USING AEROSOL PHEROMONE "PUFFERS" FOR AREA-WIDE SUPPRESSION AND SPRAYABLE PHEROMONE IN MANAGEMENT OF CODLING MOTH IN WALNUTS

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ABSTRACT

The Walnut Pest Management Alliance (PMA) continues its efforts to reduce pesticide inputs in California walnuts with a seventh year to demonstrate and extend pest management strategies based on pheromone mating disruption. The PMA has successfully demonstrated codling moth management using pheromone mating disruption in a sprayable formulation applied at very low rates with a conventional orchard sprayer in the past few years. The PMA continues to investigate new application technologies for use of pheromone mating disruption (PMD) in walnuts in an effort to improve efficacy and reduce the cost of the program so that walnut growers are willing to switch to a pheromone based mating disruption pest management program. Two application technologies were tested in 2005 using separate research methodologies. The sprayable pheromone was applied with an Ultra Low Volume (ULV) applicator to find out if codling moth control could be achieved with lower application costs. The ULV-applied CM-F treatments across sites provided codling moth damage statistically similar to grower standard treatments using less insecticides; both ULV and grower standard treatments were had significantly less than damage that untreated areas. The second approach was to start two long term area wide puffer trials in California. The area wide aerosol puffer trials completed their first year of the project with less than 0.6% CM in 180 acres in Glenn County and 2.8% CM in 564 acres in San Joaquin County. In all of the trials, PMD was coupled with systematic monitoring of CM populations and in-season damage to the crop. Insect pest pressure varies from year to year, and some years require the use of supplemental insecticides. The frequency of these supplements is determined by monitoring with traps and canopy counts.

INTRODUCTION

In the last several years, the PMA has successfully demonstrated codling moth management using pheromone mating disruption in a sprayable formulation applied at very low rates with a conventional orchard sprayer. Although this system effectively suppresses codling moth (CM) populations, it has not been adopted by growers due to a perceived high cost and lower efficacy compared to conventional insecticide treatments. In 2005, the PMA tested two different tactics for the application of PMD. Again, the sprayable formulation was used at 5 ai CM-F per acre, but applied with a custom-made ULV applicator. The applicator is ATV-mounted and can be driven up to 6-7 mph through rough or wet field conditions. It applies the same amount of pheromone material, but using less than a gallon of spray solution per acre. This application technique is thought to more closely simulate the highly concentrated "point source" pheromone distribution of hand-applied dispensers. A boom-mounted nozzle sprays a straight stream into the upper half of the tree canopy. The stream is "pulsed" so as to deliver pheromone solution to tree canopies only; the stream is shut off momentarily between trees to avoid the material falling to the ground between trees. Also new in 2005, two long-term area-wide trials were started using aerosol pheromone puffers over a large area of contiguous walnuts. The puffers have been shown to work in walnuts on a smaller scale but the long term population reduction of codling moth should work best when covering a large area. The results of this trial will be measured by comparing codling moth damage, trap catches, and reduction of insecticides from year to year. The aerosol puffer units are hung high in the tree canopy and are designed to emit pheromone all season. While the initial purchase of the units is high, the year to year costs are less than sprayable pheromone.

OBJECTIVES

1. Validate pheromone application technology required for control of codling moth. Monitor codling moth populations to watch for population increases and to determine spray timings. Monitor damage to the crop with surveys of dropped nuts and nuts in the canopy.
2. Begin long-term, "area-wide" CM management trials with the use of aerosol pheromone puffers at two locations, one each in the San Joaquin Valley and the Sacramento Valley.
3. Continue to field test new pheromone application technologies that have a high potential for use in walnuts, specifically, application of the sprayable pheromone, CM-F via ultra low volume applicator.

PROCEDURES

Sprayable pheromone. In 2005, Suterra CheckMate CM-F sprayable codling moth pheromone was used at five trial locations: three in the Sacramento Valley and two in the northern San Joaquin Valley. One of the intentions of these trials was to repeat recent work using a low (5 grams a.i./acre) rate of pheromone, but with ULV instead of air blast application. However, due to manufacturing delays and scheduling difficulties at the Sacramento Valley sites, some of the CM-F applications had to be done with a conventional orchard sprayer.

