

<i>DESCRIPTION:</i>	Development of Alternative Pheromone Dispensing Technologies for Management of Codling Moth
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Development of alternative pheromone dispensing technologies for management of codling moth

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ABSTRACT

Development of alternative pheromone delivery technologies for management of codling moth continues to look very promising. Both the sprayable formulations and the aerosol emitters (“puffers”) may present a means to potentially reduce program costs, but especially in the area of labor costs. Sprayable pheromone formulations from 2 different manufacturers appeared to provide excellent control of codling moth except for in an abandoned orchard that had excessively high codling moth pressure. However, even in this orchard, low levels of pheromone applied at 20 gm ai / acre provided strong trap suppression despite the potential for high numbers of male codling moths flying between plots. Commercially acceptable control was observed in both pears and walnut orchards despite some test programs using reduced application rates. The applications of sprayable pheromone appeared to last between 30-45 days under field conditions. These data support our moving to larger scale field trials in 2002. The “puffer” style emitters also appear promising, but results were somewhat more ambiguous. These trials were not set up to provide commercial damage suppression but rather to try and determine the effective area of suppression for both traps and damage. Lines of puffers placed mid-way in orchards were able to effectively suppress codling moth traps, damage for orchards with low levels of damage and no immediate source of mated females entering the test plots, and as well as some suppression of high density orchards for the early part of the season. The area of influence of the puffers still appears to be relatively large with an effective active area greater than 500 feet. Trials conducted next year will need to focus on eliminating confounding sources of codling moth females for at least 1000 feet from the test plots and well as to increase the overall test plot size. The more positive aspects of these data continue to support the idea that the number of puffers per acre may be reduced from 1-2 per acre to 1 puffer for every 4-5 acres depending on orchard configuration. If successful, such a reduction would have a dramatic effect on reducing overall control costs. However, this type of approach has yet to be adequately tested under multiple field conditions.

INTRODUCTION

Management of codling moth has undergone tremendous changes in both pome and nut crops with changes in pesticide registrations (e.g. loss of Penncap M in pears) and the introduction of pheromone mating disruption as an alternative control strategy. While the penetration of mating disruption has been amazingly rapid in pears (e.g. greater than 50% adoption in some regions), mating disruption of codling moth has proven more elusive in other cropping systems (e.g. walnuts). However, the two cropping systems also share many elements in common: their key insect pest being codling moth, strong

differences in canopy architecture exist between plantings, an increasing need to decrease the costs of production, and a shared political climate that is relatively hostile to conventional insecticide use.

Therefore, the following report pools data across pears and walnuts given that most of the same issues are important in development of improved mating disruption programs for codling moth. However, it is also true that each type of mating disruption tactic needs to be tested within the specific context of a particular cropping system. Difficulties with field pheromone research include our inability to accurately predict codling moth pressures within an orchard before the start of a season, the large plot sizes required for pheromone mating disruption trials the potential lack of independence between plots, and the high risk that individual growers must sustain as plot increases. Rather than only report the results from a single crop to a particular commodity, we are presenting all data across systems to increase the total datapool and the total number of experiences with a specific approach. Differences between cropping systems will be noted if apparent. The hope is that by pooling the data across systems, we will be able to present a more comprehensive, and hence, more reliable sense of how an approach is working.

Three different delivery technologies were tested in 2001 in pears and walnuts: sprayable pheromones (formulations by both Suttera and 3M) and aerosol emitters (“puffers”). Similarly, a range of orchard types were targeted for study that spanned orchards with very low codling moth pressure to orchards that had been functionally unmanaged for several years. This broad range was used since it was important to test these approaches under both ideal conditions as well as within situations under high pressure that would be predicted to fail. The only way that the boundaries of a successful program can be identified is to challenge them with extreme conditions and to allow them to fail.

Both delivery technologies demonstrated in 2001 excellent abilities to suppress pheromone traps baited with the codling moth lure, codlemone. However, researchers have also long recognized that trap suppression may not be synonymous with damage suppression. Therefore, our efforts in 2001 focused heavily on integrating trap suppression data with damage suppression data.

MATERIALS AND METHODS

A quick summary of our trials by type and location is shown in the table below.

PEARS	Orchard Location
Sprayables	
3M	Pavalina - Fairfield
Suttera	Wiseman - Sacramento
Puffers	
	Fairfield Site 2 – Glasshof (eliminated from analyses due to

insecticide overspray)
Sacramento Yuki, Limited
Management
Walnut Grove- Biagi - Limited
Management

WALNUTS

Sprayables

3M Stockton -Dondero
3M Lockeford - Locke

Puffers

Lockeford - Locke
Woodland - Organic
Linden - Organic

Sprayable Pheromone Trials

Walnuts – 3M Sprayable

A sprayable codling moth pheromone product in development by 3M was compared to grower treatment and untreated controls in two walnut orchards, the Locke in Locke and Dondero orchard in Stockton. The following methods were consistent between the two sites. 3M Sprayable CM Pheromone, Phase IVs was applied at 20 g ai / acre with a 500 gallon speed sprayer at 100 gal per acre. Applications were made on 4/18, 5/18, 6/15, and 7/13/01. Traps (Pherocon® Delta VI) were hung following the initial spray application to monitor for codling moth. Traps baited with CM standard 1mg lures (Trece 3111) and DA lures, a lure baited with a pear volatile produced by (Trece Inc.) were hung at about 6 feet. In addition, traps baited with CM 10X lures (Trece 3160) were hung about mid canopy. The results from the pheromone traps baited with 1 mg lures were used for estimating program efficacy. Traps baited with the CM 10X lures were used to monitor moth flights. Traps were monitored weekly and lures changed on a two-week schedule.

Codling moth damage in nut samples was evaluated four times during the season. A dropped nut sample taken on 6/13 consisted of all nuts collected from under 25 trees each in the treated and grower plots and 7 (Locke) or 12 (Dondero) trees in the untreated controls. Canopy samples for estimating codling moth damage were made with a pruning tower and consisted of an inspection of 40 nuts per tree on 25 trees in the 3M treated block and 12 trees (Dondero) or 6-7 trees (Locke) in the control blocks. In addition, the canopy sample of 7/20 at the Locke orchard inspected nuts on 25 trees in the grower plot. We collected 500 nuts from all treatments including controls in mid September for a harvest sample. Nuts were returned to the lab, cracked out and codling moth damage recorded.

The Dondero orchard located about 10 miles east of Stockton, CA has about 146 acres of walnuts planted to Vina, Hartley, Serr, and Chandler varieties in solid blocks. The Serr block used in this study is about 17.4 acres total, running 27 rows (594 feet) by 1264 feet. Trees are approximately 30-35 ft high, with a spacing of 44 feet within rows and 22 feet between rows in a diamond planting. The block was divided into an untreated control plot (no insect treatment), a conventionally treated grower plot and a pheromone treatment. The untreated control was a 1.3-acre square plot placed in the upwind corner of the block. The grower and pheromone blocks were long rectangular blocks accommodating the row structure of the plot. Thus, the pheromone block measured 8.4 acres (15 rows less the untreated control) and the grower treatment measured 7.7 acres (12 rows). The grower treatment consisted of a single application of PennCap-M applied mid July. The pheromone spray plot had 3 traps baited with CM standard lures, 2 traps with DA lures and a single trap baited with a 10X lure. The grower treatment plot had four traps total: two baited with CM standard lures and one each with a DA or 10X lures. The control block had one trap each of the CM standard and DA lures only.

The Locke Ranch is located in Lockeford, CA. The downwind portion of an “L” shaped 50 acre Vina block was used in this site. Trees were approximately 30 feet tall, planted with a spacing of 40 feet within rows by 20 feet between rows in a diamond planting. The 3M-treatment area was 6.7 acres in an approximately square block. The 0.9-acre control block was set in the upwind corner of the 3M-treated block, and the grower plot was a 5-acre upwind portion of the Vina block. The grower treatment consisted of an application of Confirm 2F (tebufenozide) on 5/28 and on 7/14 at the rate of 24 oz/acre (0.375 lb ai/ac). The pheromone plot was treated with Confirm at the grower’s discretion on the 7/14 treatment following a nut damage evaluation. The control block was treated with Confirm at the same rate on 7/25. In addition, the grower applied Nufos 4E on 8/7 and 8/22 at 4 pts/acre for husk fly control. Codling moth flight activity was monitored with 6 traps total: 3 traps baited with CM standard lures, 2 traps with DA lures and a single trap baited with a 10X lure. The grower treatment plot had three traps total: two baited with CM standard lures and one with a DA lure. The control block had one trap only of the CM standard lure.

Pears Rate Trial for Stabilized 3M Product - Pavalina

Three rates of a stabilized sprayable pheromone product (3M Sprayable CM Pheromone, Phase IVe) developed by 3M were compared to Isomate and untreated controls. The Phase IVe did not have a tolerance that would allow the crop to be commercially marketed. As such, an orchard located in the Suisun Valley (“Pavalina”) was used that was not planned for harvest. The Pavalina pear orchard in Suisun Valley had been untreated for two years prior to this study. A single application of Guthion (azinphosmethyl) at 1 lb/acre was made in late April to reduce the impact of a codling moth population that had not been controlled for two years. The orchard was treated uniformly in the hopes of bringing the codling moth populations down to a more moderate level. Previous experience with pheromone mating disruption of codling moth

has already shown that high-pressure orchards are not suppressed to commercially acceptable levels. The orchard is 66 acres of Bartlett pears on a 22' square planting. The site was divided into 14 - 4 acre treatment plots. Three replicates of each spray treatment and untreated control, and two replicates of Isomate were assigned. 3M Sprayable CM Pheromone, Phase IVe was applied at the rates of 1 g, 20 g, or 40 g ai/acre each of two spray applications made on 5/8 and 6/14/01. The lowest rate of 1 gm was selected so as to try and establish some lower boundary beyond which adequate trap suppression could not be expected. Isomate was applied to two blocks on 5/14 at the rate of 400 dispensers per acre the pheromone standard.

