treated plots. High variation within orchards was also observed, as indicated in the Walnut Grove sites where combo trap catch averaged from 160 to more than 500 moths. The Isleton (organic) and Ukiah (abandoned) sites both had very low pressure, which was also substantiated in fruit damage samples. The large population differences between and within sites made statistical discrimination between treatments difficult. The effects of the pheromone on the relative trap capture rates are difficult to interpret given that the combo lure also attracts females but does contain the codling moth pheromone to attract males. Similarly, the relative attractiveness of the 10X lures varies as a function of the background concentration.

Trap captures in the combo traps are generally greater than the 10X traps and appear to offer the greater resolution in monitoring codling moth flight activity. The 10X and combo lures are capable of monitoring codling moth flight activity in pheromone treated sites while 1X traps are typically shut down. All pheromone treatments, experimental and standard, in these trials suppressed the 1X traps.

The Isomate ring was deployed in an abandoned pear orchard in Ukiah. The anticipated codling moth population in this unmanaged site did not develop. Figure 12 indicates the average season total capture in combo traps was only 4.5 moths, indicating a very low population. What was surprising was the late season increases in codling moth to 1.7% (Fig 14) in some areas within the orchard despite these very low seasonal counts.

Pears: fruit damage in efficacy trials due to codling moth.

Seasonal averages in codling moth damage are shown for 4 of the sites which had at least some measureable damage (Fig 13). The Isleton site was not included in the average since both plots

had 0% damage, thus making the contrasts less useful. Pear damage due to codling moth in the Suterra meso emitter trials is shown for all sites following 1st generation (Fig 15) and at harvest (Fig.X). The managed organic orchard indicated no codling moth damage with either sample. The Ukiah site also had little damage across all treatments but the higher damage levels were observed in the untreated areas.

Walnut Grove sites did provide severe pressure as indicated by both the moth flight and fruit damage. The Walnut Grove orchard provide one of the best contrasts for the season with higher damage levels found at harvest with up to 12.5% infestation. This level of pressure appeared to be ideal with enough damage to present a serious problem, but not high enough as to overwhelm the treatments. Damage patterns observed at 1100 dd were sustained in the harvest samples. At harvest, fruit damage in meso treatments for both replicate blocks was reduced by about 76% from the untreated controls (Fig 16). The standard pheromone treatment (Checkmate CM XL1000) indicated a 63-69% reduction in damage. The south block indicated much greater damage values than the north for both 1st generation and harvest samples. A contributing factor at harvest may have been field flooding in the south replicate that delayed access for about two weeks during which time the damage continued to increase. The meso treatment provided control that was at least as good as the standard Checkmate program despite the dramatic reduction in number of dispensers.

The results from the Talmage plot are shown in Table 4 for both types of emitters. Damage levels were relatively low in all plots at 0-0.1, but similar to the other sites, as differences were detected at any point of the growing season including post-harvest.

Table 4. Effects of the ring and Suterra meso emitters on codling moth damage levels in Barlett pears.

TREATMENT	1st GENERATION		2 nd GENERATION		2nd-3rd GENERATION
	TREE	GROUND	PRE-HARVEST TREE	BIN	POST HARVEST
Meso-Emitters	0.0	0.0	0.1	0.2*	0.3
Isomate Ring	0.1	0.2	0.0	0.1**	0.0
Isomate Ties (Grower Standard)	0.0	0.0	0.1	0.3	0.3

* Damage unconfirmed, most likely OFM.

** Damage unconfirmed, worm absent.

Walnut codling moth trap data.

Typical flight patterns for the walnut orchards are shown in Fig 17-19. As summarized in Fig 20, the combo lures showed fairly high flights with seasonal totals between 190 and 360 moths per trap in the three treatments. The Suterra meso treatment provided 100% suppression of the

traps baited with 1X lures for the season with no detectable difference between trap counts in the meso and standard pheromone programs. The trap counts for the ring mesos (Pacific Biocontrol) also showed 100% suppression in both walnut orchards (Fig 12) as well as some apparent suppression of the combos.

Walnut damage suppression.

The average seasonal damage levels for the trials with the Suterra meso (G037), Checkmate, and grower standard are shown in Fig 21 ($P=0.052$). The orchards were selected based on their historical problems with codling moth in previous years. The highest levels of suppression were noted in the meso treated plots with the Checkmate XL1000 plot ranging in between the meso and grower standard plots. Patterns of damage at harvest were largely consistent across all meso trials, as shown in Fig 22. Again, all plots in a site received the same insecticide treatment regime whereas 2 treatments received an additional pheromone treatment. Thus, the reduction in the number of dispensers per acre again did not decrease the efficacy of the pheromone mating disruption program.

The results for the Isomate ring trials are shown in Fig 23 for both the canopy counts and final harvest. No statistical differences were found, but that would be expected with only 2 replicates. Secondly, the damage counts were relatively low even at harvest with all plots have less than 1% damage.

Effect of total pheromone emissions per acre at a fixed number of dispensing units.

The results from the rate trial have not been completed as the release rates are still to be determined in the laboratory by Suterra. Without these data, it is difficult to interpret these results since the dispensers may have released at rates that differed from our expectations. However, some general patterns still appear to be evident but will require final confirmation.

Walnut rate trial trap data.

All treatments effectively suppressed the 1X baited pheromone traps by 96% or more regardless of the membrane type (Fig 24 and 25). Assuming that the membranes performed as expected, then the effects of decreasing rates on trap suppression was not detectable. All were comparable to the standard pheromone (Checkmate XL1000) in this orchard. What can also be observed in the following figure are the flights monitored in the combo lures (Fig. 26) which showed peaks up to 90 moths in a week in the grower standard plots and peaks up to 72 moths per trap in some pheromone treated plots. Thus, the populations were clearly present. Total trap counts for both the combo and 1X lures are shown in Fig 24.

Walnut rate trial damage suppression.

Despite the robust flights, damage levels were low in all plots with no clear or significant differences in the data between plots. Given that the grower standard failed to exceed 1%, it is unlikely that we could have detected any meaningful pattern with the damage data from this orchard (Fig 27-28)..

Acknowledgments. We are grateful for the contributions and cooperation given by growers and advisors through the course of each field season. We thank John Arnaudo, Steve Bell, Rick Carothers, Bob Costanho, Sonny Dale, Simone Furlan, Randy Hanson, Matt Hemly, Kyle Lang, Lee Metzler, Glen Olson, Dave Sarasqueta, Tom Shea, Jim Tarke, Steve Thomas, Jed Walton, Thom Wiseman, and Steve Ziser for their contributions this past year. We also would like to acknowledge the support of Suterra and Pacific Biocontrol.

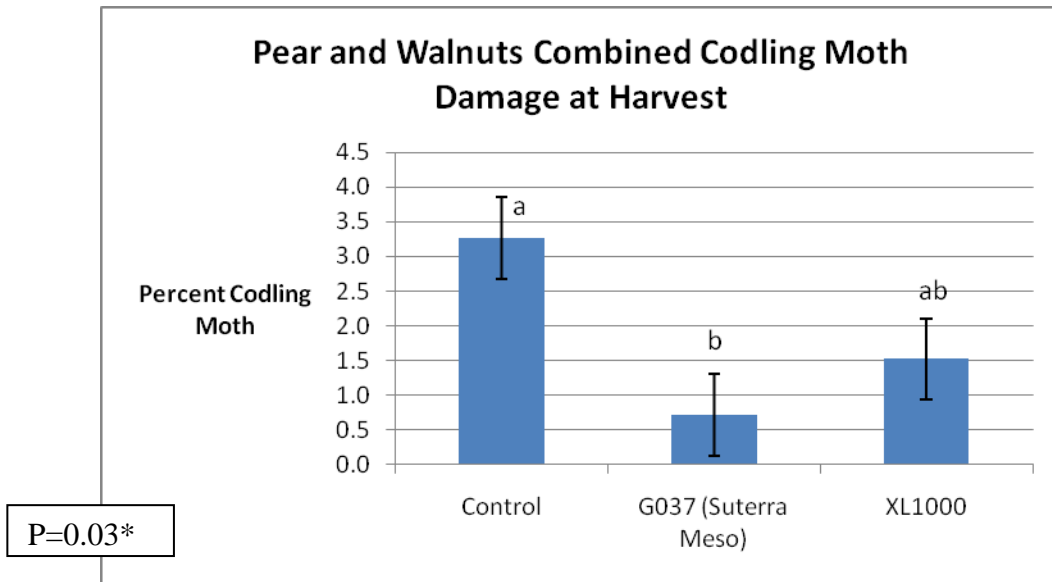


Fig. 1. The combined effect of the G037 Meso emitter on codling moth damage at pear and walnut harvests. Control for pear plots is untreated, whereas the control plots in walnut trials consists of any insecticide treatments applied by the grower uniformly to all plot including the pheromone plots.

