# IMPACT OF AEROSOL EMITTER DEPLOYMENT DENSITY ON CODLING MOTH SUPPRESSION IN WALNUT

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## ABSTRACT

Isomate® CM MIST aerosol emitters (Pacific Biocontrol Corp, Vancouver, WA) containing 36 grams of codlemone, (*E, E*)-8,10-dodecadien-1-ol, were deployed at various densities in three commercial walnut orchards located in San Joaquin and Butte counties. The resulting dosage-response profiles revealed that aerosol emitters disrupt codling via competition. Males are attracted to the emitters. Furthermore, the very low density of only 1 unit per 4 acres provided greater than 95% trap inhibition. Although very low densities of emitters provided a high level of codling moth mating disruption in walnut, we support the currently recommended deployment density of 1 emitter per 1.7-2.0 acres.

## OBJECTIVE

1. To determine the effect of aerosol emitter density on codling moth mating disruption efficacy in walnut.

## SIGNIFICANT FINDINGS

- Dosage response profiles explicitly matched the predictions for competitive rather than non-competitive disruption. Isomate® MIST aerosol dispensers disrupt codling moth by inducing false plume following rather than by camouflaging traps and females.
- Deploying only three emitters/12ac (1 unit per 4 ac) provided > 95% reduction in male captures in traps in commercial walnut orchards. However, the trials were not set up as a standard efficacy test. Traps were primarily placed in the interior of plots. A potential weakness in using extremely low densities is that the approach may leave areas of little or no pheromone coverage where mate finding may occur near orchard borders.
- These devices are practical and effective tools for disruption of codling moth in walnut at the current deployment rate of 1 unit per 1.7 to 2.0 acres.

## PROCEDURES

A replicated, large-scale, field trial was conducted in commercial walnut orchards to determine the effect of aerosol emitter density on the level of disruption achieved. The basic experimental design was a large-scale dosage response study. The aim was twofold: 1) to determine whether mating disruption using aerosol emitters is achieved via competitive attraction (also known as false-trail following), the same mechanism that operates for other types of codling moth disruption technologies and 2) to determine whether the current deployment rate of 1 unit per 1.7 per acres is sufficient, and if not, determine the optimal deployment density.

Experimental Isomate® CM MIST aerosol dispensers (Pacific Biocontrol Corp, Vancouver, Washington) containing 35 grams of codlemone, (*E, E*)-8,10-dodecadien-1-ol, were deployed at densities ranging from 0 to 3 units/ac (Figure 2) to generate a dosage-response profile. The emitters were programmed to deliver 1 dose of codlemone (*ca.* 3.5 mg) every 15 min for 7h from 17:00 h – 23:590 h. These emission parameters resulted in 70% less codlemone released over the course of the experiment than commercially available Isomate® CM MIST units (contain 70 grams of codlemone active ingredient and deliver a dose every 15 minutes for 12 hours per night). Previous walnut research trials demonstrated that such "reduced rate" aerosol emitters provided suppression equivalent to commercial "full rate" units.

Tests were conducted in three commercial San Joaquin and Butte county walnut orchards (Table 1). Test orchards were 500 to 1000 acres in size and each was divided into five plots of roughly equal size (12ac) with at least 1600' buffers. All test orchards had a history of low to moderate codling moth population pressure. One plot at each site was designated as a no-pheromone "control" and one of four dispenser densities was assigned to each of the other Isomate® CM MIST plots. Plots were arranged spatially so that no-pheromone plots were on the upwind edge or corner of each test orchard to minimize pheromone "drift" from other plots. MIST dispensers were deployed in a uniform pattern throughout the plot to achieve the desired number of dispensers per plot (Figure 1). Dispensers were hung in the upper 10% of tree canopies and secured in place with a rope/pulley system. All pheromone treatments were installed by early April 2014.