The CM-F treatment blocks were a minimum of 15 acres, and each location included a "grower standard" (GS) where the grower used conventional pest control materials of his choosing. Each trial also included an untreated area of 1 to 2 acres. The CM-F was applied at approximately 30 day intervals beginning when overwintering generation female moths began to be consistently caught in the indicator traps.

Test blocks were monitored with traps as follows: CM-F and GS blocks each had one trap hung low in the canopy and baited with a traditional 1X pheromone lure, and one trap hung high in the canopy, baited with the new "combo" lure (Trece, Inc.). Untreated areas had two traps baited with the 1X lures, one hung low and one high, and a "combo" lure trap, high in the canopy. The traps were checked weekly to follow the CM flights and changes in population. The lures were changed according to the manufacturer's instructions.

Test orchards were monitored periodically to avoid undue economic risk to the grower/cooperator. Canopy counts were done near the end of each flight, surveying 1000 nuts per treatment block for evidence of CM feeding. If, at any time, more than 2% damage was found in the CM-F test block, the grower was advised to apply a supplemental insecticide of their choice. When time permitted, the first CM flight was also monitored by a survey of the dropped nuts. Insecticide sprays listed in Table 1 include those aimed at other insects such as walnut husk fly and naval orangeworm as well as codling moth.

Harvest samples were collected during normal harvest operations. After the trees had been shaken, 50 nuts were collected from 10 randomly selected trees in each treatment block, for a total of 500 nuts per block. Samples were held in cold storage until they could be processed. All nuts were cracked and examined to determine percent damage from both codling moth and naval orangeworm.

Aerosol puffers. Two locations were identified for area-wide use of the pheromone puffers over a period of several years. Both locations are contiguous walnut orchards, including several different walnut varieties.

The San Joaquin site is located near Lockeford, California in San Joaquin County. The ranch is in the floodplain of the Mokelumne River; soils are Vina and Columbia fine sandy loams. It is owned and operated by a single business entity and managed by one person. The site consists of 564 contiguous acres of walnuts divided into 22 blocks of various size, age of trees, and varieties (Table 2, Figure 1). Some blocks have mixed varieties. Insect pressure and damage history vary among blocks depending on varietal susceptibility and past management. The ranch has a prior history of pheromone puffer use. Paramount (solenoid type) puffer dispensers were used in three blocks (7, 10, and 24) in 2002, on roughly the eastern third of the ranch (blocks 10, 19, 24, and 25), and on the entire ranch in 2004. In all years, puffers were placed in a square grid pattern at a density of one dispenser per two acres.

In 2004 and prior years, the general approach to integrating pheromone mating disruption into codling moth management was to deploy puffers beginning at first codling moth biofix and to delay chemical treatment until codling moth populations (as indicated by pheromone and/or "DA" baited traps) and/or damage (as indicated by periodic visual assessments) indicated that treatment was needed. This approach provided generally good codling damage suppression in low pressure or low-susceptibility blocks (e.g. Chandler, Howard) but not in blocks with high pressure or susceptible varieties (e.g. Serr, Vina).

The Sacramento Valley site, in Glenn County, is slightly less than 180 acres and is located east of Hwy. 45 near the town of Glenn. The site consists of a 110-acre block of Vinas, a 37-acre block of Tehamas, and a 30-acre block of Chandlers, Figure 2. For monitoring purposes, data was collected from four different areas within the Vinas, and from two areas in each of the smaller blocks. The Sacramento River runs along the East side of the orchards and on the West side is a levee. On the North and South are walnuts (a different grower) and row crops, respectively. An independent consulting firm provides Pest Control Advisor service.

Pheromone mating disruption research and demonstration trials have been conducted at this site in recent years. In 2003, approximately 20 acres in the Vina block was utilized in the "Value-Added" program, where 5 grams a.i. of sprayable pheromone was added to each insecticide spray and compared to a "Grower Standard" where the same insecticide sprays were used without the pheromone. In 2004, pheromone puffers were tested on a small scale in half of the Tehama block. Although the benefits of the pheromone puffers will extend equally over the whole trail site, within each trail, each orchard, or block, is managed separately. The two trial locations are independent and the results are not meant to be compared to each other.

