EFFICACY OF MODIFIED PHEROMONE APPLICATION METHODS FOR CODLING MOTH MANAGEMENT IN WALNUTS:
I. LOW EMISSION RATE PUFFER APPLICATION
II. NEW AEROSOL EMITTER
III. MODIFIED HAND-APPLIED DISPENSERS

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ABSTRACT

Our trials suggest that reduced load puffer applications may provide adequate control for low-moderate population levels of codling moth. Puffers loaded with only 50% of a standard pheromone load suppressed codling moth 1x traps in sites that had significant pressure as indicated by the counts in the combo lure baited traps. Codling moth damage levels were high in the grower standard of each site (both 6.2%), but reduced in the puffer treatment to 1.5% and 4.8%. A newly designed aerosol emitter from Pacific Biocontrol performed favorably in limited initial field trials. Modified (hand-applied) emitters provided significant damage suppression in walnuts across two years of field trials and were comparable to the control provided by standard hand applied dispensers when compared to a grower standard chemical program. The degree of damage reduction was compromised in some sites with very high populations. Trap suppression of 1x codling moth traps was significant in all experimental meso and ring plots.

INTRODUCTION

Pheromone mating disruption has been shown to provide excellent control of low-moderate populations of codling moths with the use of passive hand-applied pheromone dispensers or aerosol based “puffers”. Real and perceived program costs and labor requirements remain a barrier to implementation by many growers, particularly in walnuts where size of the tree canopy makes application of the hand applied dispensers cost prohibitive. Over the past several years, we have focused on modifying the existing pheromone dispensing technologies as an effort to increase efficiency and reduce costs (materials or labor) for both types of delivery devices.

Mating disruption programs for codling moth have previously assumed that higher numbers of dispensers are needed to build a successful management program. Hand-applied dispensers have been developed over the past several years which permit application of a reduced number of dispensers per acre, and are generically referred to as “meso-dispensers”. Two commercial products now available include the Suterra meso membrane dispenser and the Pacific Biocontrol “Ring” dispenser. These are deployed at only 18-40 units per acre compared to the 160 to 200 units per acre for the standard hand-applied dispensers. The rate of pheromone emission per dispenser is increased to offset the fewer units per acre such that roughly the same pheromone load is released on a per acre basis.

Our research on puffers has focused on defining the impact of the pheromone plume and optimizing their deployment rates as well as investigating the impact of changing the level of active pheromone emitted per "puff". The hope for this area of research will be reductions in overall program costs if the levels of pheromone required per acre can be reduced.

PUFFER TRIALS: OPTIMIZATION OF AEROSOL BASED PHEROMONE SYSTEMS

Efficacy of high dose aerosol pheromone emitters for codling moth control in walnuts and pears has been demonstrated in recent years and has led to the growing adoption of this technology in these crops. Data generated by this lab in recent years has observed little difference in the pheromone plume generated by a standard puffer compared to a puffer loaded with only 50% of the standard pheromone load. Our data strongly suggests that reduction of the pheromone content of the canisters is possible. In 2011, we conducted our first field efficacy trials for puffers using a 50% reduced load of pheromone.

In 2011, a second aerosol delivery system was introduced by Pacific Biocontrol (Vancouver, WA) for preliminary field evaluations. If proven reliable, introduction of this unit may offer growers an additional mating disruption technology option.

OBJECTIVES

1. To conduct efficacy trials of a reduced load pheromone "puffer" application using an emission rate of only 50% of the standard pheromone load.
2. To initiate studies on the impact of a new pheromone aerosol emitter (Pacific Biocontrol Isomate CM Mist) for codling moth control in walnuts

Reduced load "puffer" efficacy trial. Standard commercial units of the Suterra puffer cabinet (Suterra LLC, Bend, OR) were loaded with canisters containing a reduced load of active ingredient. While the commercial canisters for codling moth contain 69.33 g of active ingredient, Suterra produced canisters loaded with only 50% of the active ingredient. All other application characteristics were kept constant with current practice: volume of aerosol released remained at 40 µl per puff, units puffed at 15 minute intervals for 12 hours (5 pm to 5 am) each day, and the units were deployed at 1 unit per 2 acres.

Efficacy trial using Isomate CM Mist aerosol unit. Aerosol units of a preliminary design from Pacific Biocontrol, "Isomate CM Mist" were used in two trial sites for basic efficacy studies. Similar pheromone emission rates were used relative to frequency and amount compared to the Suterra Puffer units except the number of units per acre was matched to the number in pome fruit orchards at 1 unit per acre.

PROCEDURES

Reduced load "puffer" efficacy trial. The Suterra puffer unit prepared with canisters loaded with only 50% of the standard pheromone load was deployed in three sites. Recent studies have suggested the area of influence for a pheromone plume generated by a 50% reduction in the active ingredient may be highly similar to that of a full rate puffer canister. These studies have been based on recapture of released sterile codling moths to determine the range of trap shutdown and size and shape of the plume. Based on these data, we proceeded with initial efficacy trials of a 50% of standard pheromone load. Three sites were selected that either had a history of codling moth damage or were believed to host high populations of CM and/or were adjacent to long term pheromone program area. Two sites were located in adjacent orchards near Hamilton City, CA (28 treated acres in Chandlers and 12 treated acres in a Vina/Hartley block) and the third outside of Hughson, CA (16 treated acres in approximately 35 acres of Paynes). The Hughson site also included a distant upwind area without pheromone as second grower standard. Suterra puffers loaded with ½-rate active ingredient canisters were deployed at the standard rate of 1 unit / 2 acres. Thus, treated acreage was receiving only 50% of the current standard pheromone application for walnuts.

New aerosol emitter efficacy trial. A new design of aerosol emitter was introduced for preliminary testing in 2011. The Isomate CM Mist sprayer (Pacific Biocontrol) is currently machined, programmed and loaded to emit a pheromone load of 7.22 mg ai / puff or 347 mg ai / day when programmed to puff at 15 minute intervals for 12 hours per day. While these parameters are comparable to the Suterra units, a conservative deployment rate of 1 unit per acre was used instead of the more typical two units per acre for walnuts. Sites were located in Ashley variety nuts at Riverbank, CA (35 treated acres in an 80 acre block) and Chandler variety nuts near Hamilton City (20 treated acres in a 26 acre block).