*Table 1. Isomate® CM MIST test sites descriptive information*

| Site | Cultivar | Orchard size | Orchard spacing |
|---|---|---|---|
| D | Chandler | 1000 acres | 25' X 25' |
| R | Chandler & Howard | 500 acres | 28' X 26' |
| S | Tulare | 700 acres | 24' X 23' |

To assess codling moth activity and mating suppression efficacy, six plastic delta (orange Pherocon® VI) traps baited with Trécé CM Long-Life™ L2™ pheromone lures were installed at mid-canopy heights in the center 6ac of each plot. Traps were monitored weekly. Suppression of L2-baited traps is considered a reliable indicator of the effectiveness of mating disruption. Two additional traps baited with Trécé CM-DA Combo™ lures were deployed in each 12ac plot to assess the background resident CM populations in each block (Figures 2a-f).

Orchard operators and their pest control advisors were informed of the results of weekly trap monitoring and allowed to make supplemental insecticide treatments for codling moth and other pests as they deemed necessary. When treatments were applied, the same treatments were applied to all the plots at the site. The number, type, and timing of supplemental insecticide applications – targeting codling moth or other pests with possible suppressive effects on codling moth - varied among sites (Table 2).

*Table 2. 2014 insecticide applications in test orchards (targeting codling moth or walnut husk fly; Miticides are included when tank-mixed).*

| Site | Date | Treatments applied |
|---|---|---|
| D | 4/7/14 | MIST units deployed |
| | 5/19/14 | Hatchet @ 2 qt/ac + Phosgard @ 1 pt/ac + Freeway @ 4 fl oz/100 gal |
| | 6/5-6/14 | Reaper 0.15 @ 12 fl oz/ac + Liberate @ 1 pt/ac to borders by gravel/dirt |
| | 7/7/14 | Delegate WG @ 7 fl oz/100 gal + Nu-Lure @ 1 gal/100 gal |
| R | 4/4/14 | MIST units deployed |
| | 7/2/14 | Warrior @ 2.5 oz/ac + Intrepid 2F @ 16 oz/ac + Reaper @ 20 oz/ac |
| S | 4/5/14 | MIST units deployed |
| | 7/3/14 | To various plots: AgMectin EC @ 20 oz/ac + Asana XL @ 12.8 oz/ac; OR Bifen 2 AG @ 12.8 oz/ac + Altacor @ 4 oz/ac + AgMectin EC @ 20 oz/ac |

Sterilized codling moths obtained from the Okanagan-Kootenay Sterile Insect Release (SIR) Program in Osoyoos, British Columbia, Canada were released into the plots to ensure even codling moth densities across treatments. SIR moths were transported to field sites in chilled containers and were released at locations no closer than 10m from traps by placing 800 individuals into brown paper bags secured to tree trunks. Each release consisted of approximately 400 male and 400 female moths at 10 locations in the interior of each plot (Figures 2a-f), for a total of 4000 males and 4000 females per plot. The numbers of sterile male moths captured in the six L2-baited traps in each plot were recorded seven days after each release.

Three releases of moths were conducted at each of 3 farms at the following dispenser densities:

1. 0 units/ac (No MD Control)
2. 0.25 units/acre or (3units/12ac)
3. 0.5 units/acre or (6 units/12ac)
4. 1 unit/acre or (12 units/12ac)
5. 3 units/acre or (36units/12ac)

Due to very low catch of SIR moths in some of the pheromone treatments, the number of MIST units was reduced from 36 per 12ac to 1 unit/12ac at the R and D sites in July. Reducing the number of dispensers was necessary in order to generate the beginning of the dosage response curve. The third (S) site was dropped altogether for the remainder of the season as the grower sprayed insecticides in some but not all of the plots, thus confounding our assessment of pheromone treatment effects.

Four releases of moths were conducted at each of 2 farms at the following dispenser densities:

1. 0 units/ac (No MD Control)
2. 0.08 unit/acre or (1 unit/12ac)
3. 0.25 units/acre or (3units/12ac)
4. 0.5 units/acre or (6 units/12ac)
5. 1 unit/acre or (12 units/12ac)

Dosage response profiles were generated using the mean number of moths captured / L2-baited trap. We calculated the mean number of male moths captured in plots for ca. 10 releases. Percent disruption was calculated as (1 - (mean catch in treatment ⁄ mean catch in control)) x 100. Graphical plots of catch *vs.* point source density, 1 ⁄ catch *vs.* point source density (Miller-Gut plot), and catch *vs*. point source density x catch (Miller- de Lame plot) were generated to determine the type of disruption mechanism underlying the pattern of moth captures. A competitive disruption profile is concave and approaches zero asymptotically on an untransformed plot, gives a straight line with positive slope on a Miller-Gut plot, and a straight line with negative slope on a Miller-de Lame plot. By contrast, a non-competitive profile generates a straight line with negative slope on an untransformed plot, an up-curving line on a Miller-Gut plot, and a re-curving line on a Miller-de Lame plot.