Codling moth activity was monitored by 4 traps (Pherocon® Delta VI) in each block, two baited with CM standard lures (Trece 3111) and two baited with CM 10X lures (Trece 3160). Traps baited with standard lures were placed about 6 feet high, those with 10X lures were hung in the upper canopy. Traps were monitored weekly and lures changed biweekly. Codling moth damage was assessed three times beginning 5/31/01 and following at about 4 week intervals on 6/26 and 7/26. To sample each plot, a total of 1000 fruit (20 fruit per tree from the central 50 trees of the plot) were inspected for evidence of codling moth. If evidence was observed, the fruit was cut to identify the stage of larva if still present. In addition, 20% of the fruit sample with no apparent damage was cut to look for cryptic infestations.

Pears – Suterra Sprayable- Wiseman

A sprayable codling moth pheromone product under development by Consep was tested in a Sacramento delta pear orchard. The 31-acre Wiseman orchard is planted to Bartlett (17 ac) and Bosc (14 ac) variety pears. The orchard is “pie” shaped, narrowing to a point at the side planted to Bosc. The broad end of the plot, planted to Bartlett, was divided to two treatment blocks, high and low rates, plus two untreated controls. Because of the narrow formation of the Bosc plot we assigned a single treatment rate and control block. Two controls in the Bartlett pears were located on the upwind edge of the orchard, whereas the Bosc control was located on the downwind corner. Two rates of Consep (Checkmate CM-F) were applied four times during the season: the high rate was 30 g ai/acre for all applications and low rate treatment consisted of an initial 20 g ai/ac application with the remaining three applications at 10 g ai/ac. Applications were made 4/9, 5/7, 6/9, and 7/9. Codling moth flight activity was monitored by traps (Pherocon® Delta VI) baited with CM standard lures (Trece 3111) or CM 10X lures (Trece 3160). Traps baited with standard lures were placed about 6 feet high, those with 10X lures were hung in the upper canopy. Traps were monitored weekly and lures changed on a two-week schedule. Codling moth damage was assessed three times: following first generation (6/12/01), prior to first harvest ((7/10/01) and prior to second harvest (7/31/01). On each sample date, 20 fruit from 24-25 trees were inspected in each sample site. Fruit exhibiting codling moth damage were cut to identify the presence and stage of the larva. Seven sites were sampled 6/12: each control (three sites), one site in each low rate block and two sites in the high rate block. On 7/10 nine sites were sampled: each control block, one site in the low rate Bosc block, two sites in the low rate Bartlett block and three sites in the high rate Bartlett block. For final harvest we sampled 10 sites total:

three control sites, two sites in the low rate Bosc block, two sites in the low rate Bartlett block and three sites in the high rate Bartlett block.

Puffer trials – Efficacy

We evaluated the impact of multiple puffer units for control of codling moth in pear and walnut orchards and navel orange worm in an almond orchard. The goal was to impact a limited area with the puffer units and begin to understand the relationships between trap catches and damage. All trials utilized the Paramount Puffers, (Paramount Farming, Bakersfield, CA) loaded with the appropriate pheromone canisters. Codling moth trials were conducted using a puffer emission rate of 7.05 mg ai/puff or 338.4 mg ai/day for each unit. Navel orange worm trials used a puffer emission rate of 0.2 mg ai/puff or 9.6 mg ai/day. Puffer units were set to run from 6pm to 6 am in all trials. Codling moth or navel orange worm activity was monitored through a grid of traps set upwind and downwind of the puffer units. Traps (Pherocon® Delta VI) baited with CM standard lures (Trece 3111) or DA lures (walnuts only, Trece) hung low, or CM 10X lures (Trece 3160) hung mid or upper canopy were used to monitor CM activity. Traps were monitored weekly and lures changed on a two-week schedule. Codling moth damage was assessed twice during the puffer trials. In walnuts we sampled dropped nuts in June by collecting all dropped nuts from a nine-tree site and inspecting them for codling moth damage. A grid of sites in each orchard was sampled. At harvest, we collected nuts after trees were shaken and before they were swept. Samples of 200 nuts were collected from 13 sites in the Locke orchard and 300 nuts were collected from each of 18 sites in both the Ferrari and Ferrero orchards. All samples were cracked out to inspect for codling moth damage. In addition, we conducted two canopy samples in the Locke orchard, as these trees were small enough to access the canopy by ladder. These canopy samples consisted of inspecting 270 nuts from each nine-tree site in the grid. Pear orchards were sampled in similar grid patterns. Samples of 500 fruit were made at each grid site by inspecting 20 fruit per tree from 25 trees. Fruit with evidence of codling moth infestation were cut to identify presence and age of the larva. In addition, 20 percent of the fruit without evidence of damage were cut to look for cryptic infestation. Pear orchards were sampled three times beginning early June and then at approximate four-week intervals.

Walnut sites.

The Cache Creek Organic Orchard (Ferrero orchard) is located north of Woodland, CA. This is an 18-acre site planted to Serr variety and under CCOF certified organic management. It measures approximately 990' x 900' at broadest dimension with trees planted on a 30' square. A grid of 36 traps baited with 1 mg lures was placed with traps set 150' apart on square. Three traps each loaded with DA or 10X CM lures were also placed in the orchard. A line of five puffers were placed in a central trap row perpendicular to the wind direction and such that approximately 400' of orchard was in the perceived upwind direction from the puffer line. Puffers were started on 5/2/01 at the rate indicated above following CCOF approval of their experimental use. The harvest samples were collected on 9/23/01 as described earlier.

The Ferrari orchard is located outside of Linden, CA. It is a 17- acre block of Payne variety walnuts under CCOF certified organic management. The site measures approximately 830' by 950' at broadest dimensions. A line of five puffers was placed diagonal to row orientation such that the puffer line was perpendicular to the prevailing wind direction. Puffers were spaced 150 feet apart. The trap grid was oriented to the puffer line with downwind traps spaced 150' apart on square. The upwind portion of the grid was adjusted for buildings that disrupted the square of the orchard. Three traps baited with DA lures and five baited with 10X lures were also placed to monitor CM activity. Following CCOF experimental approval, puffers were started on 4/11 at the rate indicated above. The harvest sample was collected 9/21/01.

The Locke orchard is located adjacent Lockeford, CA. The puffer plot was located in a 27-acre block of Howard variety walnuts. This is a young planting of 15 to 20 foot tall trees with an open canopy structure. Orchard dimensions are approximately 612' x 1900', narrowing to a northern point. The prevailing wind direction was from the northwest and diagonal to row direction. Nine puffers total were placed on the southern 15 acres of the block. Six puffers were placed 150 feet apart on the western edge of the plot and three more created a northern boundary to the treatment block. Puffers were deployed in the orchard on 4/10/01. A 28-trap grid was set with traps 150 feet apart on square in the puffer block. An additional six traps, three each baited with DA or 10X CM lures were placed in the puffer site. The upwind portion of the block was untreated control and was monitored with three 1 mg lure baited traps and 2 DA lure baited traps. Canopy samples were conducted by sampling a 10-site grid on 6/21 and a 17-site grid on 7/24. Harvest samples were collected on 10/4/01.

Pear sites.

The Biagi orchard in the Sacramento delta is 18 acres of Bartlett pears. The site was not actively managed the previous year. The orchard measures approximately 1500' by 475'. Initially, three puffers were deployed on 4/10/01. They were spaced 150 feet apart in a line across the short dimension and approximately 200 feet or more from the western edge. An additional four puffers were deployed on 6/6/01: two were added within the established puffer row and two along the southern edge 50 and 150 feet east from the established puffer line. A grid of 21 traps was placed into three rows running east from the original puffer placements. Traps were placed approximately every 200 feet down the row beginning with the puffer tree. Two traps were placed upwind in the control area. Four 10X CM lure baited traps were also located downwind of the puffers and two upwind. Fruit samples were conducted 6/5, 7/10, and 7/31/01.

The Yuki orchard is located north of Sacramento, CA. The portion of the orchard used for this study was not scheduled to be farmed or treated for pests this year. The available plot was triangular-shaped. The initial puffer treatment consisted of three puffers placed 150 feet apart toward the southern corner of the plot and perpendicular to prevailing winds. They were located on the side of the triangle such that maximum throw of the pheromone could occur. Puffers were deployed on 4/10/01. Two additional puffers were interspersed within the original puffer line on 6/12/01. Traps were placed at 200-foot intervals downwind in the three original puffer rows and the pattern was continued in

rows at 150-foot intervals lateral to the outside puffer row. A grid of 29 traps was placed such that traps were upwind of the puffers, directly downwind of the puffers or at increasing lateral distances from the puffers. Four 10X CM lure baited traps were placed in the grid downwind of the puffer and one upwind of the puffer. Fruit samples were conducted 6/5, 7/13, and 8/2/01.