All experimental aerosol emitter sites near Hamilton City were adjacent an ongoing long-term puffer program. Past experience at this long-term puffer site suggests the program has been challenged by significant codling moth pressure from adjacent walnut blocks that have not participated in the puffer program. The grouping of these experimental trials was an effort to improve the efficacy of the long-term program by including adjacent properties and increasing the areawide program.

For all aerosol emitter trials, codling moth flight activity was monitored using large plastic delta traps (Suterra). Traps were baited with 1X Biolures (Suterra) or Pherocon® CM-DA COMBO™ lures (Trécé, Inc., Adair, OK 74330). Traps baited with 1x lures were hung low, and with combo lures high in the canopy. Traps were read weekly and lures changed on the recommended schedule. Damage assessments were made at harvest by examining 1000 nuts from each treatment block.

MODIFIED HAND-APPLIED DISPENSERS: SUTERRA MEMBRANE EMITTERS AND PACIFIC BIOCONTROL RINGS

Two products have emerged as a result of ongoing research over the past 5 years to develop a hand applied dispenser that could emit a higher rate of pheromone and be applied at fewer units per acre. The primary advantage of the meso emitters is the rapid application of only 20-40 dispensers per acre compared to the standard 160 to 200 dispensers per acre. The Suterra Meso emitter deployed at 20 units per acre and the Pacific Biocontrol Ring at 40 units per acre emit roughly equivalent rates of pheromone on a per acre basis, as traditional hand-applied dispensers. The speed of application of 20-40 units per acre is improved dramatically in pear orchards and permits these products to be a realistic alternative for walnut growers.

OBJECTIVES

1. Continued evaluation of the meso-style emitters in field plots for suppression of codling moth damage.

PROCEDURES

Large plot field trials of "meso-emitters" for codling moth control. In 2011, we completed our trials evaluating the reliability of reduced point source pheromone applications for codling moth management with additional replication across years, sites, and varied codling moth pressures. Products used were the Suterra Meso (Suterra LLC, Bend, OR 97702) and the Isomate Ring (Pacific Biocontrol Corporation, Vancouver, WA). The Suterra Meso dispenser utilizes the membrane technology of their CM-XL1000 dispenser whereas the Isomate Ring consisting of uncut lengths of the Isomate-C TT dispensers such that each "ring" is the equivalent of 5 C TT units.

Efficacy trials were evaluated in replicated plots of six walnut orchards various cultivars in the California Central Valley (Table 2). The Suterra Meso was used in four sites (Waterford, Lodi, Escalon, and Lockeford), and the Isomate Ring was used in two sites (Hamilton City and Butte City). Sites were selected based on reported codling moth pressure and past damage levels such that any benefit of an added pheromone treatment could be demonstrated. Growers were permitted to employ their standard insecticide programs with the assumption that there would still be a measurable moth population. Insecticide treatments were applied across all pheromone and grower standard treatments at the discretion of each grower so that the only contrast was the impact of the pheromone treatments (Table 3).

The Suterra meso was deployed at 18 units per acre and the Isomate Ring at 40 units per acre. The Isomate ring was dispensed as 2 rings at each of 20 points per acre to achieve the 40 units per acre. Deployment rates for each of these "meso" dispensers resulted in pheromone emissions on a per acre basis roughly equivalent to a full standard application of their related products. Dispensers were distributed in a uniform grid pattern through treatment plots of five to twenty acres. Emitters were placed into

the upper third of the tree canopy or as high as possible in very large trees using extension poles and a pruning tower. Isomate®-C TT applied at a rate of 200 dispensers per acre was the pheromone standard in the two Isomate Ring trial sites. Checkmate CM-XL1000 applied at 200 units per acre was used as the pheromone standard the four Suterra Meso trial sites. Pheromone applications were completed between April 15 and 28, 2010.

Codling moth flight activity was monitored using large plastic delta traps (Suterra). Traps were baited with 1X Biolures (Suterra) or Pherocon® CM-DA COMBO™ lures (Trécé, Inc., Adair, OK 74330). Traps baited with 1x lures were hung low, and with combo lures high in the canopy. Traps were read weekly and lures changed on the recommended schedule. Damage assessments were made at harvest by examining 1000 nuts from each treatment block.

RESULTS AND DISCUSSION

Reduced load "puffer" efficacy trial.

The Suterra puffer unit using canisters loaded with only 50% of the standard pheromone load were deployed in three commercial walnut blocks. Codling moth flight curves generated by the weekly trap counts indicated typical flight peaks throughout the season and the puffer and data from the Combo®-baited traps showed the grower standard blocks tracked together and with very similar counts (data not shown).

Traps indicated significant population pressure in the Glenn WH Chandler block which was located directly west of the long-term puffer site with trap totals averaging between 170 and 310 moths per trap (Figure 1). The N.Glenn block of Vina/Hartley planting (located immediately to the north of the Glenn WH block) appeared to be a very low pressure site, averaging a season total of 10 moths per trap. The Hughson site also showed significant codling moth pressure with Combo® traps averaging 240 to 380 moths per trap for the season.

Traps loaded with 1X lures did not capture significant numbers of codling moth in the grower standard of either Glenn site. Grower standard plots at Hughson averaged a season total of 30 to 35 moths per trap, while those in the 50% load CM puffer treatment were completely shut down (Figure 1).

Damage levels at the N.Glenn site were 4.8% and 6.2% in puffer and grower standard treatments, respectively, in major contrast to trap data which had implied this was a low risk orchard site (Figure 2). At Hughson, we found 1.5% nut damage in the reduced load puffer treatment, 1.0% damage in the adjacent north area and 6.2% damage in the grower standard located more than 2000 feet to the west. Unfortunately, a harvest sample was not collected at the Glenn WH site because of a miscommunication. We find these results promising, though additional replication is necessary to document the efficacy of this reduced load application.

New aerosol emitter efficacy trial.

A newly designed aerosol emitter, Isomate CM Mist (Pacific Biocontrol) was deployed into two walnut orchards for preliminary field trials. The Biocontrol emitter was deployed at 1 unit per acre for initial field assessment in 2011. While this is double the placement in walnuts currently used for the Suterra puffers, it was a conservative and safe approach to initiate trials testing the efficacy of the new unit.