## RESULTS AND DISCUSSION

Wild codling moth populations varied but were extremely low overall as indicated by seasonal catch in L2-baited traps in no-pheromone plots (Figure 3). The mean sum catch/trap ranged from very low (1.6 male moths/trap) at the farms in San Joaquin County to low (47 male moths/trap) at the farm in Butte County. Moth capture was highest during 1st generation and decreased with each successive generation through September. Surprisingly, CM catch in combo lure-baited traps was the same or less than the L2-baited traps indicating that wild populations at these sites were extremely low.

Dosage response profiles for Isomate® CM MIST explicitly matched the predictions for competitive rather than non-competitive disruption (Figures 4a-c). Moth captures decreased asymptotically as Isomate® CM MIST densities increased (Figure 4a). Data fit to Miller-Gut and Miller-de Lame plots yield straight lines, with positive and negative slopes respectively (Figures 4b & c). This set of profiles conclusively demonstrates that Isomate® CM MIST dispensers compete with traps for male responses and do not camouflage female pheromone plumes as previously assumed. Additional studies in apple reveal that disruption likely results from males bypassing females as they move upwind toward the high-releasing aerosol emitters.

Fairly low numbers of released moths were captured; mean recapture was 1% in the control treatment. Significantly fewer moths were recovered in traps in the MIST treatments at all dispenser densities compared to the control treatment ($F=10.9$; $df=5, 12$; $p<0.0005$), (Figure 5). Catch of male moths decreased from 24 / trap in the control to 0.4 / trap at the highest emitter density. Surprisingly, disruption of > 95% was realized at emitter densities of only 3 units/12ac (Figure 5).

Very low densities of emitters appear to provide a high level of codling moth mating disruption in walnut. Only 1 unit per 4 acres provided > 95% inhibition of moth catch in pheromone-baited traps. Despite the high level of disruption achieved using a very low density of emitters, we support the currently recommended deployment density of 1 emitter per 1.7-2.0 acres. Our dosage response trials were not set up as a standard efficacy test. Traps were primarily placed in the interior of plots. A potential weakness in using extremely low densities is that the approach may leave areas of little or no pheromone coverage near orchard borders where mate finding may occur. In addition, failure of a single unit would leave a large unprotected area.

Mating disruption using aerosol emitters is a practical and effective tactic for managing codling moth in walnut. We conclude that reported failures of the approach are probably not a result of deploying too few units per acre. Rather, inadequate levels of disruption are more likely associated with high population densities, use of ineffective supplemental insecticides, or treatment of small blocks. The approach is likely to benefit substantially from treatment of large contiguous blocks of walnuts. Treating small and irregular blocks will be problematic. Deploying some of the pheromone emitters along upwind orchard borders may help ensure the entire block is protected. It is important to monitor orchard borders in order to detect areas lacking pheromone where mating could occur.

## ACKNOWLEDGEMENTS

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*Figure 1. Generalized plot layout Isomate CM MIST dispenser density treatments, 2014.*

*Figures 2a-f. Generalized plot layout indicating relationship of Isomate® CM MIST units, monitoring traps, and locations of moth release. 2014.*