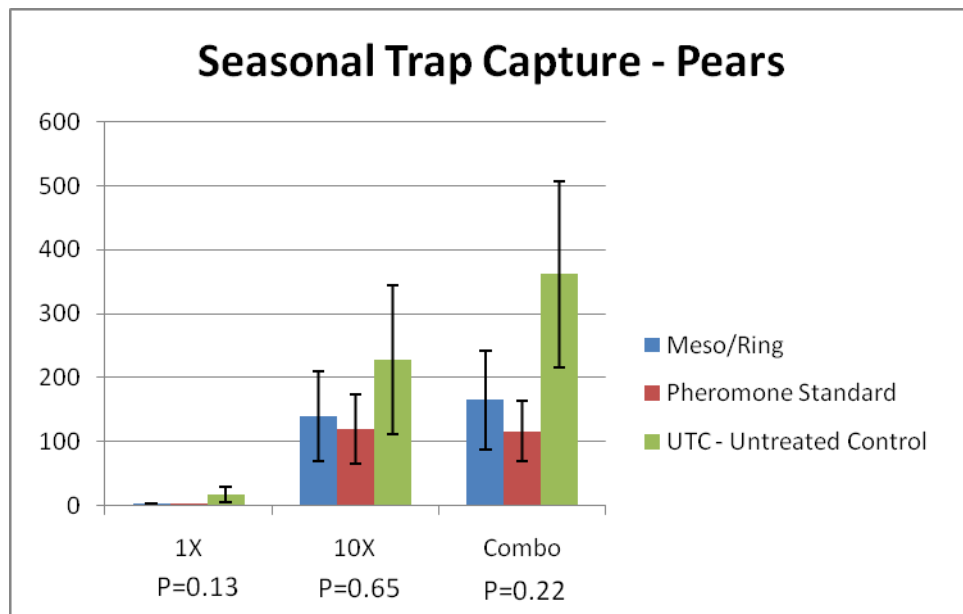


Fig 2. The seasonal totals for all meso treatments (Suterra and Pacific Biocontrol) are shown for the 3 lure types, 1x, 10x, and combo lures.

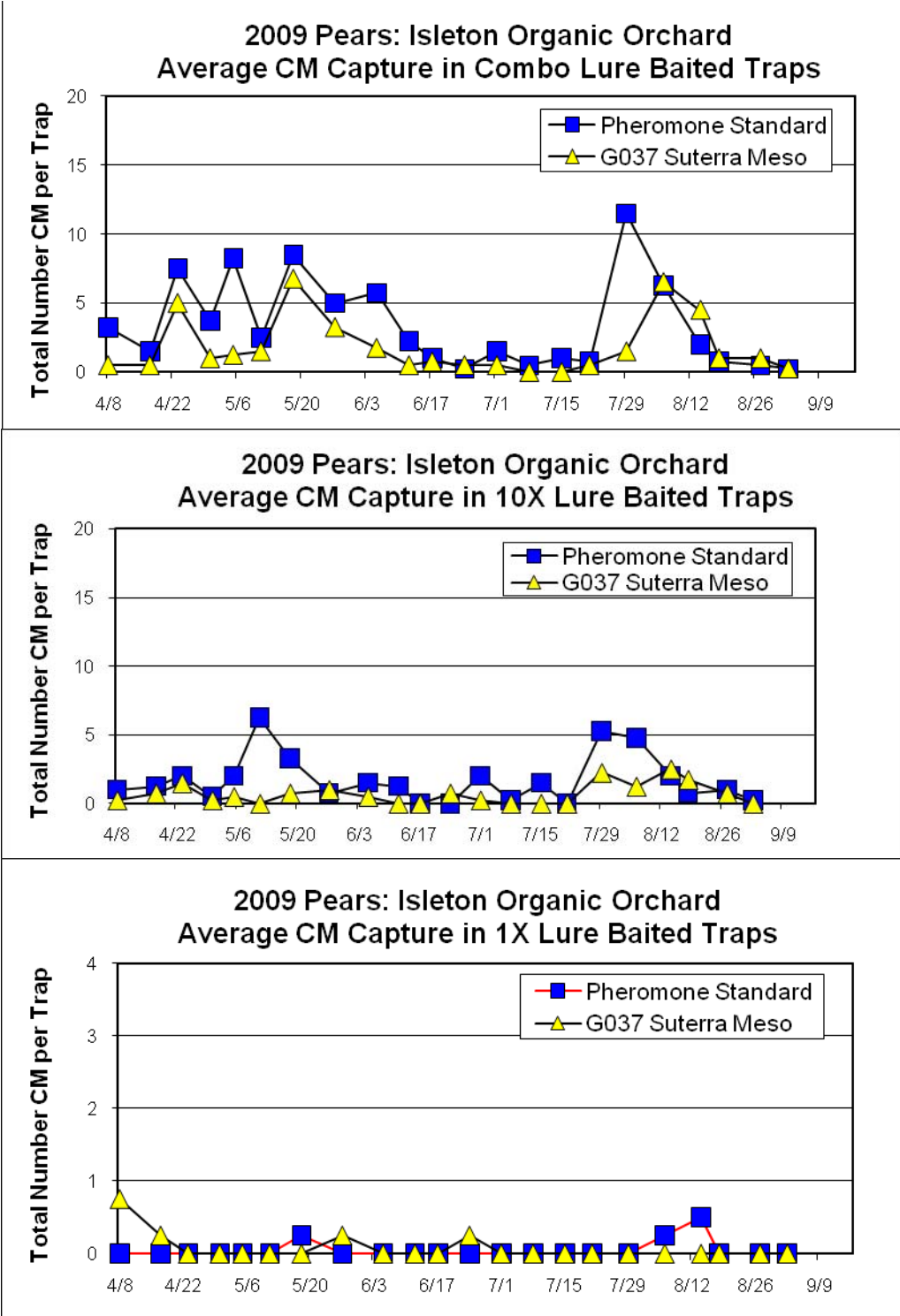


Fig 3-5. Seasonal codling moth flight data for Combo, 10X, and 1X baited traps in the Isleton organic pear orchard. The pheromone standard in this site was Isomate-C TT applied by the grower to the remainder of the orchard. Insecticide treatments were applied by the grower uniformly to all treatment plots.