Flight curves for the Riverbank trial site are shown in Figures 3 and 4. The codling moth population in both treatments showed typical flight patterns through the season with the Combo® baited traps. The 1X traps in the pheromone treatment were completely shut down through the entire season, though few were captured in the grower standard after May (Figure 4).

Codling moth pressure was significant in both the N.Glenn Chandler and Riverbank sites as indicated by the Combo-trap average total captures of 200-250 moths and 200 to 400 moths respectively. Traps baited with 1X lures averaged a season total of 30 moths in the grower standard and were completely shut down in the pheromone block (Figure 5). At the N. Glenn Chandlers, 1X traps in the grower standard captured only5 codling moth for the season. This was a small 26-acre block with 6 of those acres designated as grower standard. With no separation from the aerosol emitter area, pheromone was likely moving into the control area.

Codling moth damage at harvest was reduced in the Isomate CM Mist treated plots (Figure 6). The Riverbank orchard demonstrated 3.8% and 2.0% damage in the grower standard and pheromone plots, respectively. Damage in the N.Glenn Chandler plots was 0.4% and 0.2% for grower and pheromone treatments, respectively. The similar damage levels between treatments in this site, in combination with the low 1X trap capture in the grower standard suggest we did not have adequate separation of treatment and control.

Efficacy trials using modified dispensers for codling moth control.

***Codling moth flights*.** A representative chart showing seasonal flight curves for the Suterra Meso treatment compared to the flights in the standard pheromone and grower standard is shown for one walnut site (Figure 7 and 8). The 1X baited traps in the pheromone treatments were highly suppressed during entire season (Figure 8). In this site, the Combo baited traps recorded very strong flights throughout the season and in all treatment plots.

Codling moth pressure was in the low to moderate range overall with trap season totals averaging from 18 to 400 moths per treatment in five of the sites (Figure 9). One exception was the Waterford orchard, where average Combo®-trap totals for each treatment ranged from 900 to more than 1500 moths per trap. This site has a history of

high codling moth pressure and has repeatedly shown significant codling moth damage. Despite this population, and with the 1x traps in the grower standard averaging 325 moths, 1x-traps in the Suterra meso and XL1000 plots were 99.5% and 98.2% suppressed (Figure 10). All trial programs of the Suterra meso and Isomate Ring provided excellent 1x-trap suppression compared to the grower standard, ranging from 98.5% to 100% across sites. In the standard pheromone programs for all sites, the codling moth counts in traps baited with the 1X lures were suppressed by 95.5% to 100%. In the Isomate Ring treated sites, 1x trap suppression when compared to the grower standard was 100% in any pheromone treatment, however, traps in the grower standard caught very few moths.

Codling moth damage at harvest. Total damage due to codling moth in all 2011 trials is shown in Figure 11. (The harvest sample for the pheromone standard was missed at one site; though damage for two treatments is shown, the site was excluded from the data analysis.) Damage level of all treatments at four of the sites was low, ranging from 0.2% to1.7%. Damage in the grower standards ranged from 0.4 to 1.4%. Plots treated with the Suterra meso indicated damage ranging from 0.2 to 1.7% and for the XL1000 treatment 0.9 to 1.6%. One site, Escalon, demonstrated a control failure, with the grower standard registering 18.9% codling moth damage at harvest. While the addition of either the Suterra meso or XL1000 pheromone treatment appeared to provide some benefit, damage levels still exceded acceptable levels. Given the overall low damage levels in four sites and extreme damage in one site, and a small sample size, no clear treatment impact was found ((P=0.43). However, when data from walnut trials is pooled across trials conducted in 2010 and 2011, we find that treatments of any meso (Suterra meso or Isomate Ring) significantly suppressed codling moth damage compared to the grower standard (P=0.055) and that the meso treatments did not differ from the standard pheromone treatment (Figure 12).

CONCLUDING STATEMENT

Developing technologies and modifications of existing technologies show promise to improve the efficiency and costs of pheromone-based codling moth management programs. We have documented the efficacy of modified hand-applied dispensers that offer a more rapid and affordable application in pears and a viable application speed in walnuts. Initial trials with aerosol emitters using a 50% reduced pheromone load have been positive and warrant additional investigation. Studies examining the roles and interactions of puff frequency and concentration of aerosol emissions may suggest additional strategies to optimize these management systems in the future. The introduction of these new products and strategies will offer growers a broader selection of tools to implement pheromone-based control programs.

Table 1. Summary of 2011 codling moth pheromone field trials with Suterra Meso or Isomate Ring.

		Treatment Plots (number of acres)			
Crop	Site / Variety	Ring	Meso Membrane	Pheromone Std	Conventional Grower Std
Walnuts	Butte City / Vina	1 (15)		1 (5)	1 (5)
	Hamilton City / Serr	1 (20)	(+3 ac buffer)	1 (5)	1 (5)
	Lockeford / Serr		1 (10.3) (+ 9.8 ac buffer in Chandlers)	1 (3.9)	1 (7.7)
	Lodi / Serr		1 (10.5)	1 (4)	1 (4)
	Escalon / Ashley		1(11.3) (+ 2.8 ac buffer in Ashley and Vina	1 (4.2)	1 (5)
	Waterford / Vina		1 (11.6) (+ 12 ac buffer in Chandlers)	1(5)	1 (3.5)
Total number of plots = 18 (163.6 program acres)		2 (35)	4 (71.3)	6 (27.1)	5 (30.2)

- Number of acres for each plot is indicated in parentheses.

Table 2. Hand applied modified dispenser efficacy trial locations and grower applied insecticide treatments.