Puffer Plume – Souza Orchard

We conducted the pheromone plume detection studies again in the orchard that had been used in 2000. This was of Chandler variety walnuts planted in 1994. The 74-acre orchard dimensions are approximately 1210' x 3180' and is orientated length wise in a west-east direction. Tree rows are planted in a north-south direction with 22' between trees within each row and 19' between rows. The site has a well-developed canopy. The dominant wind direction at the site was estimated to be from the west, and would therefore travel perpendicular to the tree rows. The orchard is bordered on the south by cherries and apples, on the west by apples, on the north by an open field and on the east by a highway.

A single trap grid was utilized during the course of this project. A single puffer unit was placed in the upwind portion of the grid plot approximately 1300 feet from the west end of the plot. Sterile moths were released into the grid and all release points were exactly two rows, 38' directly east (i.e. downwind) of each trap. Experiments were setup in two-week intervals. Two-week experiments consisted of a puffer "on" period followed by a puffer "off" period. These periods were used to first establish a pheromone plume in the orchard, then to turn off the puffer device and examine the presence and effects of any "ghost" plume and to confirm result of our experiments conducted in 2000. All experiments received one moth release at the beginning of each "on" and "off" period.

A trap grid was setup to confirm the presence of the pheromone plume and to investigate the possible existence of a "ghost" plume of residual pheromone after the puffer device had been turned off. The grid was composed of 35 traps (Trece Delta VI) and one puffer device. Traps were hung in 7 rows with 5 traps per row, each spaced 198' (9 trees) apart. The first two rows were placed upwind of the puffer device at 456' and 912' west of the puffer; this was done to ensure an upwind control trap row. We expected the upwind row traps to be unsuppressed by the pheromone. The puffer device was hung, facing east, in the uppermost third of the center trap tree of the second row. Each of the remaining four rows of traps were spaced 456' from each other, with the final row east at a distance of 1824' from the puffer device.

In attempting to create a uniform moth population in the orchard, we released sterile moths in a uniform grid pattern into the orchard. Sterile codling moths were obtained from the sterile insect release facility operated by Sterile Moth Release Program in Penticton, British Columbia. Moths were typically shipped on a Tuesday from Canada, received in Berkeley on Wednesday and taken to the field for release that same day. Moths, contained in sealed petri dishes were kept cool on blue ice until release in the field. Petri dishes were placed into a limb crotch in the lower third of each walnut

tree. Releases of ca. 800 moths per release point were made for all experiments, hereafter referred to as a sterile release. Sex ratios are approximately 50:50. Sterile moths are identified by a pink coloration of the gut contents, which is the result of a dye placed in to their diet by the rearing facility. Moths were verified as being sterile in the field by crushing and noting the presence of the pink color of their internal fluids.

We wanted to test 2 objectives: a) the size and shape of a pheromone plume emitted and b) how long does the effect of the pheromone plume last after the puffer device is turned off. Each experiment lasted 2 weeks; for the first week the puffer device was turned on, for a 12-hour cycle each day and then was turned off for the next week to look for any “ghost” or residual effects. The puffer device was programmed to emit on a 12-hour cycle, from 6 pm to 6 am, at the standard emission rate (7.05 mg ai/puff at 4 puffs/hour) for a total of 338 mg pheromone delivered per cycle. The timing of the emission was set to roughly coincide with assumed daily moth flight, occurring around the time of sunset and through the early morning hours. During the “on” period, traps were checked, moths removed and verified as sterile on days 1, 2, 3, 5, and 7 after the sterile release. A second sterile release was made the day the puffer was turned off. During the “off” period traps were checked and moths verified and removed on days 1 through 3, 5 and 7 after the sterile release. A total of 2.37g of pheromone was emitted during the 7-day “on” period. The traps were checked; moths were removed and verified as sterile on days 1 through 3, 6 and 7 after the initial sterile release. As before, a second sterile release was made the same afternoon that the puffer was turned off. Traps were again checked on days 1, 2, 3 and 6 after the sterile release.

RESULTS

Sprayable Pheromone Trials

3M Sprayable: Fairfield Pavalina – Pears

The effects of the different application rates of the 3M Sprayable product on moth flights are shown in Figure 1. The pheromone treatment appeared to have a general suppressive effect with no clear population peaks until late in the season which was approximately 2 months after the last application. The lowest application rate of 1 gm per acre did not provide sufficient suppression for much of the season. By mid June the counts in the plots treated with 1 gm ai per acre were similar to the untreated control plots, occasionally reaching trap counts that exceeded the untreated control (July 2). By July 30, all sprayed plots were starting to lose their ability to suppress codling moth from finding pheromone-baited traps. It should be noted that the Isomate treatment also failed to provide commercially acceptable suppression by Aug 14 given the high pressure observed in the field. However, it also be noted that the Isomate product also gave the slightly more consistent and higher levels of trap suppression for the entire season.

The total codling moth counts per trap through 7/23 are shown in Figure 2. As observed in the past, there was no strong rate response above 1 gm ai per acre. Both the

20 and 40 gm per acre treatments gave statistically significant trap suppression that was comparable statistically to the Isomate treatment. Because we were able to discriminate between treatments in terms of trap suppression suggests that the plots were sufficiently large to prevent uniformity in pheromone concentrations across the orchard.

However, if fruit infestation level is used, then all plots look equal to both the control and to the Isomate pheromone standard (Figure 3). Given that we already know that Isomate provides commercially acceptable suppression of damage, these data suggest that either the population levels were too high in this orchard to expect good control or that female codling moths were moving between plots and overwhelming any potential treatment effects. These data functionally demonstrate the difficulties with conducting pheromone mating disruption studies in that even 4-acre contiguous plots were not sufficiently isolated to develop meaningful damage assessment data, which severely limits our ability to conduct replicated experimental designs within a single orchard for damage suppression.

3M Sprayable Locke – Walnuts – 3M

The flights for codling moth are shown in Figure 4. Overall, codling moth counts were quite low in this orchard, but this was not reflected in low damage estimates at various points during the growing season. Given the relatively close proximity of the plots within the orchard, one potential explanation is that the pheromone treated plots were suppressing trap counts in the adjacent areas, but were not suppressing damage or females to any great degree other than in the pheromone treated area. This pattern is reflective of the observations made in the Fairfield pear trial discussed above. Trap suppression is clearly more easily achieved than damage suppression, which again speaks to the need for caution to not overemphasize the positive nature of trap suppression data.

The damage from codling moth was approximately equal at ca. 2% on July 20 between the commercially treated grower plot and the pheromone treated plot (Figure 5). Damage levels in the control almost reached 6% based on the damage estimates made from direct observation of fruit using hydraulic lifts into the tree canopy. The high infestation level in the control precipitated an application of Confirm. Concerns about other pest species (e.g. husk fly) precipitated August applications of Nufos to the plots. By harvest on Sept 11, damage levels were estimated at much lower levels with the control only having ca. 2% infestation. Two potential reasons may exist for this drop: a) damaged nuts may have fallen off preferentially as the season progressed or b) the direct examination under lab conditions may have provided a more accurate estimate of damage. Given that less damage was observed at harvest, it would appear to be more likely that differential nut fall had occurred.

Therefore, damage estimates at harvest for both the commercial grower plot and the plot treated with the sprayable pheromone experienced ca. 0.2-0.3% damage compared to the 2.2% observed in the control plot which was part of the same orchard block. As such, at all times during the season, the sprayable pheromone program appeared to be provided control comparable to the more conventional program.

3M Sprayable IVs - Dondero – Walnut

The result from the Dondero plot were not interpretable given that the control plots yielded 0% codling moth damage for any canopy or harvest sample (Table 1). Similarly, no codling moth larvae were ever observed in the tree canopy or at harvest for all samples taken from the 3M treated or conventionally treated plots. Early in the season, minor infestations were detected in dropped nuts on June 14, but the % infested was extremely low at 0.1-0.2%. Moth pheromone traps also did not detect any meaningful populations with the control plot peaking at 2 moths per trap in one week in the 1 mg lures, whereas the 10 mg lures failed to catch any moths all season. Oddly enough, the DA baited traps did suggest slightly higher counts in the control plots with counts exceeding 7 moths per week on 2 occasions in one location, whereas the 3M plot peaked at 4 moths in one trap. The positive message might be that the counts for both the pheromone treated and the DA baited traps had predicted little to no damage at harvest and this was reflected in the damage estimates.

Suttera Sprayable: Wiseman (Delta) – Pears

The results from the Suttera sprayable product were quite encouraging (see Figures 6-7). Damage levels in the two control plots that were along the upwind edge of the orchard experienced the highest levels of damage on both sample dates. For the first harvest damage evaluation on July 10, damage in the controls were 4.5 and 1.6% for the Bartlett pears, while the Bosc control plot that was downwind of the pheromone treated area never had detectable damage. Regions of the pheromone treated plots that were immediately adjacent to the untreated controls also had high levels of damage

Puffer Trials

Puffer Trial – Walnut – Linden Organic

The results from the puffer trial were very interesting in the apparent incongruity of the data between trap suppression and damage suppression. As shown in Figures 8 and 9, trap suppression was quite consistent and strong across the entire downwind region of the puffer trial. Seasonal total counts ranged from 0-5 moths for the season for all traps that were downwind except for one trap that was in the corner and slightly upwind of the projected plumes. Counts for the SW corner totaled 158 moths, whereas the 2 traps upwind captured 84 and 47 moths during the season.