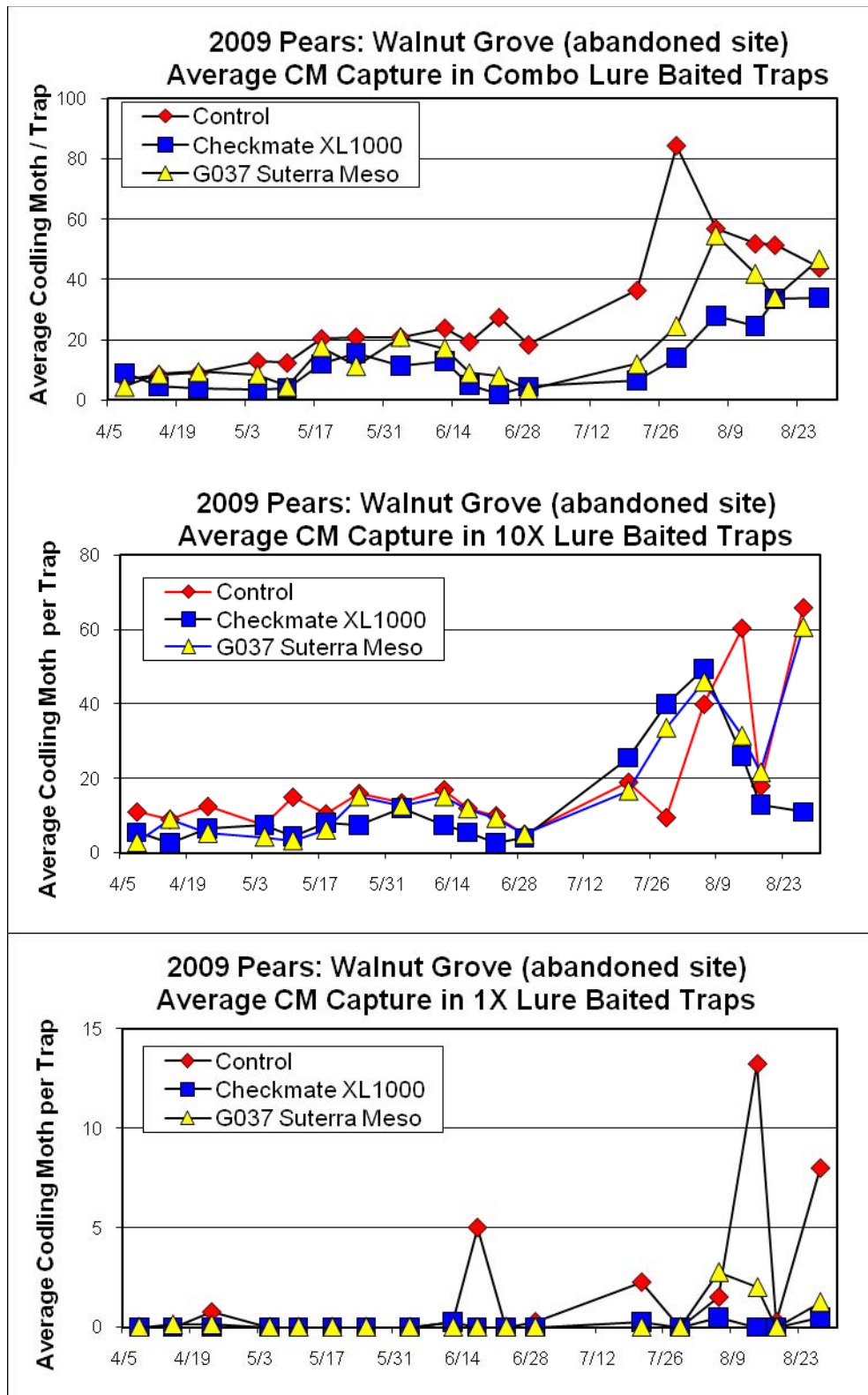


Fig 6-8. Seasonal codling moth flight data for Combo, 10X, and 1X baited traps in the abandoned Walnut Grove pear orchard. No insecticide was applied to any of the treatment plots in these sites.

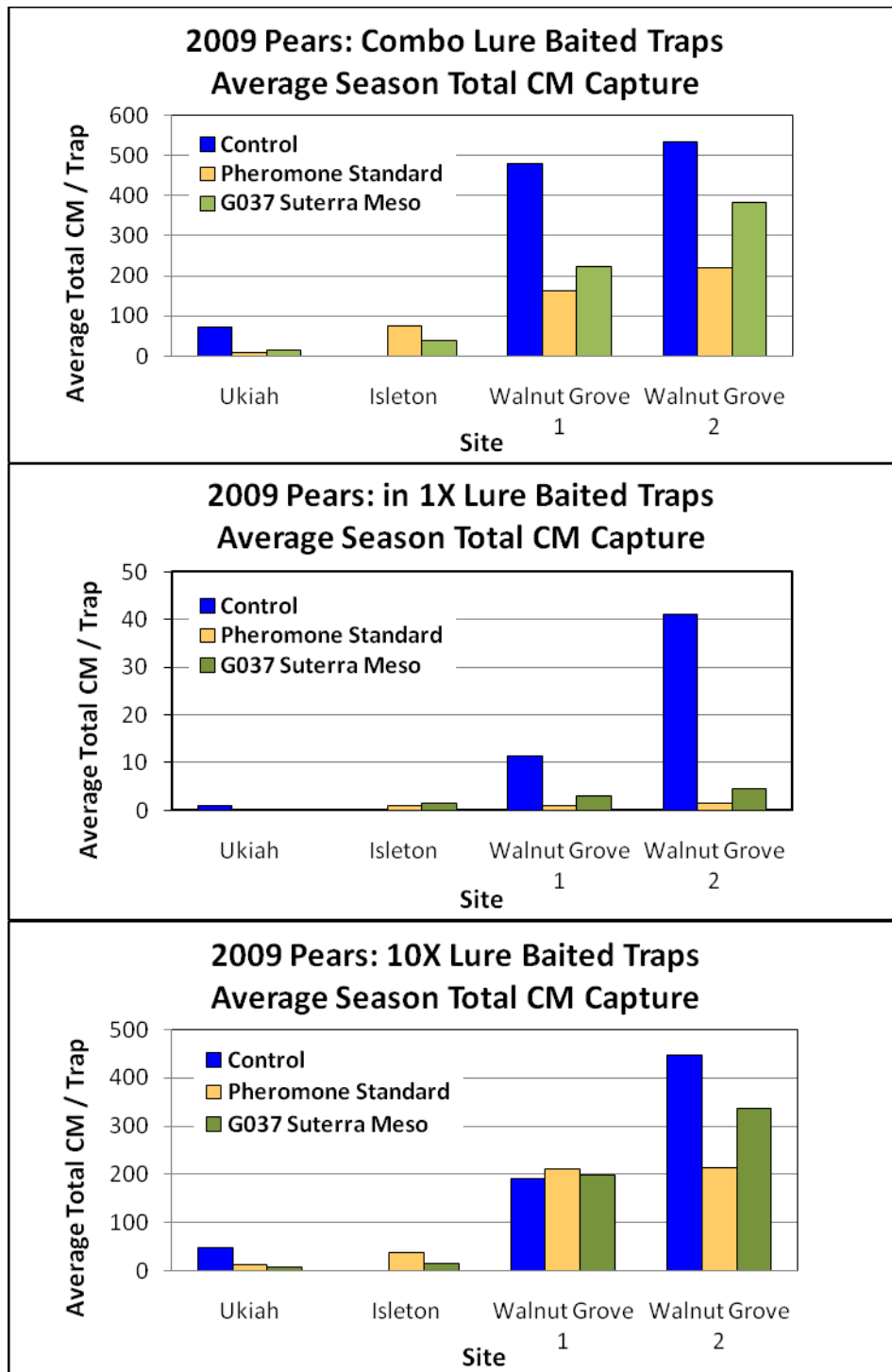


Fig 9-11. Season total codling moth capture in four sites for Combo, 10x, and 1x baited traps. Isleton was the only site to receive supplemental insecticide treatments across all plots and lacked non-pheromone control. No insecticides were applied to any of the other treatment sites.