Crop	Site	Grower Standard Treatments
Walnuts	Butte City / Vina	Isomate Rings, CTT (4/26/11) Lambda cy (5/13/11) Lorsban (7/25/11) Warrior + Ethrel (9/1/11)
	Hamilton City / Serr	Isomate Rings, CTT (4/16/11) Bifentrhin, Kocide, Manzate (5/12/11) Altacor (6/3/11) Altacor, Asana (7/7/11)
	Lockeford / Serr	Suterra Mesos (4/8/11) Spray data requested
	Lodi / Serr	Suterra Mesos (4/1/11) Spray data requested
	Escalon / Ashley	Suterra Mesos (4/6/11) Spray data requested
	Waterford / Vina	Suterra Mesos (4/11/11) Spray data requested

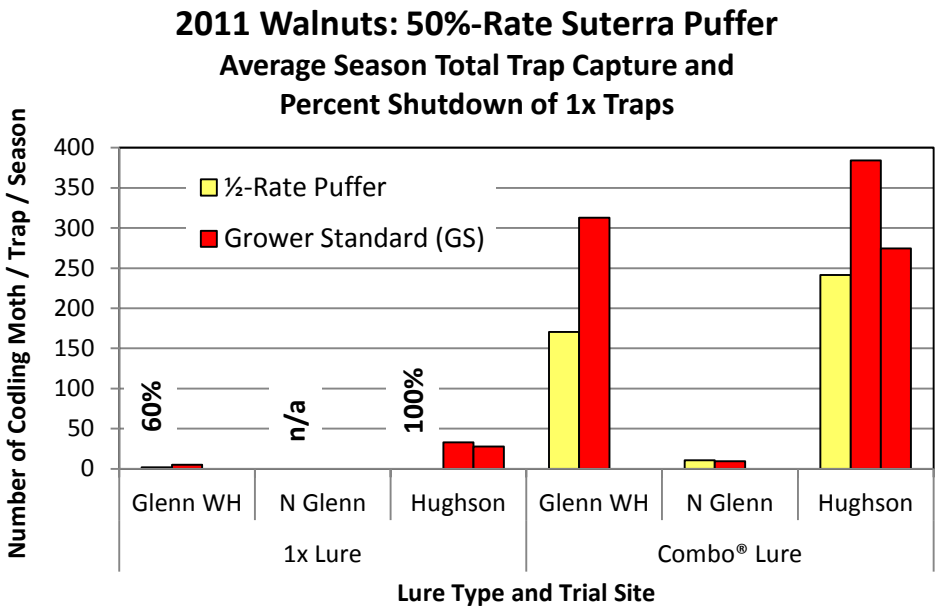

Figure 1. Season total trap capture in 1x and Combo™ lure baited traps. Pheromone treatment consisted of Suterra puffers placed in a standard density (1 unit/2 acres) loaded with 50% of the standard pheromone concentration. The Hughson site had two plots without codling moth puffer treatment.

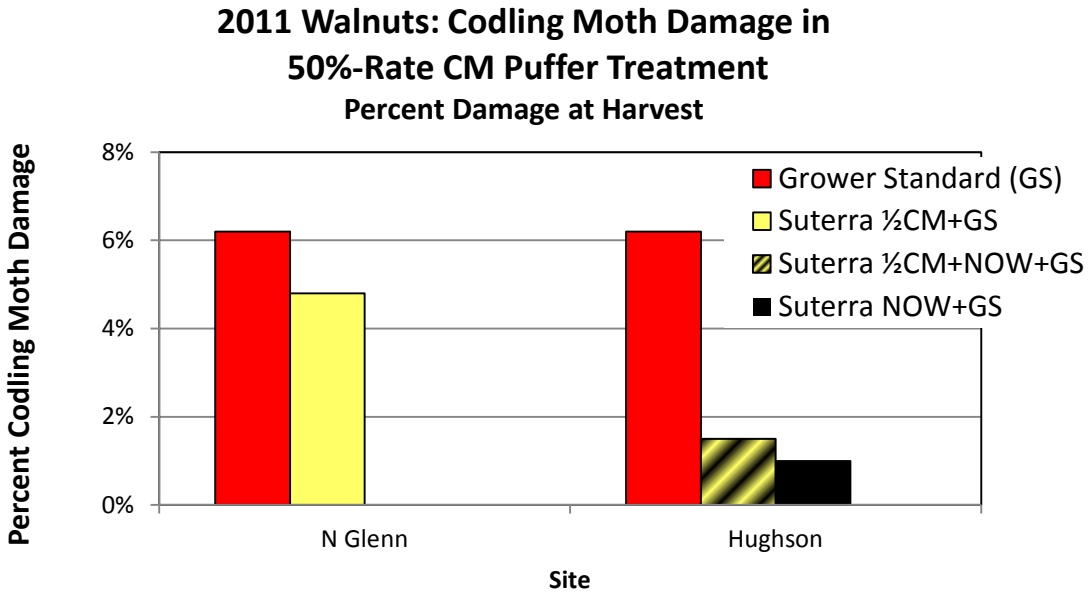

Figure 2. Nut damage at harvest due to codling moth. The Hughson site had two plots without codling moth pheromone applications, one immediately upwind and one distant from the puffer treatment. However, both the ½ rate CM puffer and adjacent block were treated with NOW puffer units. Harvest evaluations were not conducted for the Glenn WH site.