Damage shown in Figure 9 did not show the same pattern with damage distributed widely across the plot. Damage ranged from 5.7 to 6.7 upwind of the puffer whereas damage downwind ranged from 2.3% to 7.7%. The fact that the damage was uniformly distributed across the plots may have resulted from the relatively short distance of only ca. 700 feet between the edge of the control region and the pheromone treated area. Female moths may have moved freely between the regions, thus compromising the independence of the plots. A similar pattern of “bleeding over” of damage between

uncontrolled areas and controlled areas was observed when looking at damage patterns over time in the pear puffer plot located near the Sacramento airport.

The distribution of females and males using traps baited with the pear ester (the DA lure) are also shown in Figure 9. The trap totals have on average about 83% females and this pattern was consistent across the orchard. The number of females caught per trap was fairly high uniformly across the orchard with 104 moths caught in the control region, whereas one of the traps caught 138 moths in the downwind region. This may mean that females are moving readily between plots and compromising any control efforts. What is also not clear is what might have happened if the control plots were eliminated from the trial altogether, thus minimizing the number of mated females that might enter the treated area. Therefore, while there may be experimental and logistical reasons to explain the high levels of damage, these data also point out the puffer deployed in this manner is not giving consistent results. More importantly, we need to identify the sources of variability such that more consistent results can be achieved similar to those achieved in Lake County on pears.

Puffer – Woodland – Organic Walnut

This orchard was located in a region that experiences a different wind pattern in that it lacked a consistent direction throughout a day. Whereas most orchards have a daily wind pattern with regular times of more or less intensity, many of our orchards in the Valley had a relatively uniform direction with some variation along that axis. As shown in Figure 10, the wind direction would reverse itself during the course of the day. Typical wind directions and timing are shown on the figure. Therefore, all components of the orchard were exposed to either the direct pheromone plume or potentially the secondary residual plume during the 24-hour daily period. Despite being an organic orchard, the moth counts were highly suppressed over the entire orchard independent more or less of position.

Total moth counts are shown in parentheses and ranged from 2 – 34 moths. For these 19 traps, the mean total counts were only slightly more than 6 moths per trap for the season using traps baited with the traditional 1 mg lure. Conversely, when traps were baited with the DA lure, the seasonal total counts were 27, 32 or 44 moths (male and female combined). So, the orchard did have a population that potentially could have resulted in damage unlike the Dondero walnut discussed above.

In contrast to the other studies that had unsuppressed upwind areas, this orchard configuration and the shifting wind conditions appear to have resulted in a more broad control program. As such, damage levels are very low throughout the orchard with damage estimates ranging from 0% to 1.7%. Mean damage was 0.48% across all sample sites. So, despite at least 9 years under an organic program, the absolute damage levels were easily within commercially acceptable levels. However, caution needs to be urged given that 1) there are no controls within this orchard setup and 2) variation between years could also potentially explain these positive results.

Puffer – Biagi

The levels of codling moth in this orchard were extraordinarily high with more than 405 moths caught within a single trap within a 6-week period along the upwind border of the orchard (Figure 11). Despite the very high population pressures, the line of puffers were able to suppress moths downwind of the puffers to levels much lower than the upwind regions, but not 100%. With the addition of the 2 puffers later in the season to account for the angle of the wind across the orchard, a larger area of trap suppression was observed. The area of suppression as in the past extended for up to 600 feet before angling out the orchard.

The results from the first flight are shown in Figure 11 with the upwind region of the orchard having trap counts between 292-373 moths per trap, whereas traps in the pheromone plume had between 3-13 moths per trap. Traps placed along the upwind margin also caught high numbers of moths (124-169 moths per trap) as did traps placed farther down into the orchard. The wind direction angled across the orchard less leaving the back edge non-exposed to the pheromone.

However, damage suppression did not reflect the pattern observed with the flight data. The area of trap suppression is presumably too close to areas with high numbers of mated females (upwind controls or the leading edge of the orchards) such that female movement into the treated areas overwhelmed any treatment effect on damage.

A similar pattern was observed for the second flight with strong trap suppression for the same general area of the orchard (Figure 12). Again, extraordinary pressure of 557 and 597 moths were caught in the upwind control region of the orchard within the 6-week sample period. In contrast, only 3 moths were caught within traps only 200 feet into the pheromone plume. However, again damage suppression was not adequate as mated females presumably moved in high numbers into the treated area. Damage levels ranged from 18-26.8% across the entire orchard.

Puffer – Locke – Walnuts

Only a single infested walnut was found throughout the entire sample. As such, patterns of infestation are meaningless for this study. However, the pattern of trap suppression continued to follow the results observed in previous years: high trap suppression within the body of the orchard with upwind regions catching moths in the control treatments (Figure 13). Traps placed in the control plot caught 28 in a 1 mg baited pheromone trap suggesting little interference by the puffer with this plot. Only the southwest corner of the orchard caught significant number of moths in the pheromone-permeated portion of the orchard. We assume that the average direction of the wind with a slight southeasterly lean allowed this corner to remain unsuppressed throughout most of the summer. However, most traps caught 0 moths for the season if within the body of the downwind plume. Conversely, the DA baited traps caught moths in relatively high numbers (50-70 moths for the season in individual traps). While most of these were females (ca. 80%), these counts do suggest that a population of codling moth was in

residence in the orchard. However, these counts combined with the low 10 mg lure counts are suggestive of only a moderate population.

Again, while the results were very positive and the general pattern of the traps, the fact that 0% damage was also found in the control plot undermines our ability to consider this an example of successful damage suppression.

Puffers - Yuki Pears – Sacramento

The results from this trial were very encouraging for several reasons. The orchard started off as a low-pressure situation given that this was the first year of a low input management program. The results are presented for 3 independent samples taken throughout the season, which shows the pattern of damage and how it changes over time.

For the first sample on June 5, trap counts are relatively low across the entire orchard as indicated by the numbers in parentheses in Figure 14. While trap total counts in traps placed within the pheromone plume ranged from 0-2 total moths, the upwind edge only had 8 moths while the corner of the field not directly in line with the puffers had a trap, which caught 24 moths. The percent damage also shown on the same figure had a roughly similar pattern with the highest damage levels found first in the corner of the field with the highest moth trap counts. Similarly, the sites within the immediate line of puffers and most adjacent to the upwind plots also experienced low levels of damage at 0.8 and 1.9% damage.

Approximately one month later on July 13, the moth counts had continued to increase in the unsuppressed corner of the field to 52, whereas the most upwind corner had increased from 8 to 94 moths for the season (Figure 15). The traps directly in the pheromone plume continued to be suppressed overall with the lowest counts (2-6 moths) found along the west margin of the orchard that were farthest away from the corners with high counts. Damage levels had also continued to increase with the highest damage levels being in the east corner of the field at 25.2% infested fruit. There is a west-east gradient in the damage levels with the highest counts in the eastern portion of the plot. The areas immediately in front of the puffers and farthest away from the east corner had the lowest counts as would be predicted from the moth counts. The only surprising results were the fact that the southern corner had not experienced much higher levels of damage.

The same general pattern continued until August 2 (see Figure 16) with damage continuing to be the highest in the eastern corner. Overall, the trap counts and damage were roughly correlated, but the area of damage suppression appeared to be progressively shrinking. By Aug. 2, the damage levels in the eastern corner were at 34.5% and presumably a strong source of mated females that continued to push into the pheromone-permeated regions.

Puffer Plume – Souza Orchard

The results obtained in past years were repeated again in 2001. The results from a single plume study are shown as typical results. In Figure 17, the results of trap suppression within the walnut orchard extended for almost 1800 feet despite the release of larger numbers of sterile male moths. The highest counts were found in the upwind regions of the orchards as expected counts of 0 moths being fairly typical of regions downwind.

The residual nature of the plume is shown in Figure 18. The results are overall consistent with previous results, but the plume structure in this case started to dissipate relatively quickly with a severely reduced effective area of less than 400 feet by day 1 after the units were turned off. By Day 3, no clear evidence of any effective plume structure was observable. These data have now been confirmed with the data reported above for wild moths as well with strong trap suppression observed in even very high-pressure situations.

CONCLUSION

The sprayable formulations of codling moth pheromone appeared very promising with strong trap suppression of wild males throughout the season regardless of population pressure. Damage suppression looked very positive in all trials when populations were from low to moderate levels and when movement of females from untreated areas was less likely. With the exception of the Pavalina plots, all treatments regardless of rates or crop produced commercially acceptable fruit with low average infestation rates. In situations like the Pavalina orchard in which high rates of movement of mated female moths is likely, none of the pheromone treatments including Isomate provided acceptable control. In areas immediately adjacent to untreated controls (e.g. parts of the Wiseman pear plots), migration of females into the treated area also appeared to be likely. Therefore, identification and isolation of potential sources of codling moth (e.g. nearby orchards, plots within the same orchards, or bin piles) will need to be identified prior to any large-scale implementation. At this time, we would expect that the pattern observed in plots with hand-applied dispensers for increased efficacy associated with increasing plot size will be repeated for sprayable pheromone treatments.