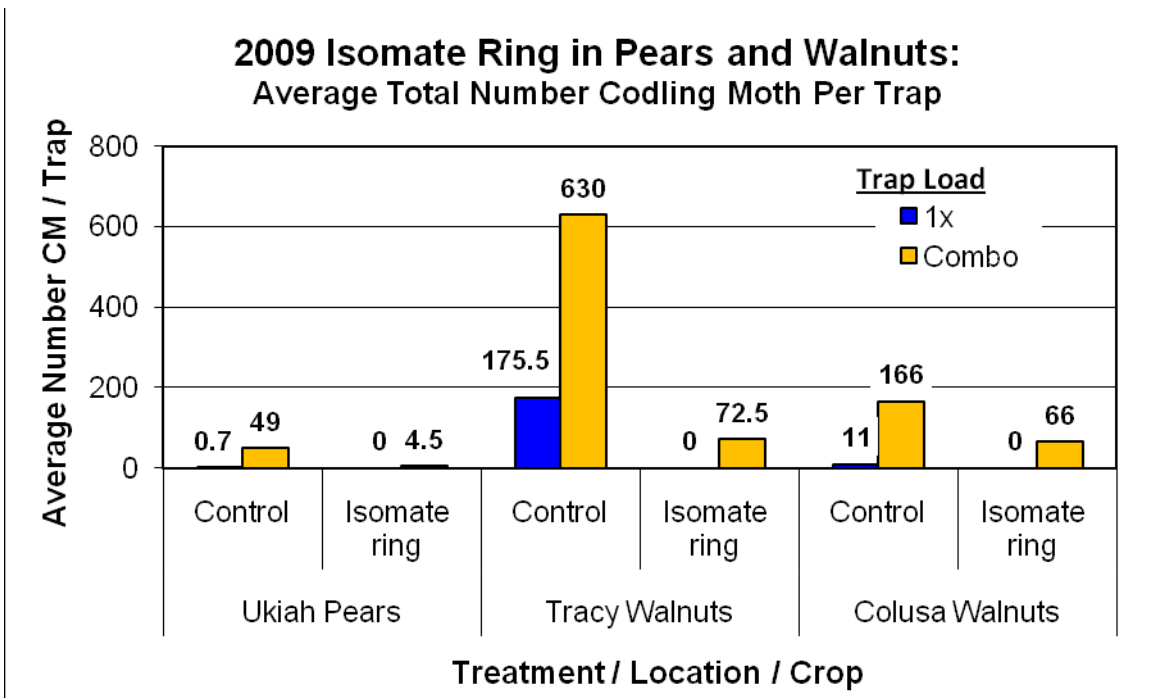


Fig 12. Average season total number of codling moth per trap collected in pear and walnut plots treated with the Isomate ring dispenser. Pear control plot is untreated, whereas the control plots in walnut trials consists of any insecticide treatments applied by the grower uniformly to all plots including Isomate ring.

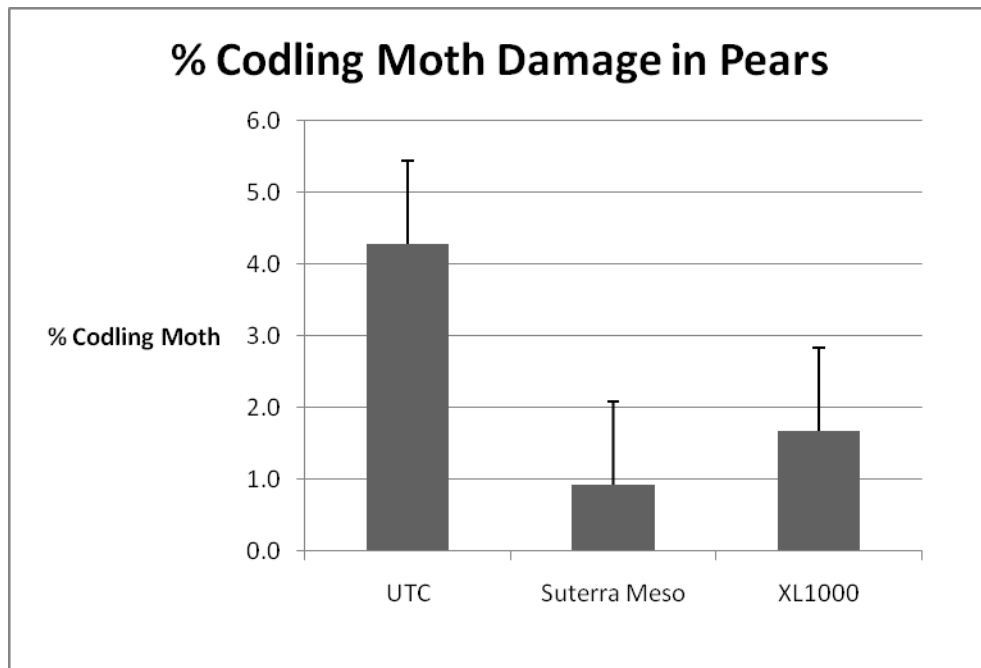


Fig. 13. The average codling moth damage levels in pears at harvest by treatment.

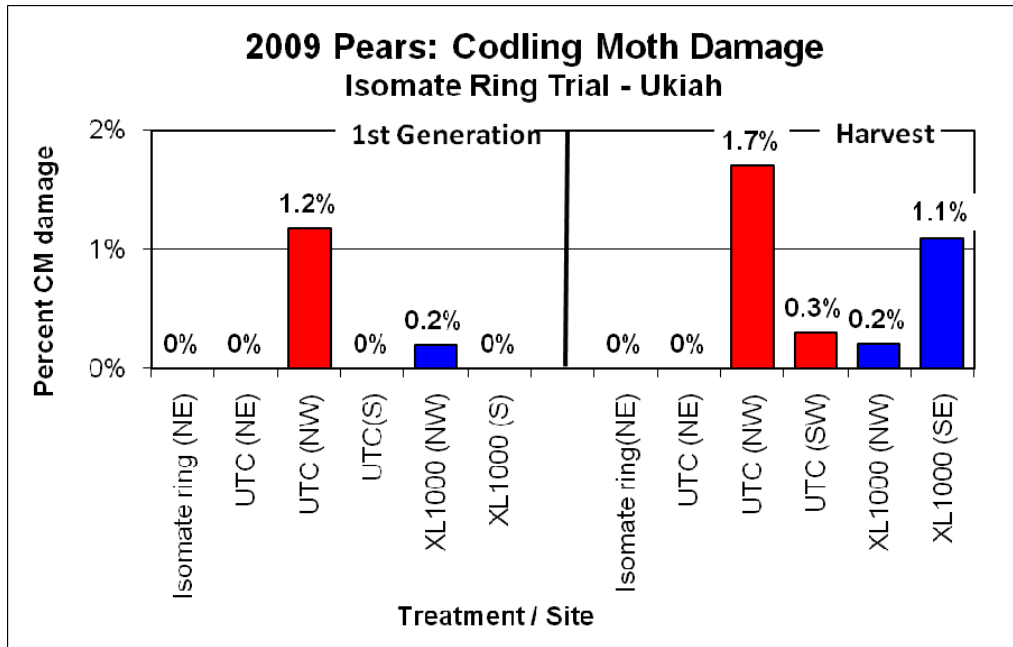


Fig 14. Codling moth damage evaluations for the Isomate “ring” trial in an abandoned Ukiah pear orchard, 2009. Assessments were made after 1st generation (1100 degree days) and at harvest timing.