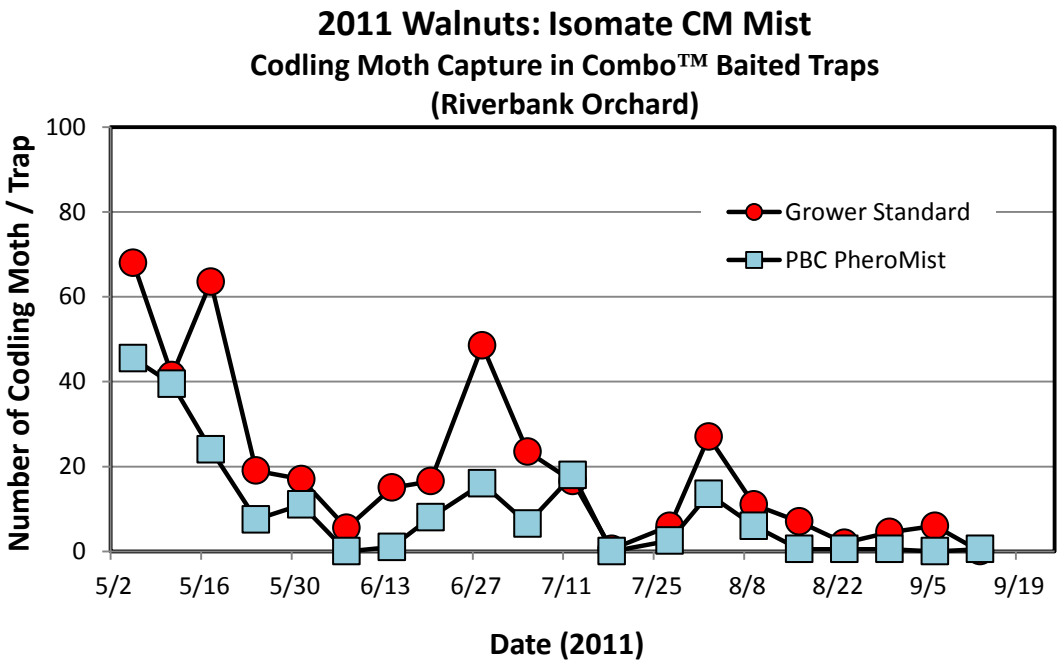

Figure 3. Representative example of codling moth flight curve for Combo™-baited traps. Pheromone treatment of the Isomate CM Mist aerosol unit is compared with the grower standard (no pheromone) in Riverbank, CA walnut orchard.

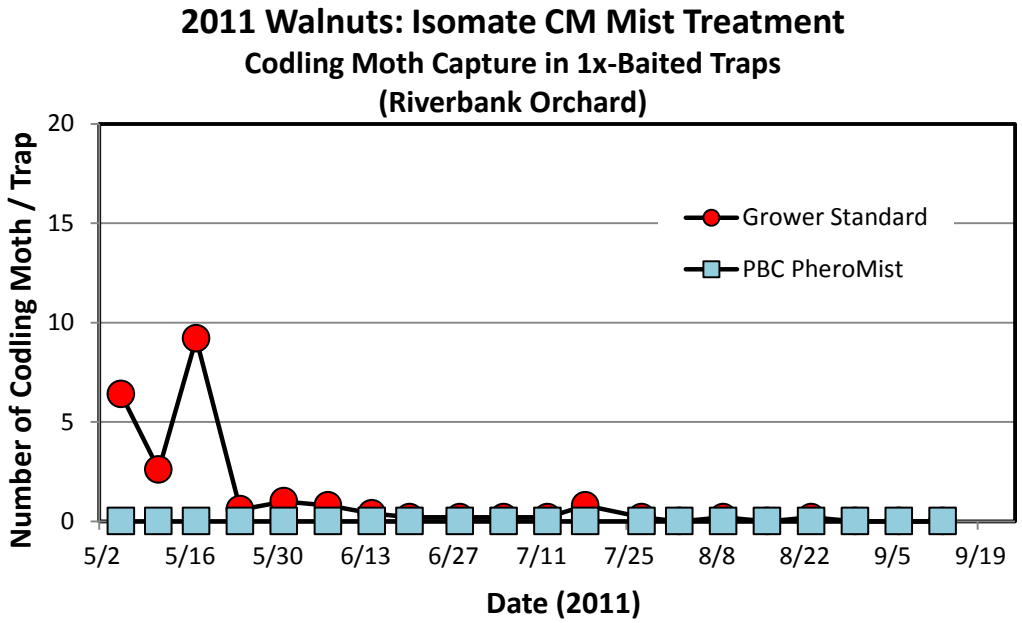

Figure 4. Representative example of codling moth flight curve for 1x-baited traps. Pheromone treatment of the Isomate CM Mist aerosol unit is compared with the grower standard (no pheromone) in Riverbank, CA walnut orchard.

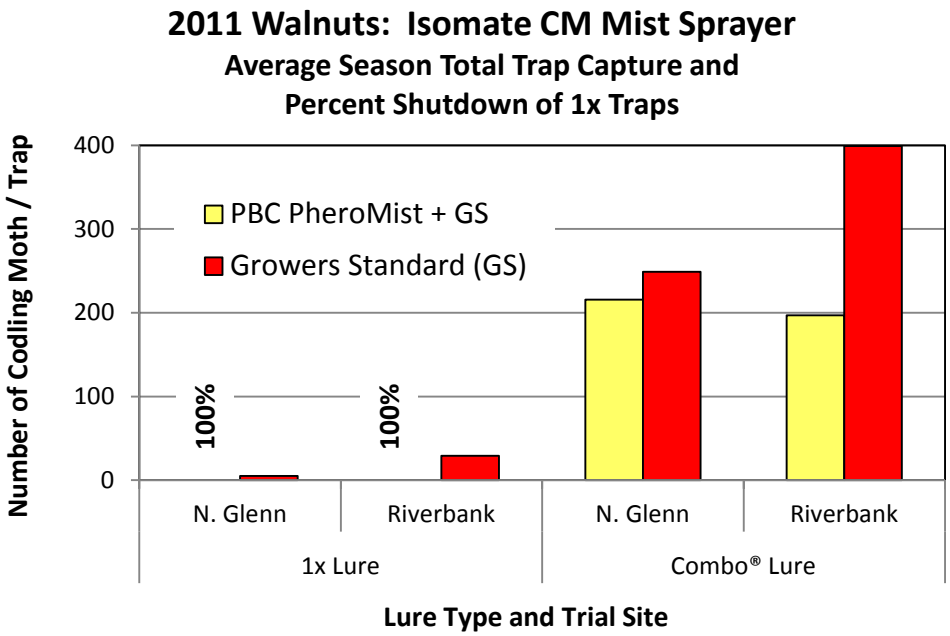

Figure 5. Season total trap capture in 1x and Combo® lure baited traps for trials using the Pacific Biocontrol Isomate CM Mist aerosol sprayer. Percent shutdown of 1x baited traps in pheromone plots compared the grower standard is also indicated.