For the “puffer” style of emitter, the same trend held true. Damage was more suppressed in the treated regions assuming that large sources of codling moth were not readily migrating into the treated areas. The initial success of the puffer plots in the Yuki pear plot was ultimately undermined by the increasing front of damage from the eastern corner of the field. Similarly, plots with shorter distances from the untreated controls also tended to fare less well (e.g. Organic walnut orchard – Linden) given its relatively shallow depth. However, situations in which little of the orchard remained untreated produced much better results (e.g. Organic walnuts – Woodland). Recognizing the inconsistency within the dataset should result in increased caution for adopting these approaches too rapidly. However, the hope is that the variables identified in these studies can be isolated, confirmed, and eliminated from trials in 2002 such that program efficacy and reliability can be improved while simultaneously attempting to harvest the potential benefits intimated by the results from 2001.

Table 1. Results of sprayable pheromone trial in walnuts (Dondero -Stockton) for 3M IVs formulation

Treatment	Dropped Nut Sample (6/14)		Canopy Counts (% Damage)		Harvest (% Damage)
	No. of Dropped Fruit per Tree	% Damage	22-Jun	20-Jul	19-Sep
Pheromone	9.08	0.2	0	0	0
Conventional	14.2	0.2	0	0	0
Untreated Control	3.5	0.1	0	0	0

3M Sprayable Pheromone - Phase IV Pavlina Orchard - 1mg Trap Summary

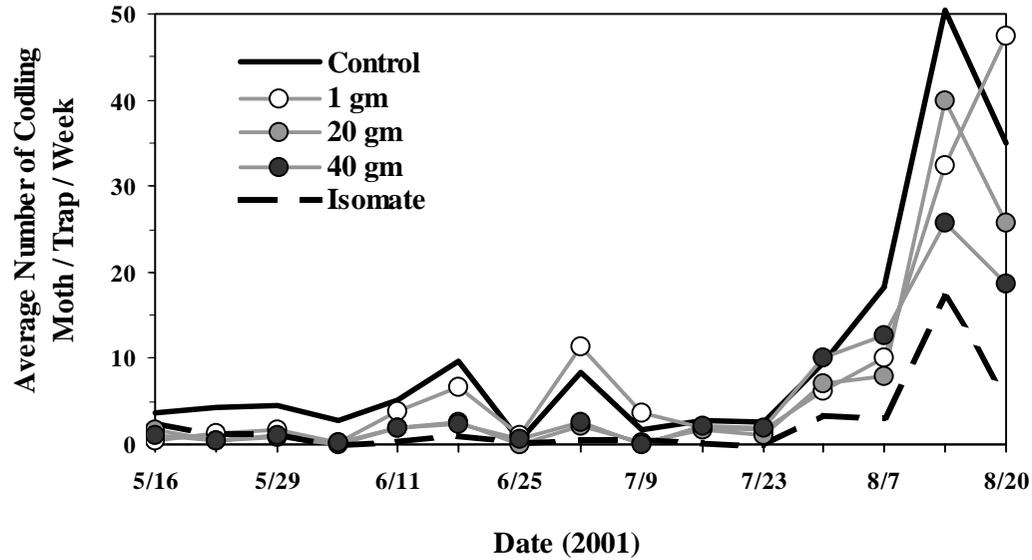


Figure 1. The effects of the 3M sprayable pheromone on the flights of codling moth in a Bartlett pear orchard. Applications were made on May 9 and June 14.

3M CM Sprayable: Phase IV Pavlina Pears - Seasonal Codling Moth 1 mg Trap Counts through 7.23.01

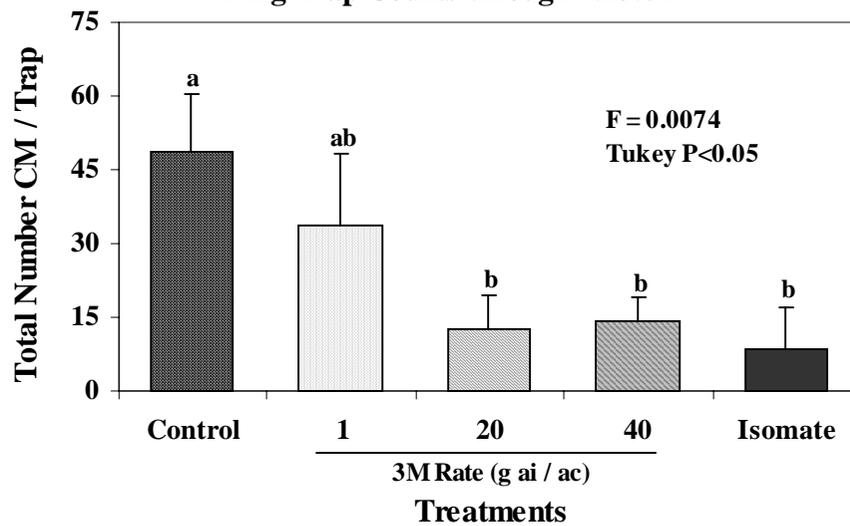


Figure 2. Total average seasonal trap counts for codling moth for plots treated with various rates of the 3M sprayable pheromone.

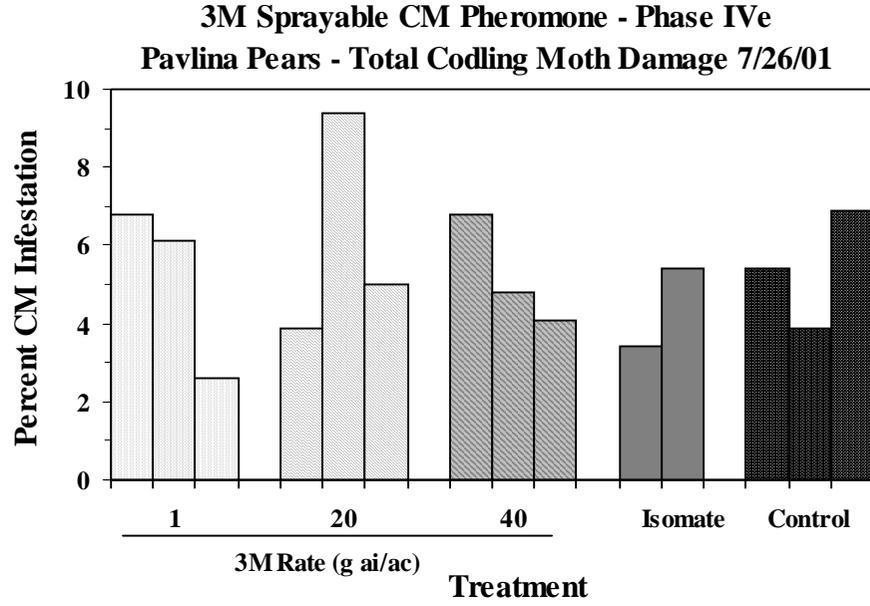


Figure 3. Final damage estimates for plots treated with the 3M sprayable formulation in an abandoned Bartlett pear orchard.

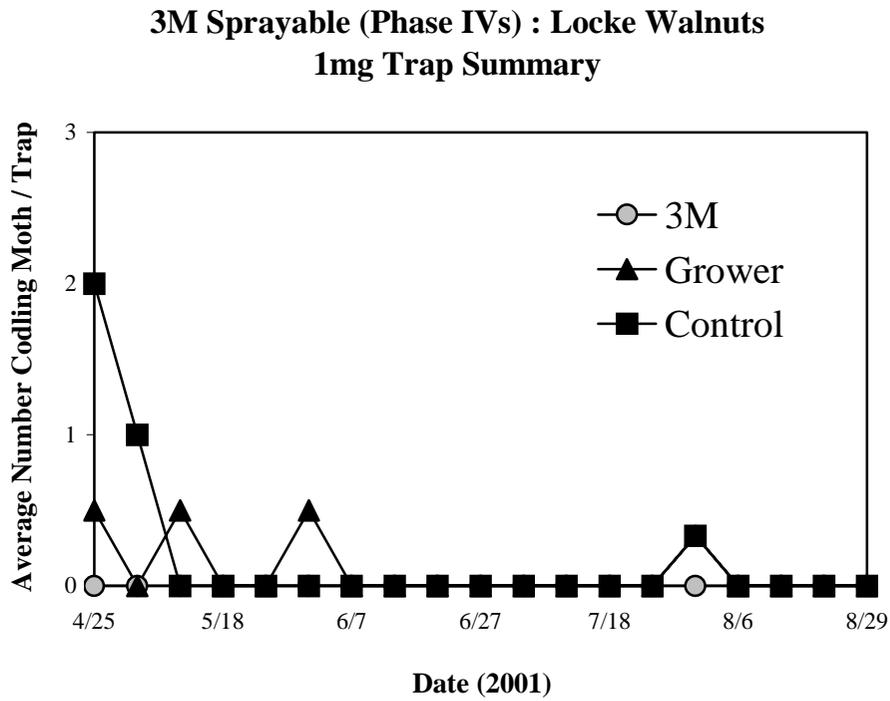


Figure 4. Seasonal flights of codling moth in walnuts treated with 3M sprayable pheromone.