*Figure 2a. Zero MIST units/12ac, No MD.*

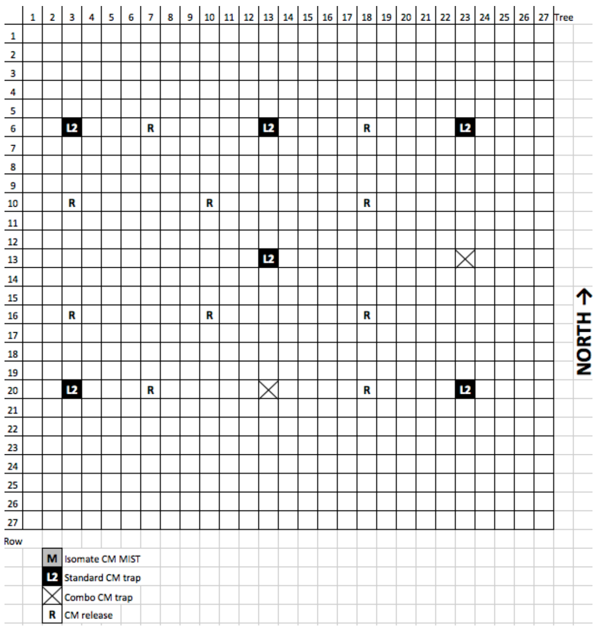



*Figure 2b. One Mist unit/12ac.*

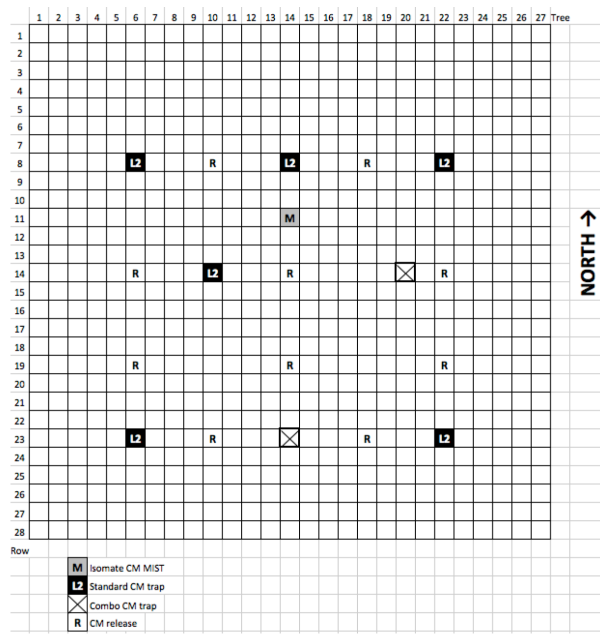



*Figure 2c. Three MIST units/12ac.*

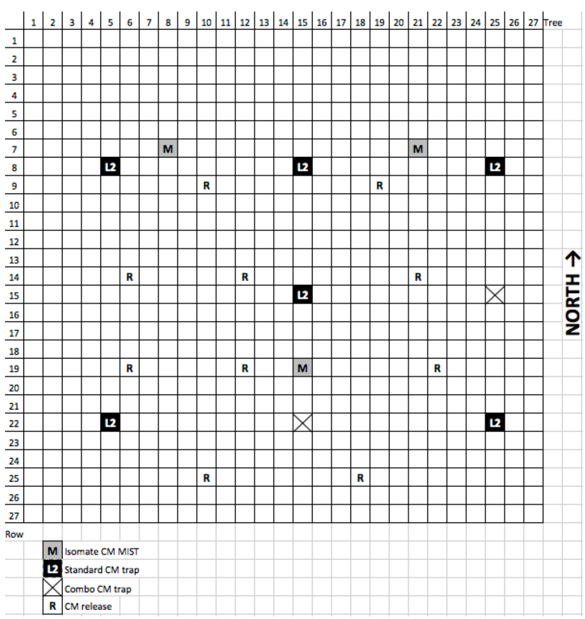



*Figure 2d. Six MIST units12/ac.*