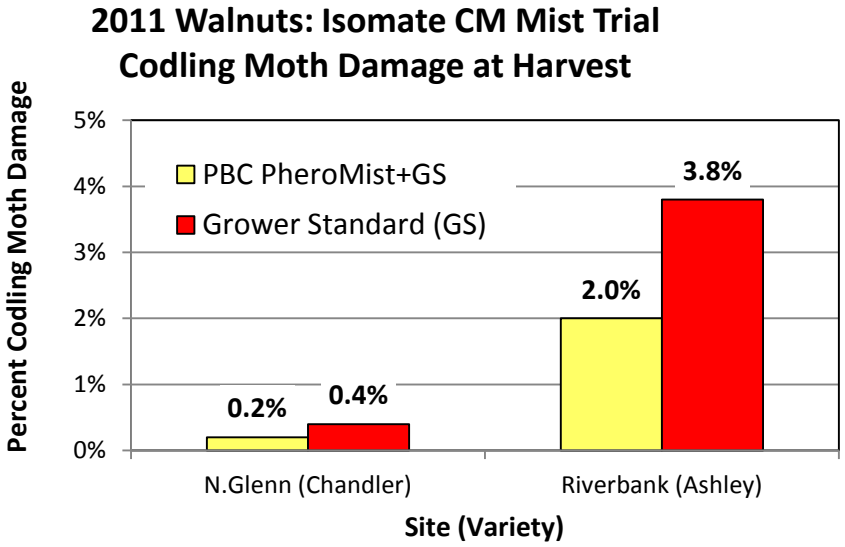

Figure 6. Nut damage at harvest due to codling moth in trials using the Pacific Biocontrol Isomate CM Mist aerosol sprayer.

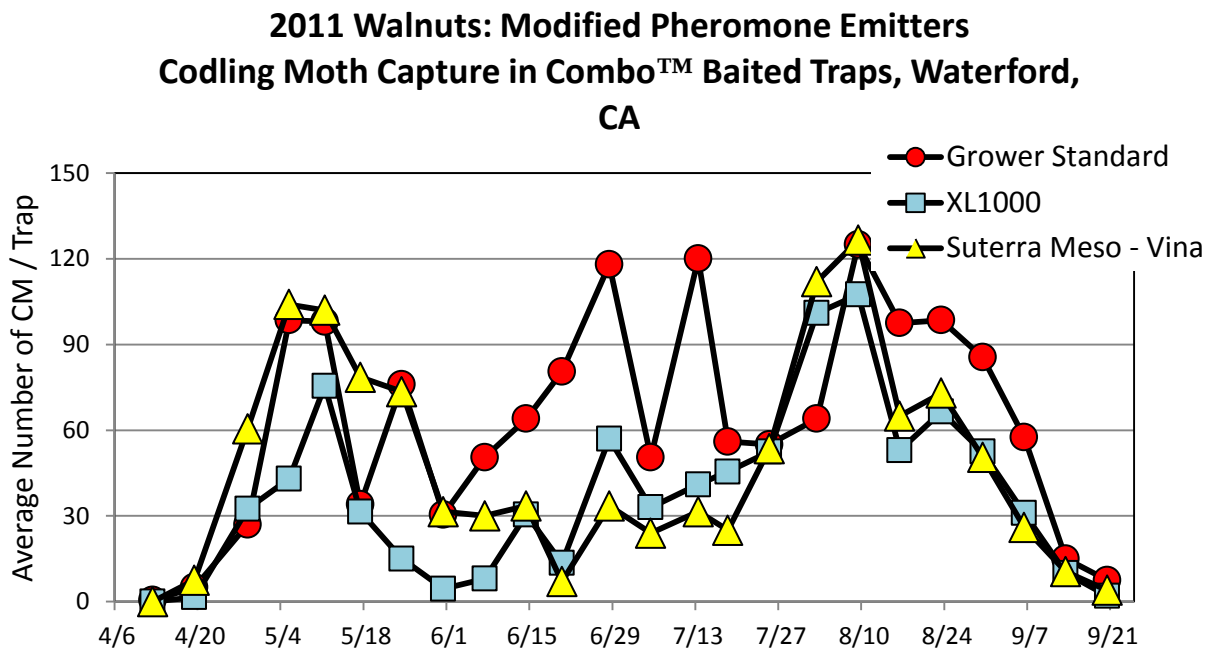

Figure 7. Representative example of codling moth flight curve for Combo™-baited traps. Suterra meso treatment compared with a standard pheromone (CM XL1000) and the grower standard (no pheromone) in Waterford, CA walnut orchard.

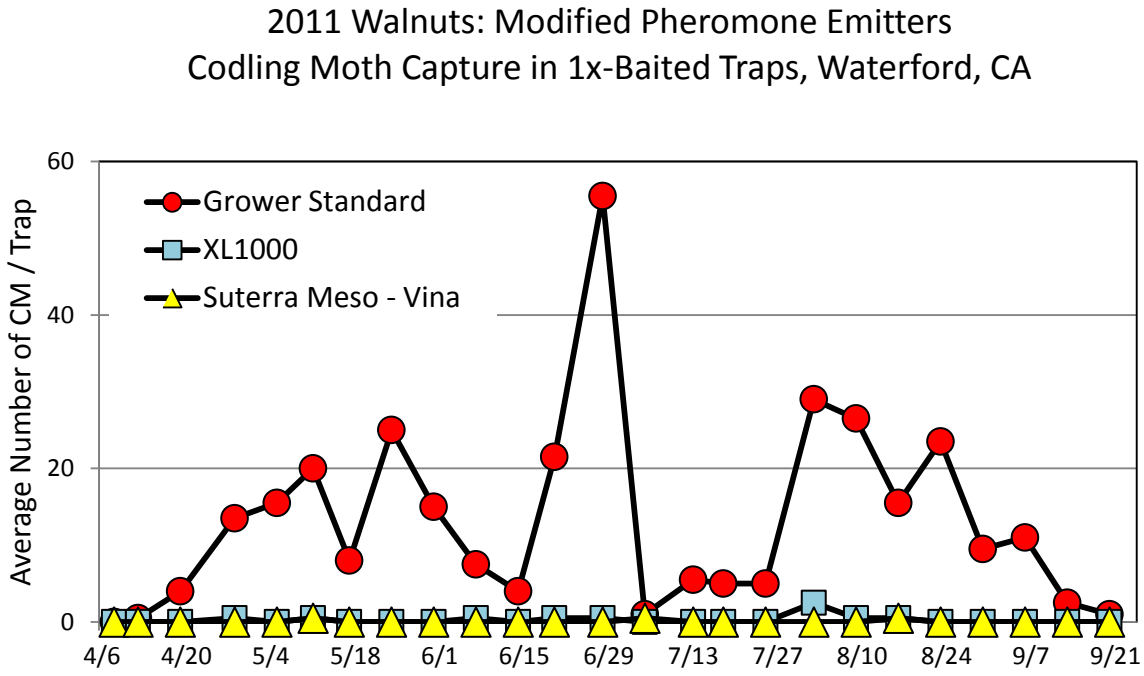

Figure 8. Representative example of codling moth flight curve for 1x-baited traps. Pheromone treatment of the Suterra meso compared with a standard pheromone (CM XL1000) and the grower standard (no pheromone) in Waterford, CA walnut orchard.