**3M Sprayable (Phase IVs) : Locke Walnuts
Canopy (7/20) and Harvest (9/11) Damage**

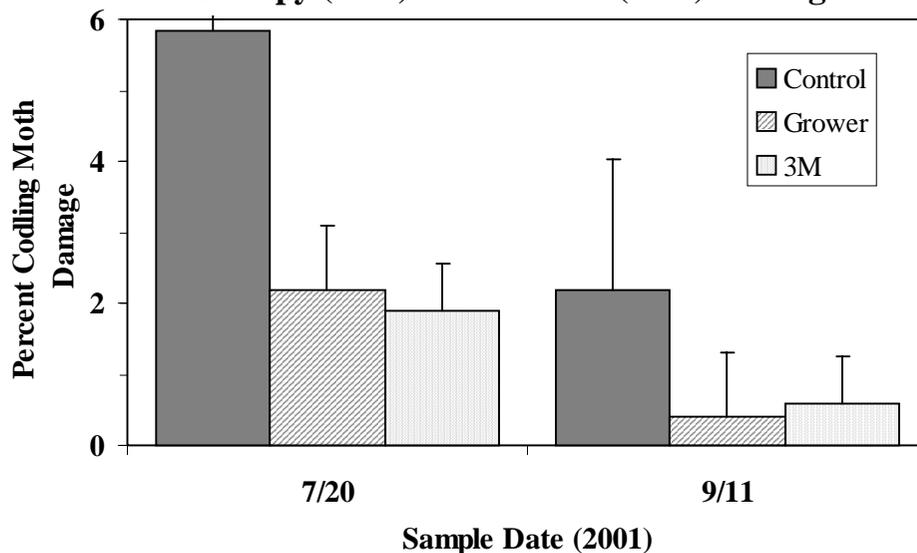


Figure 5. Codling moth damage levels in walnut plots treated with 3M sprayable pheromone product.

**Consep CM Sprayable: Pears
Wiseman Orchard - Walnut Grove, CA**

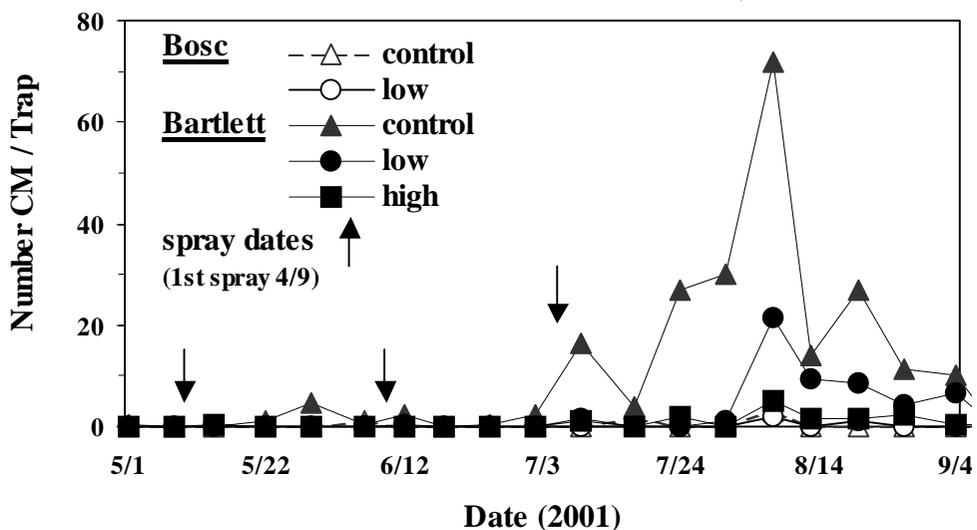


Figure 6. Seasonal trap counts for pear orchard treated with Suterra sprayable pheromone product.

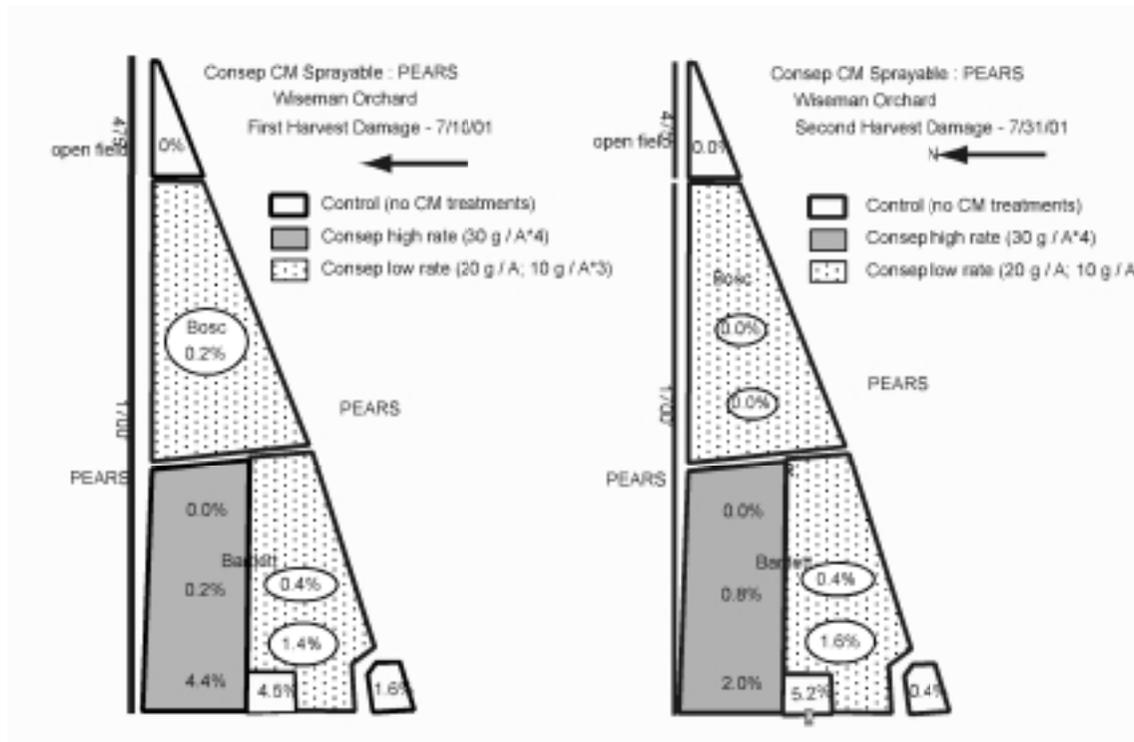


Figure 7. Patterns of codling moth damage in Bartlett pear orchard treated with Suterra sprayable pheromone product.

Paramount Puffer - 1 mg trap Summary Organic Walnuts, Linden, CA

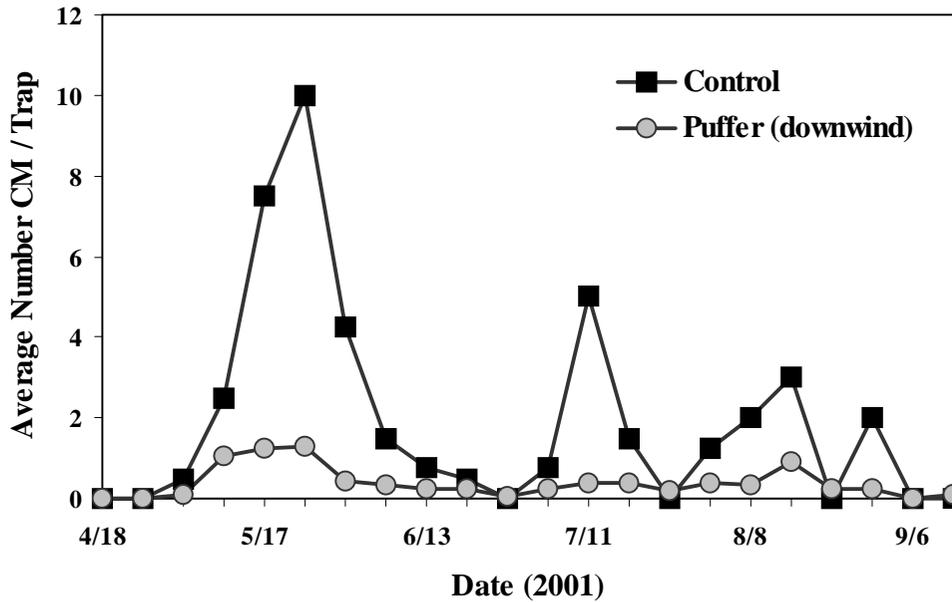


Figure 8. Trap suppression in puffer-treated and upwind control regions of organic walnut orchard.