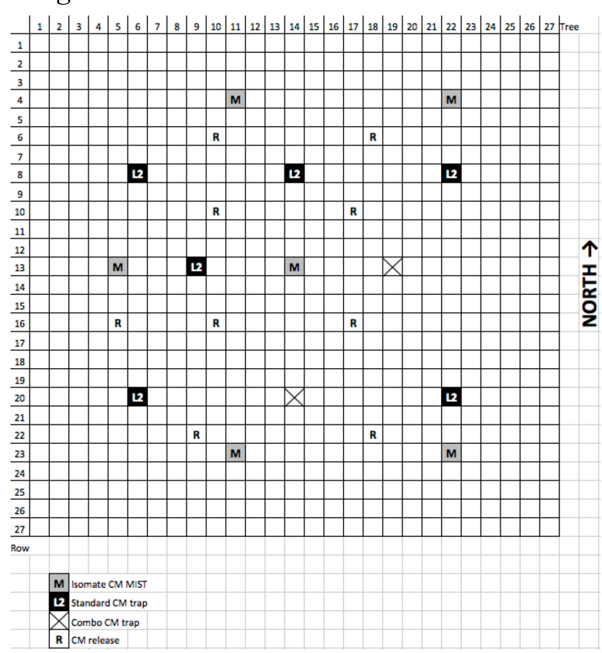


*Figure 2e. Twelve MIST units/12ac.*

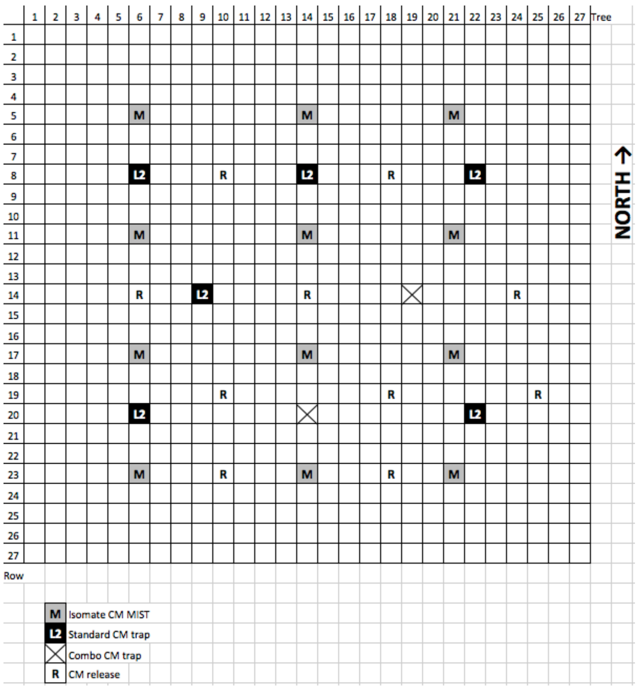



*Figure 2f. Thirty six MIST units/12ac.*

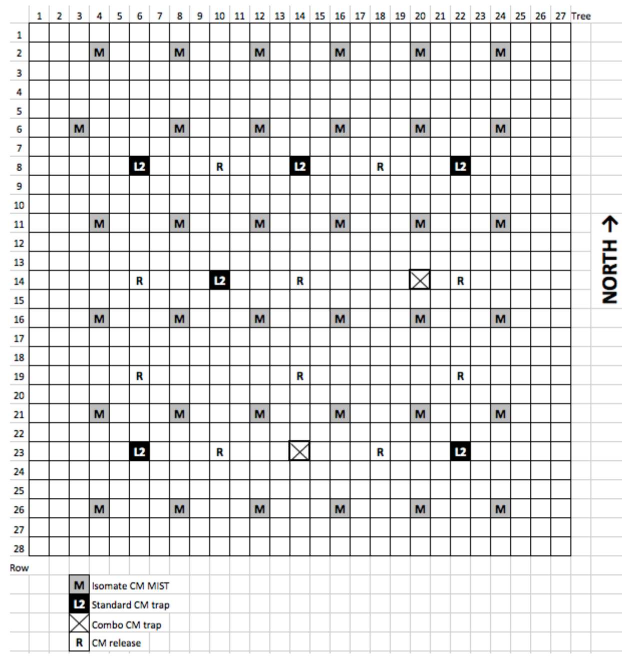
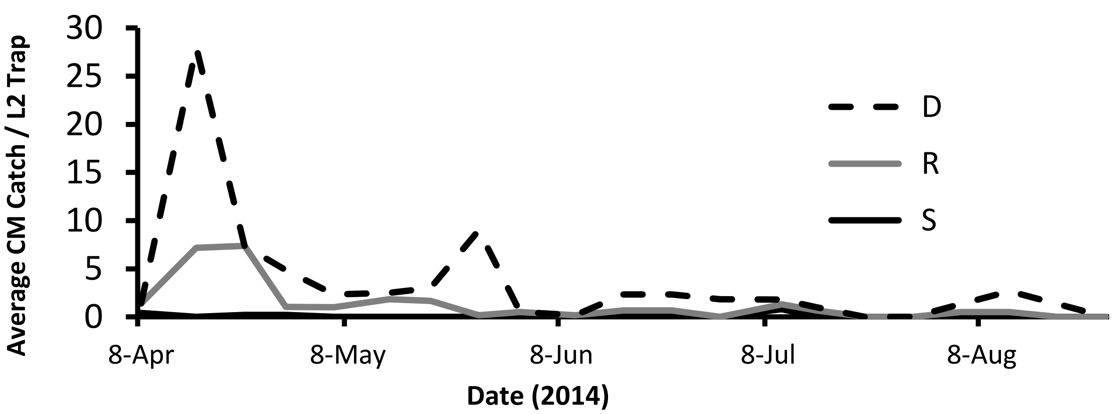