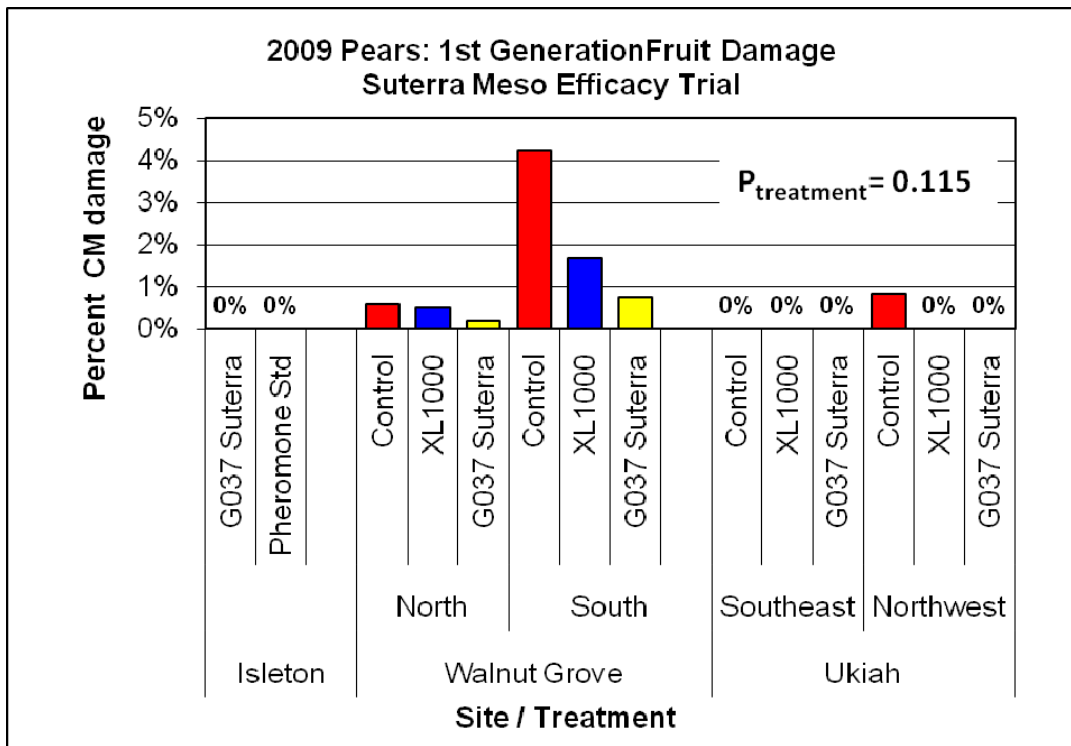


Fig 15. Pear damage in all plots due to codling moth following 1st generation. Supplemental insecticide treatments we applied in the Isleton site only.

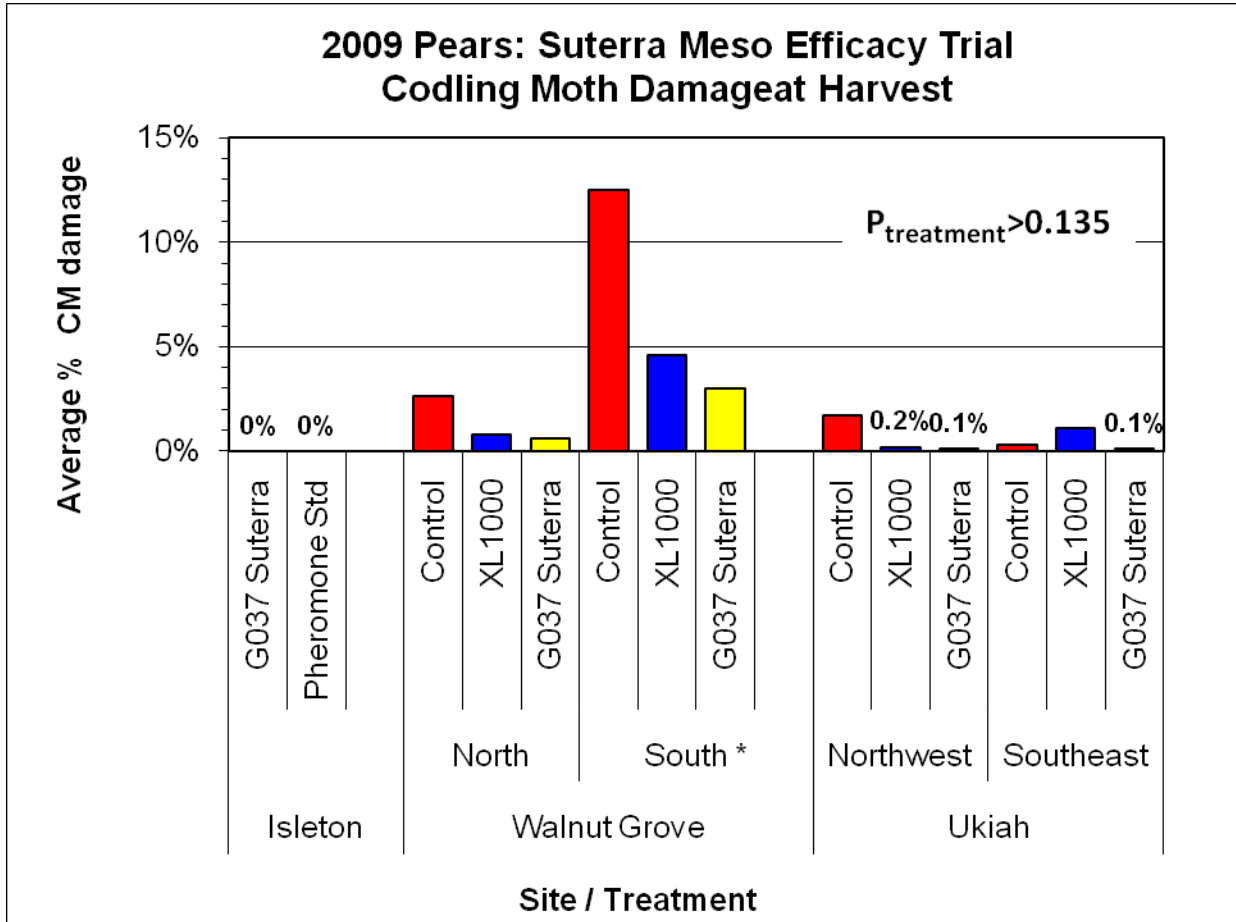


Fig 16. Pear damage at harvest in Suterra meso emitter efficacy trial sites. Damage assessment in the Walnut Grove south block was made two weeks later than the north block because of limited access due to water. Supplemental insecticide treatments we applied in the Isleton site only.

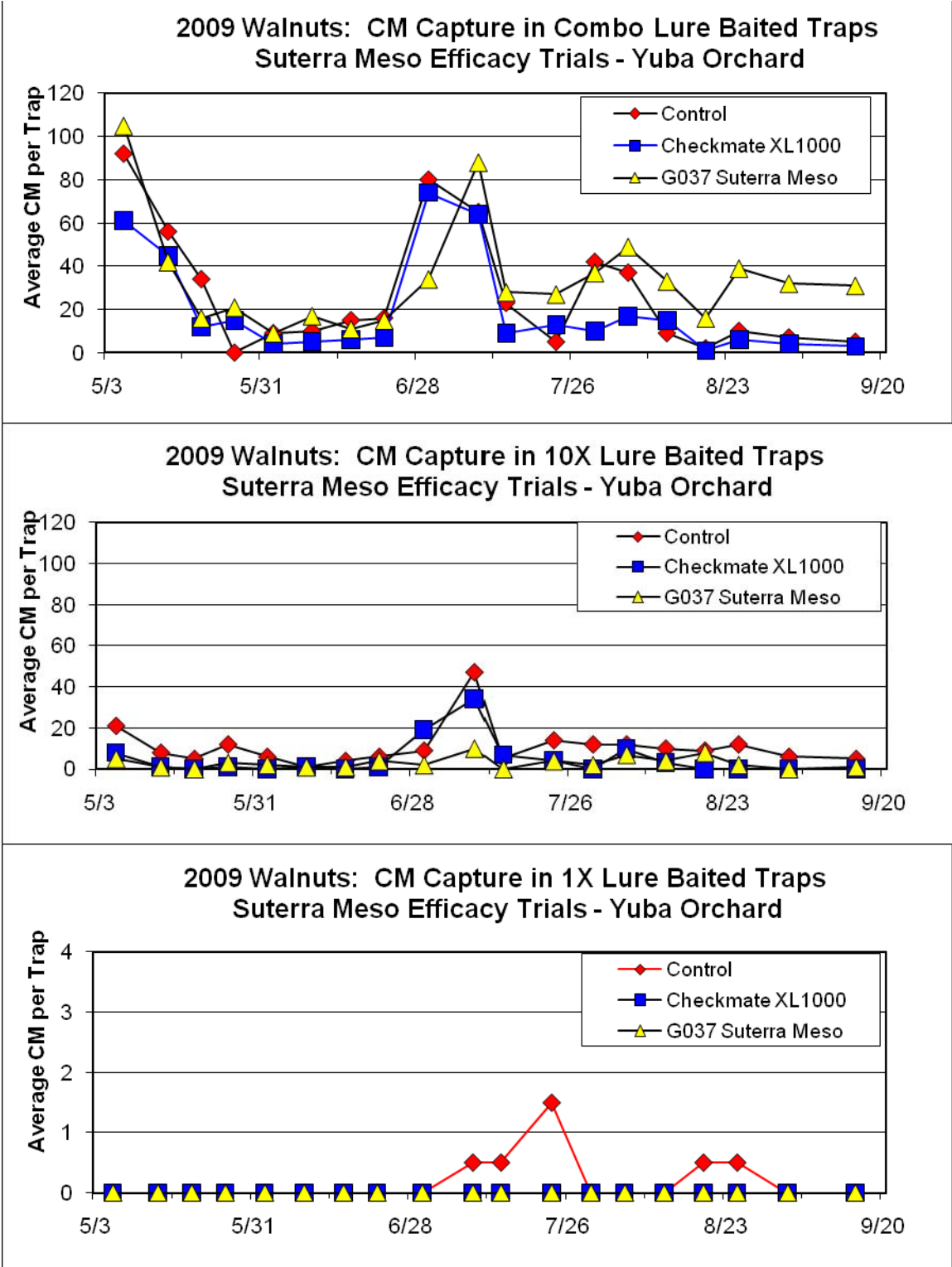


Fig 17-19. Weekly trap capture in Combo, 10x, and 1x baited traps at the Yuba walnut orchard. Supplemental insecticide treatments were applied by the grower uniformly to all plots.