Paramount CM Puffers : Organic Walnuts - Linden, CA
Percent Codling Moth Damage at Harvest (9/21/01) and
Total Codling Moth Counts for Season

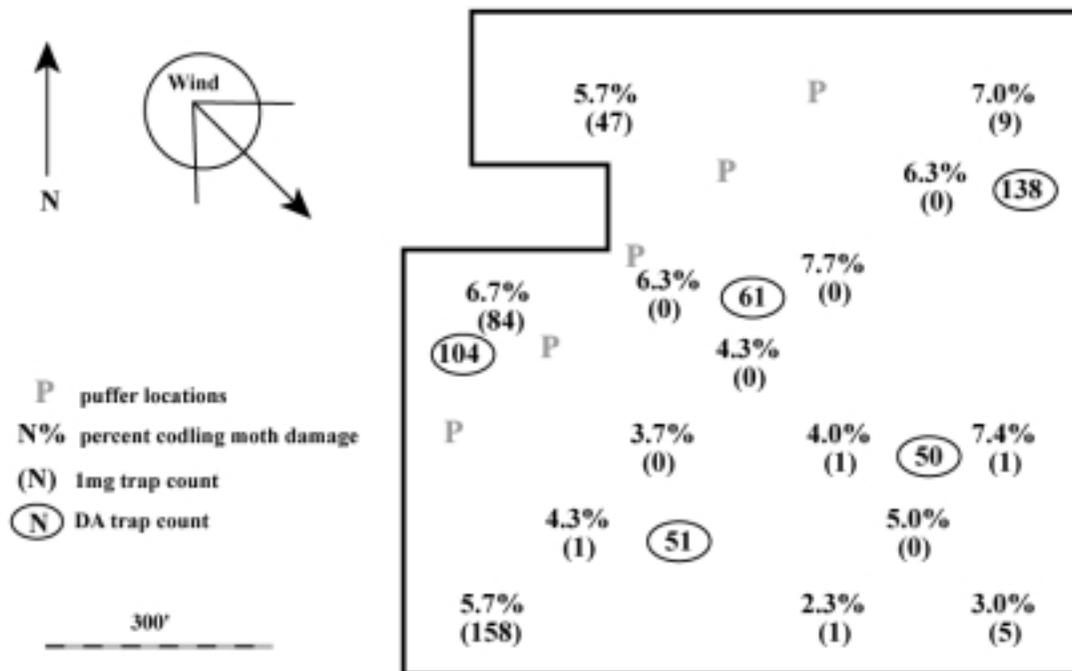


Figure 9. Distribution of trap counts and damage suppression within puffer treated orchard walnut orchard. DA traps in Ferrari Orchard averaged 83% female capture (range 80-93%).

Paramount CM Puffer: Organic Walnuts - Woodland, CA
Percent Codling Moth Damage at Harvest - 9/23/01 and
Season Total Trap Catches

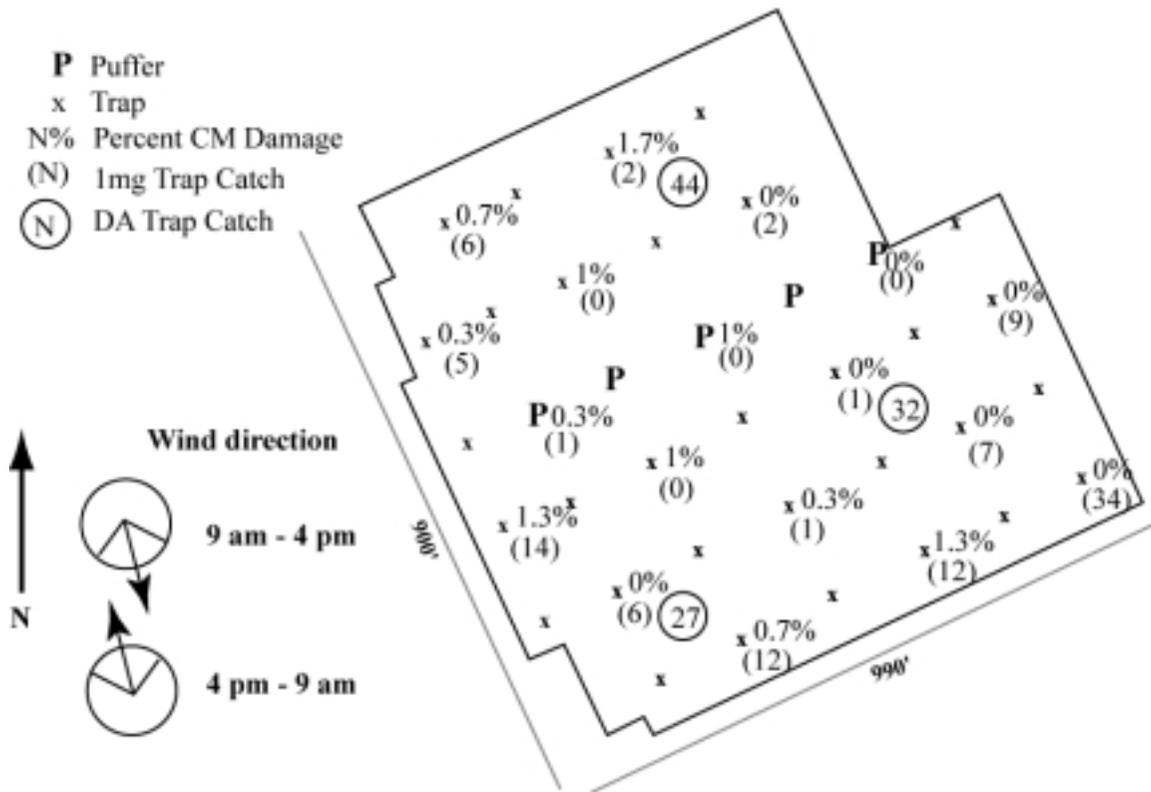


Figure 10. Damage and trap suppression in an organic walnut orchard in Woodland, CA.

**Paramount CM Puffer: Pears
Biagi Orchard - Rio Vista, CA
1st Flight CM Infestation 6/5/01 and
Season-to-Date Trap Catches**

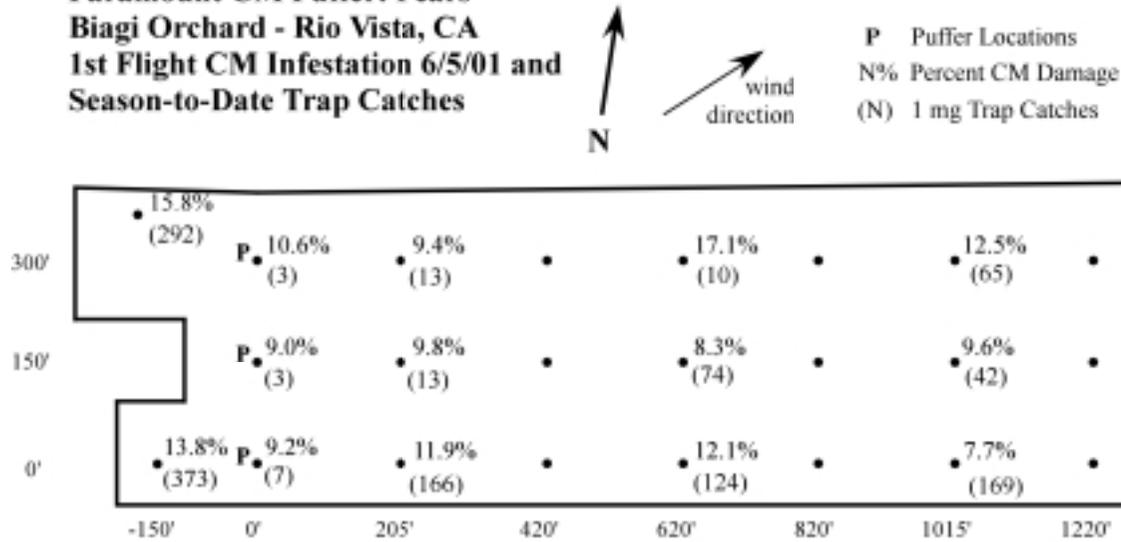


Figure 11. The distribution of codling moth counts in parentheses and codling moth damage after the first flight of codling moth.

**Paramount CM Puffer: Pears
Biagi Orchard - Rio Vista, CA
Final Harvest CM Infestation 7/31/01
and CM Trap Catch Sums 6/5-7/31/01**

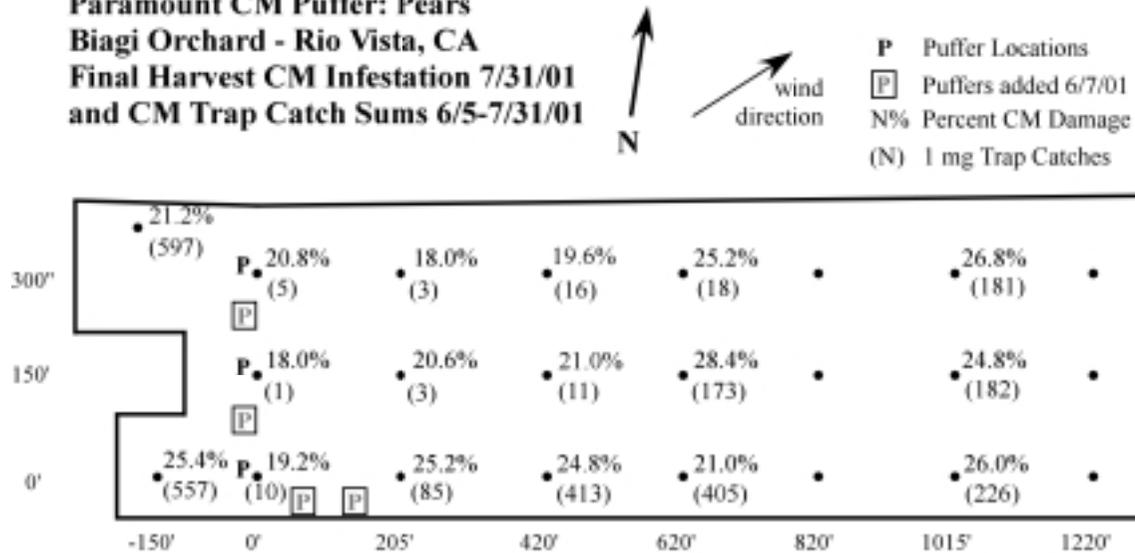


Figure 12. The distribution of codling moth counts in parentheses and codling moth damage after the second flight of codling moth.