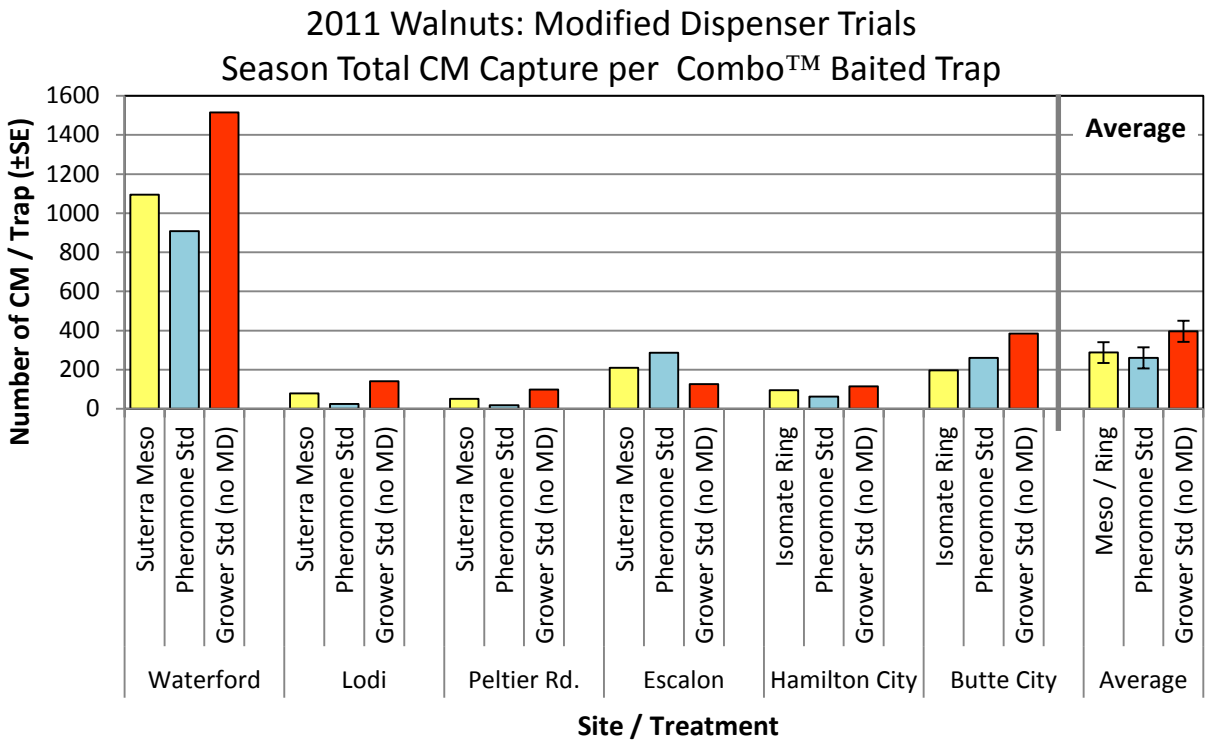

Figure 9. Total number of codling moth captured per Combo™ trap in 2011 season. Modified dispenser efficacy trials were conducted in six orchard sites.

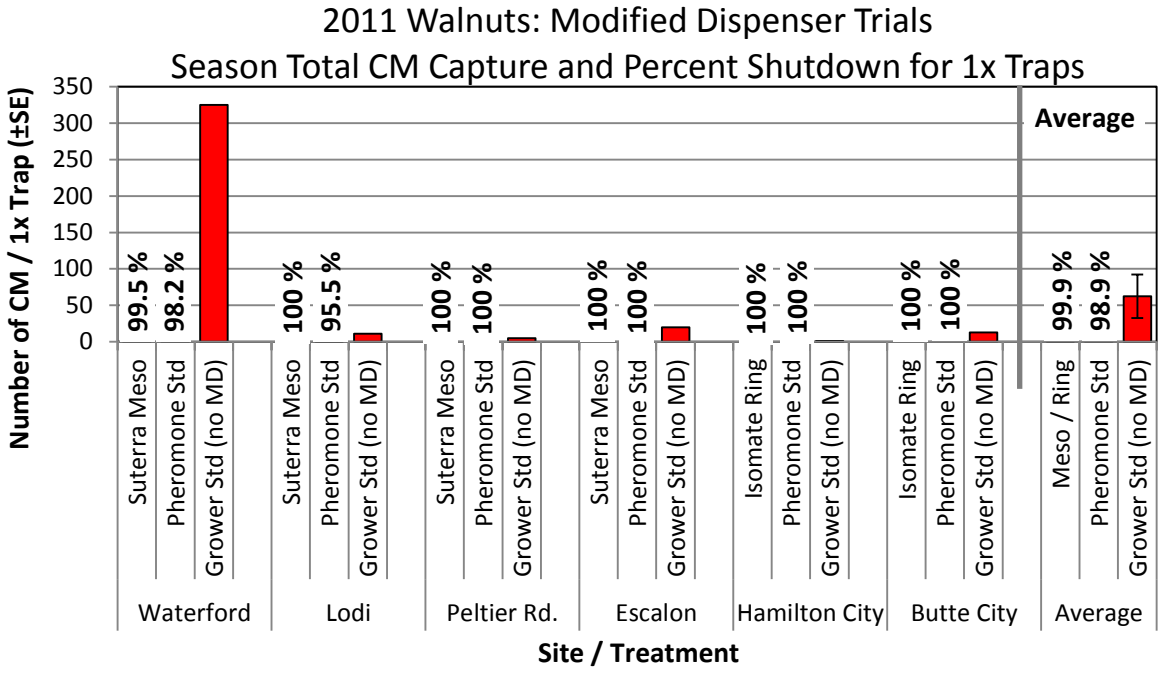

Figure 10. Total number of codling moth captured per 1x-baited trap in 2011 season and percent trap shutdown of traps in pheromone treated plots. Modified dispenser efficacy trials were conducted in six orchard sites.