*Figure 3. Mean seasonal moth captures in No MD treated blocks (L2 pheromone baited traps) at three California walnut farms, 2014.*



*Figures 4a-c.  Farm D - Plots of (A) male moth catch vs. point source density, (B) 1 / catch vs. point source density, and (C) catch vs. point source density*catch in Isomate® CM MIST mating disruption*

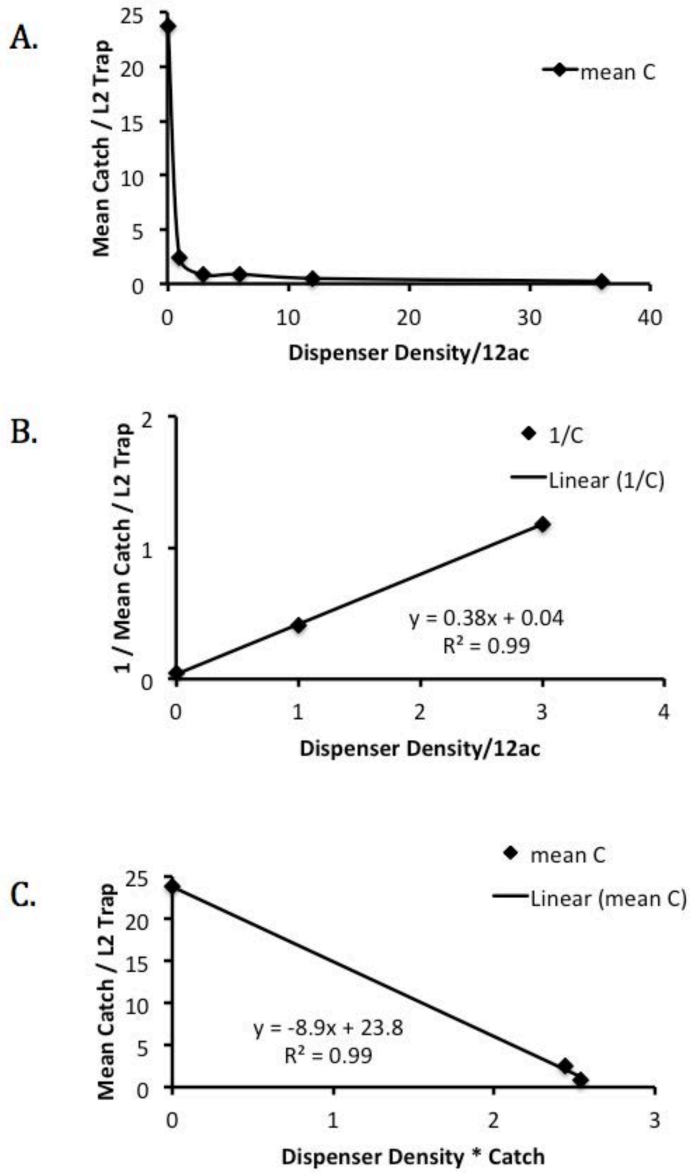


*Figure 5. Male moth catch (mean ± SEM) and % disruption, measured with L2-baited Pherocon® VI monitoring traps, in plots treated with varying densities of Isomate® CM MIST, 2014.*
*One way ANOVA, means* separation Tukey's HSD (F=10.9; df=5,12; p<0.0005)*