**Paramount CM Puffer: Locke Walnuts
Season Total CM Trap Catches**

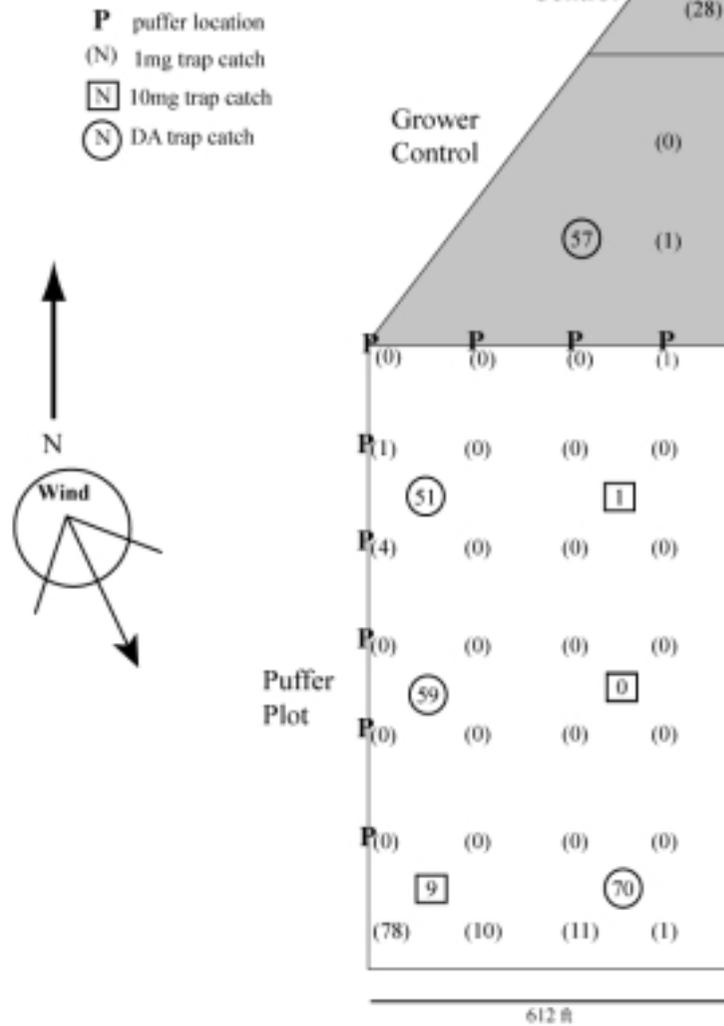


Figure 13. Results of trap suppression in walnut orchard in Lockeford, CA.

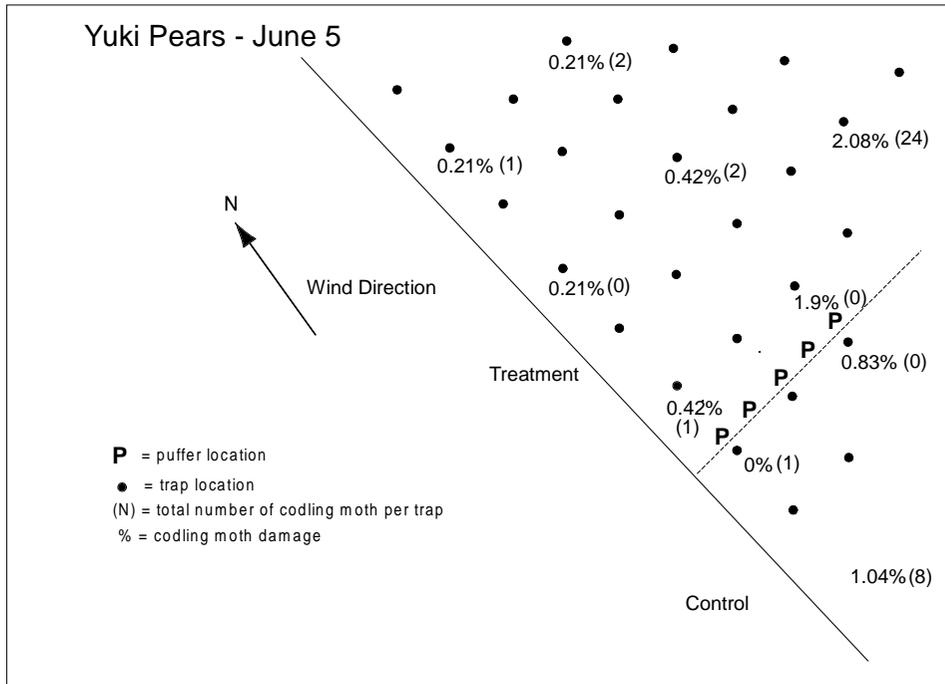


Figure 14. Distribution of codling moth pheromone trap counts and damage estimates for June 5, 2001 with Sacramento Bartlett pear orchard.

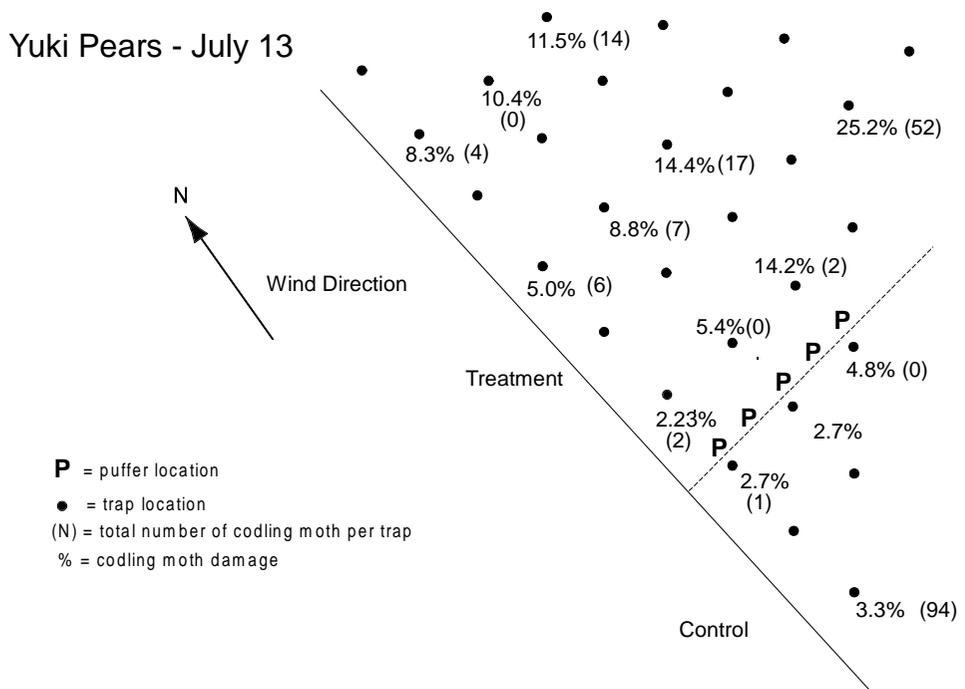


Figure 15. Distribution of codling moth pheromone trap counts and damage estimates for July 13, 2001 with Sacramento Bartlett pear orchard.

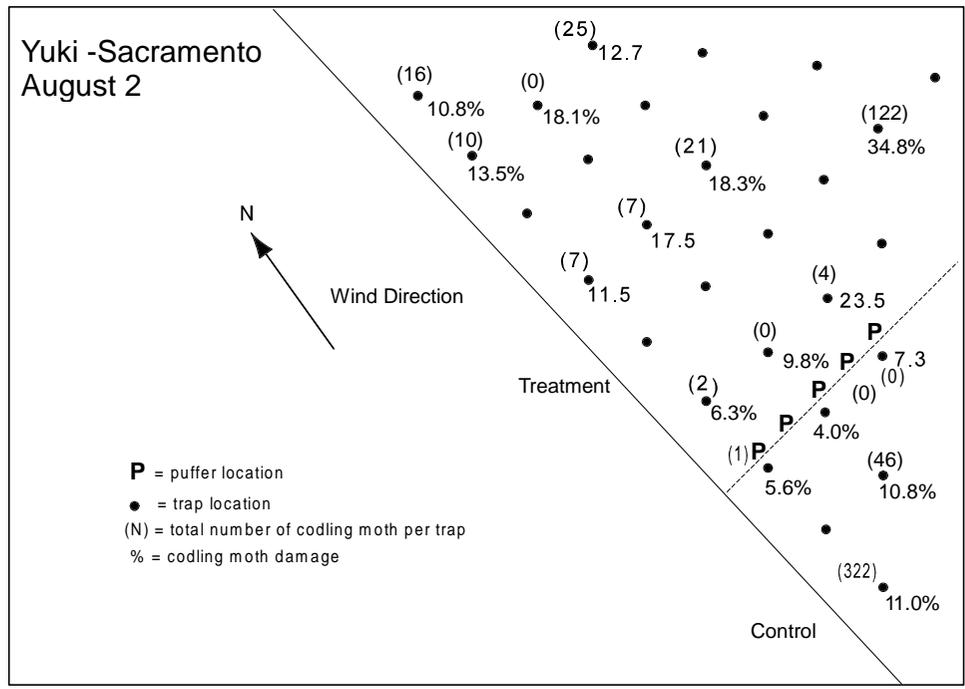


Figure 16. Distribution of codling moth pheromone trap counts and damage estimates for August 2, 2001 with Sacramento Bartlett pear orchard.