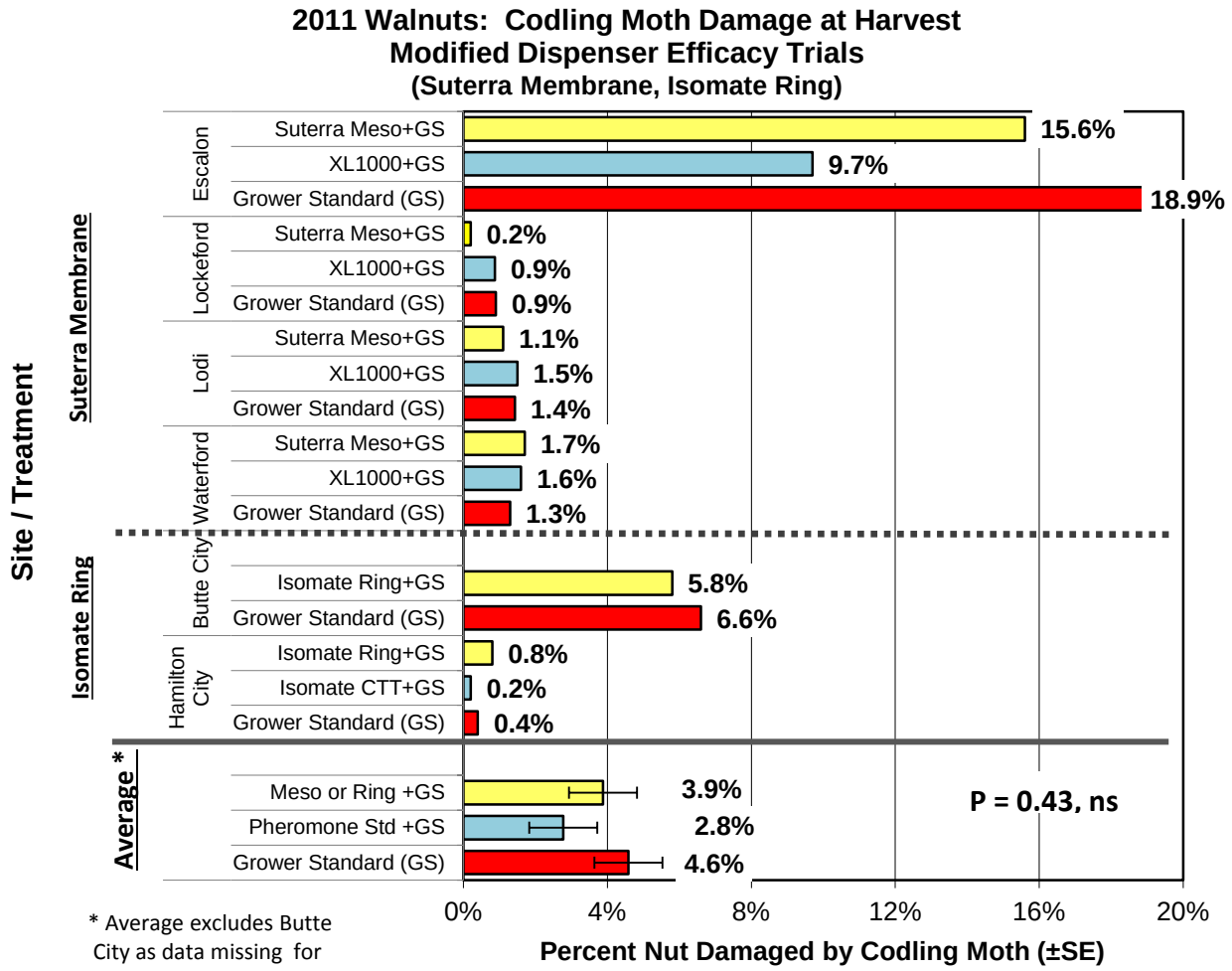

Figure 11. Percent codling moth damage at harvest.

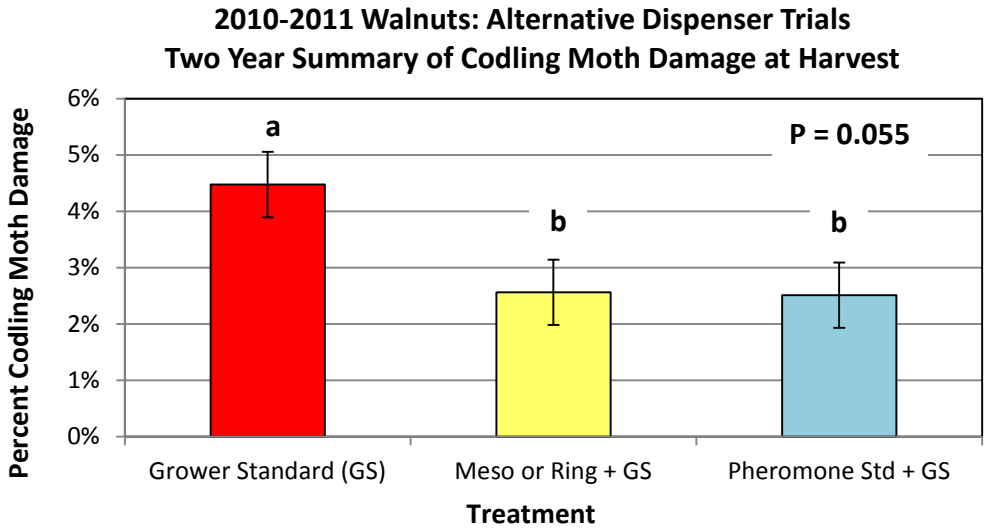

Figure 12. Two year summary of codling moth damage levels in modified dispenser trials conducted in walnuts. Eleven trial sites were included in the analysis.