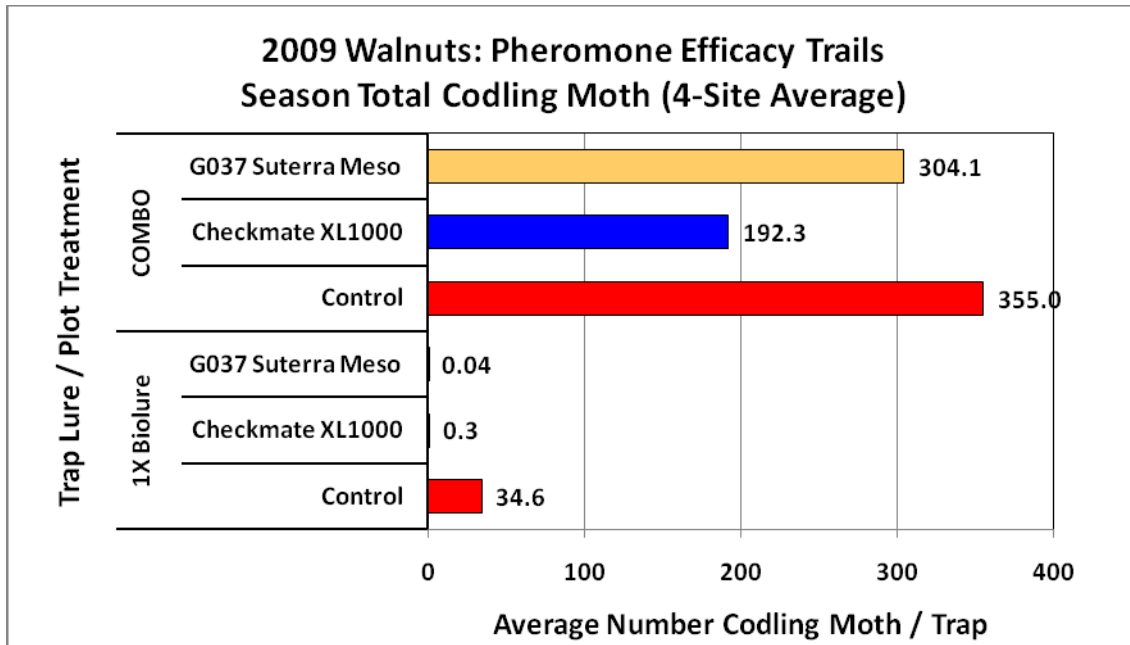


Fig 20. Average total number of codling moth captured in Combo, 10x, and 1x traps for each treatment. Any supplemental insecticide treatments made by the grower were applied uniformly to all treatment plots of that site.

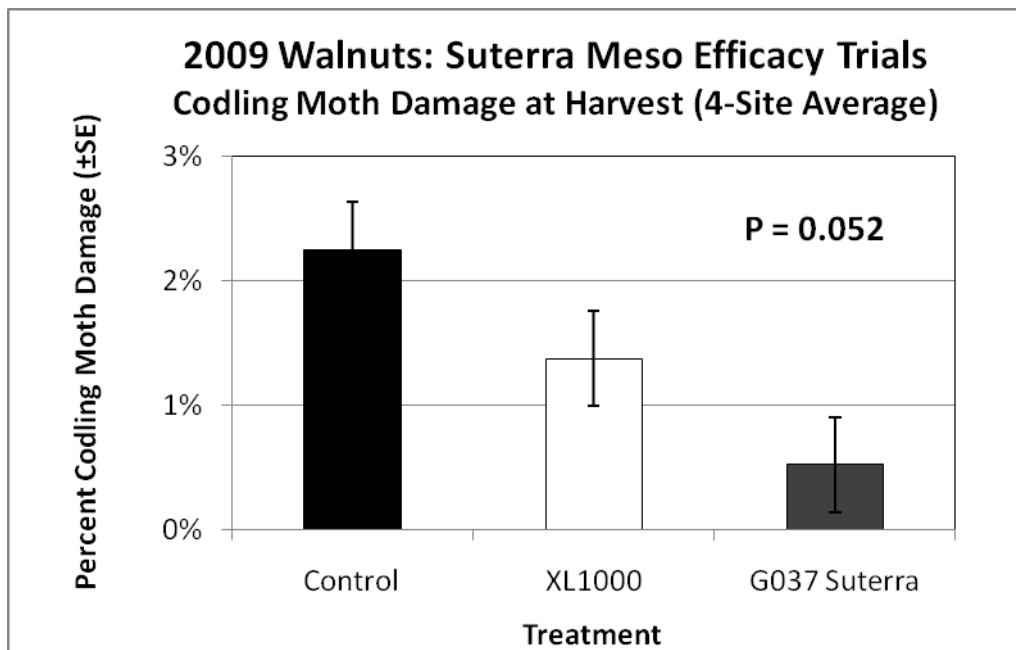


Fig 21. Average codling moth damage in walnut efficacy trials. If applied, any supplemental insecticide treatments made by the grower were applied uniformly to the control and all pheromone treatment plots of the site.

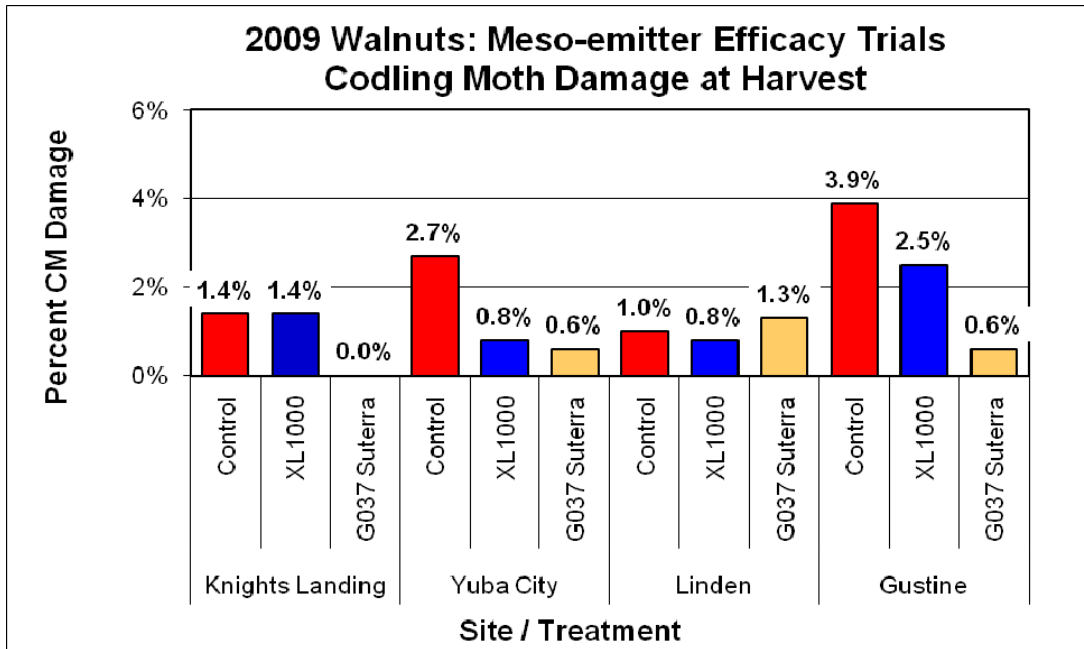


Fig 22. Walnut damage at harvest in the Suterra meso efficacy trial. Any supplemental insecticide treatments made by the grower were applied uniformly to all treatment plots of that site.

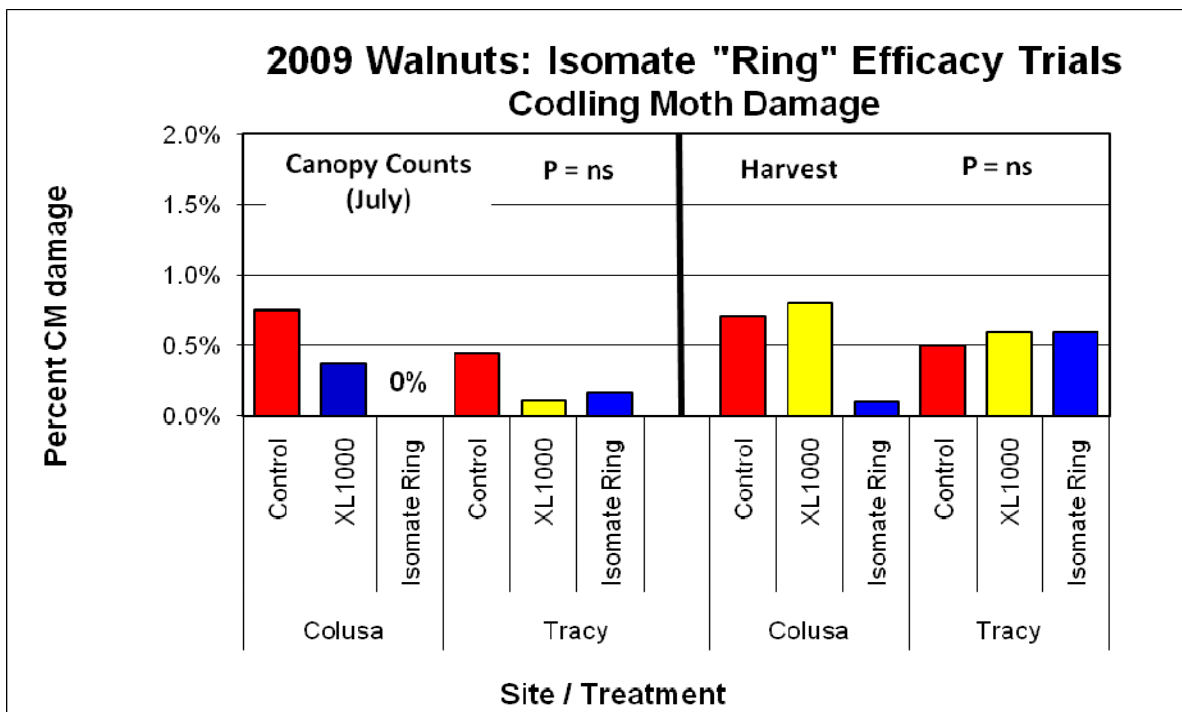


Fig 23. Codling moth damage observed in Isomate ring trials at mid-season canopy and harvest evaluations. Any supplemental insecticide treatments made by the grower were applied uniformly to all treatment plots including the controls and pheromone plots of each site.

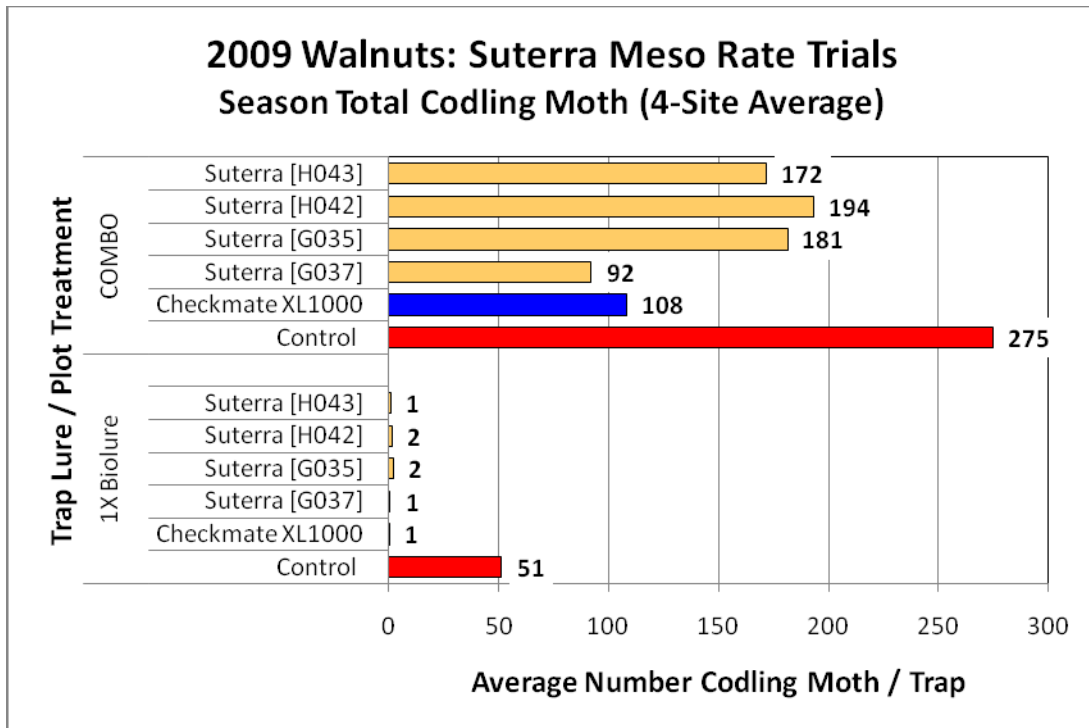


Fig 24. Average Combo and 1x trap capture in all pheromone and control treatments of the Suterra meso rate trial. Any supplemental insecticide treatments made by the grower were applied uniformly to all treatment plots including the controls and pheromone plots of each site.

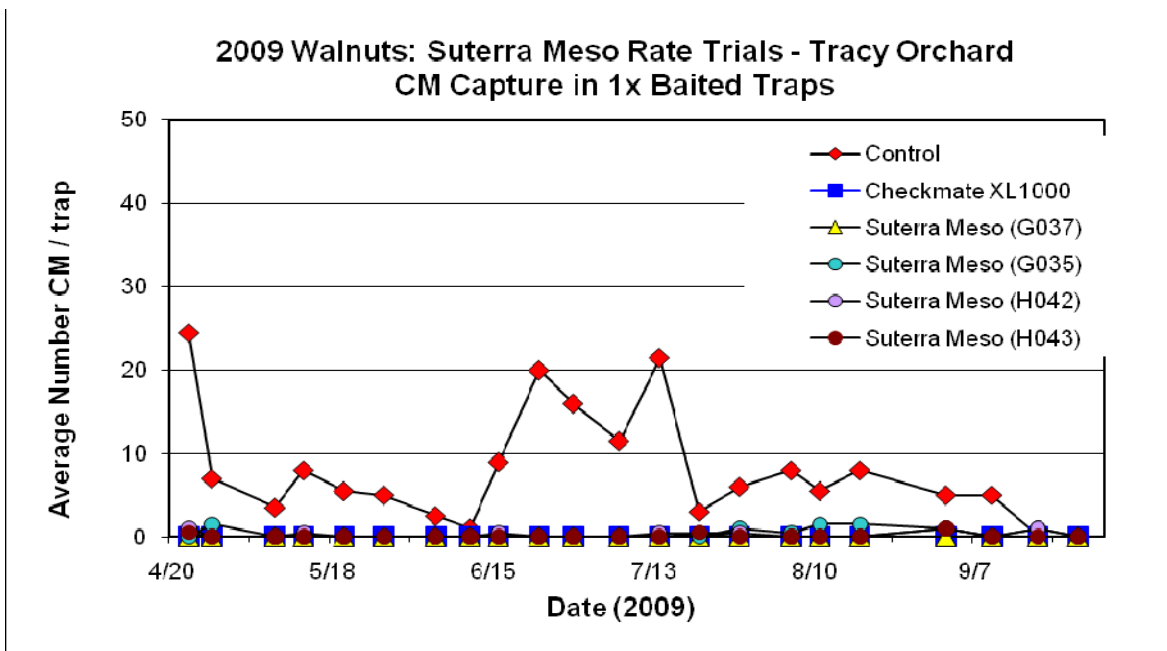


Fig 25. Weekly 1x trap capture for a representative walnut rate trial site. No insecticide was applied to any of the treatment plots in this site.

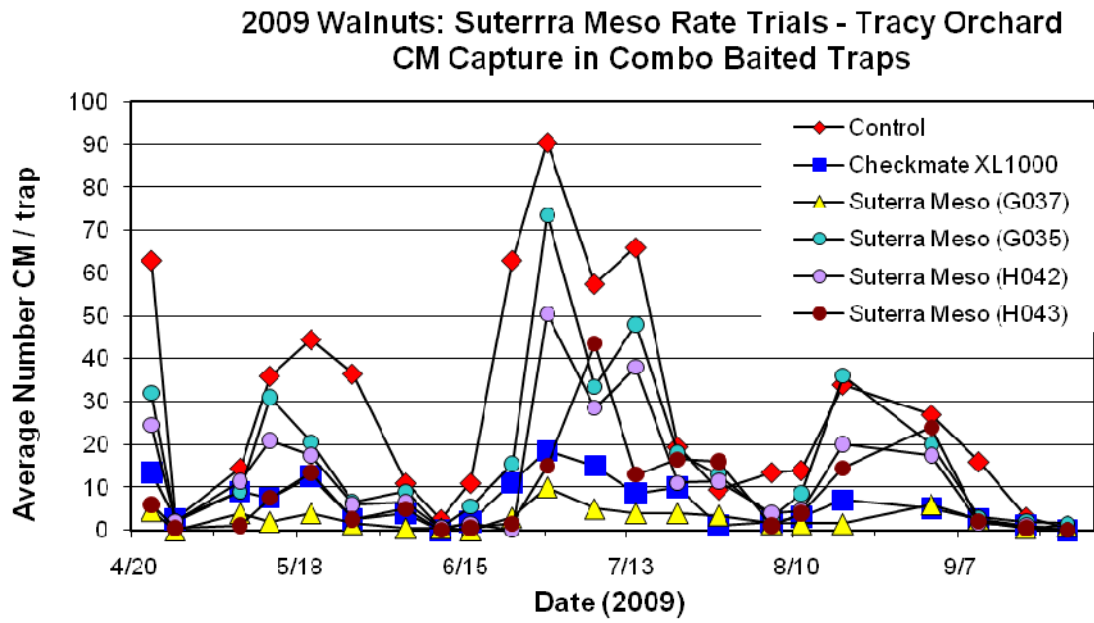


Fig 26. Representative flight patterns for codling moth in Combo traps at the Tracy orchard rate trial. No insecticide was applied to any of the treatment plots in this site.

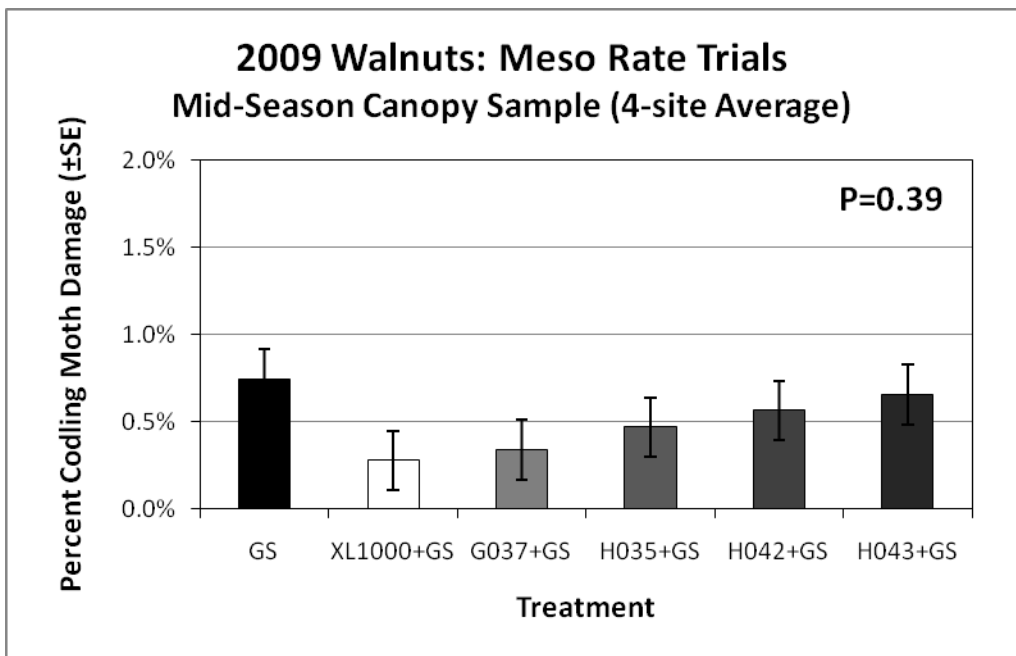


Fig 27. Average mid-season codling moth damage observed for Suterra meso rate trials. Any supplemental insecticide treatments made by the grower were applied uniformly to all treatment plots including the controls and pheromone plots of each site.

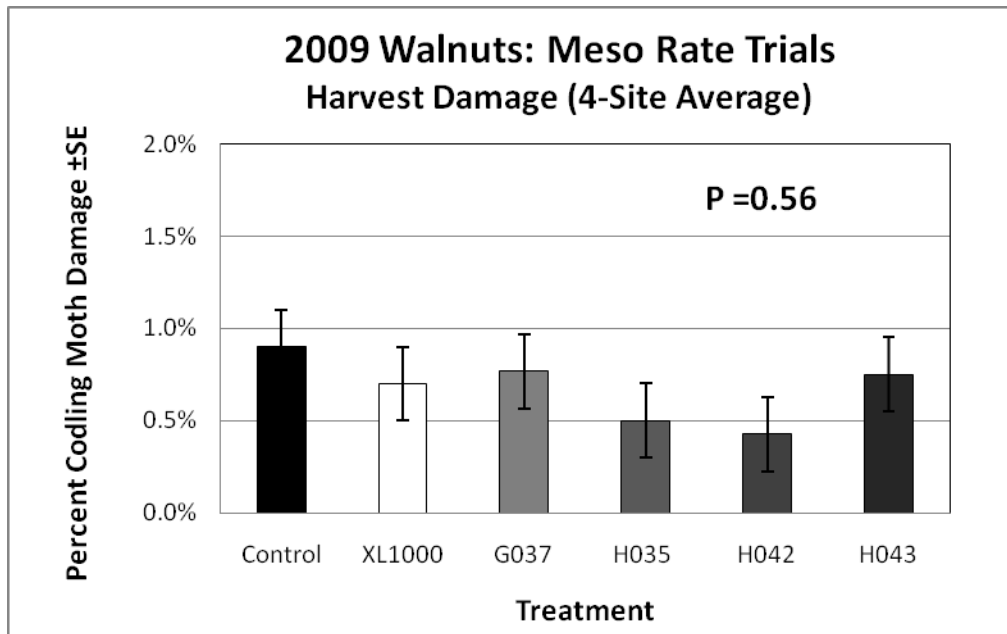


Fig 28. Average codling moth damage observed at harvest in the Suterra meso rate trials. Any supplemental insecticide treatments made by the grower were applied uniformly to all treatment plots including the controls and pheromone plots of each site.