At both sites, Suterra CheckMate puffer dispensers were installed at a rate of one puffer per two acres with a slightly higher concentration along the outside edges. The units were hung with rope in the upper ¼ of the tree canopy and programmed to emit a 40 mg. "puff" of pheromone at 15 minute intervals for a period of 12 hours each night, beginning at 3 or 4 PM. Each unit is made up of a plastic cabinet containing an aerosol can of pheromone, metered release valve, and electronic circuitry powered with 2 D-cell batteries. Although they are designed to last a whole season, up to 200 days, the trial protocols called for servicing of the units on a regular basis to ensure operational integrity. The aerosol cans were weighed before being installed in the field, were weighed at each servicing, and again at the end of the season when they were removed from the field.

The puffer trials were monitored with pairs of traps. Each pair included one trap baited with the newer "combo" lure and hung high in the tree canopy to follow CM flight activity. The other trap was hung low in the canopy and baited with the traditional 1X pheromone lure. The 1X traps act as an early warning system, they should not catch any moths in an orchard treated with pheromone. The Glenn County trial had a pair of traps for approximately every 25 acres, the San Joaquin trial used traps at a higher density, with a total of 37 pairs of traps. All traps were checked every week and the lures changed as suggested by the manufacturer.

Canopy counts, in-season monitoring for damage to the crop, were performed at least twice during the season, more if time allowed. For approximately every 25 acres, 1000 nuts in the canopy were examined for CM feeding damage. If more than 2% damage is found, a supplemental insecticide may be necessary. Data collected from all monitoring activities was shared with the grower/cooperator and Pest Control Advisor.

Supplemental insecticides were applied to the orchards in the puffer trials using the growers' choice of materials. Tables 3 and 4 list insecticide sprays to the San Joaquin and Glenn sites, and include all those which could affect codling moth, even though some sprays are aimed at walnut husk fly or navel orangeworm. Blocks with a history of recalcitrant codling moth problems - or where "Combo" (Trece, Inc.) baited trap catches indicated significant activity – were treated with insecticides during the first and/or second codling moth generations, before damage reached levels considered unacceptable. The intent of this strategy was to reduce resident codling moth populations and damage potential early in the season, thus allowing pheromones to maintain control of codling moth for the remainder of the season. Codling Moth damage, total trap catches, and the number of sprays will be compared to subsequent years to demonstrate reduction of broad spectrum insecticides and to move to softer insecticides to supplement PMD.

Harvest samples were collected during the normal harvesting operations. Protocols for the collection of harvest samples varied somewhat between the two sites due to the difference in plot layout. At the San Joaquin site, ten 50-nut samples were collected from trees throughout each test block. At the Glenn Co. site, ten 50-nut samples were collected in the general area of each of the 8 monitoring areas listed above. Samples were held in cold storage until they could be processed. All nuts were cracked and examined to determine percent damage from both codling moth and navel orangeworm.

RESULTS

Sprayable pheromone. The primary measure of success of any reduced risk pest management program is control of crop damage, especially in comparison to the grower's standard spray program. Data collected from the five CM-F trial sites was pooled and analyzed with each site considered a replication. Across all sites, both conventionally and ULV-applied pheromones provided codling moth damage suppression equal to GS treatments and superior to that achieved in untreated areas (Figure 3, Table 5). The reduced damage found in both the CM-F and GS blocks as compared to the untreated area was statistically significant at the 95% confidence level ($P = 0.0003$). Some test sites had substantial navel orangeworm infestation at harvest (Table 5). Harvest samples included some "unsound" nuts that would probably be discarded during normal pickup and processing operations, so the damage levels found in these samples were likely slightly higher than that in growers' harvest grade results.

Overall, this trial showed that CM-F treatments were the same as the grower standard with fewer insecticide applications. This shows CM-F can be integrated into a codling moth management program and sprayable pheromone can control CM damage as well as conventional methods. In several of the 2005 CM-F trials the 1X trap caught moths during the spring rainy season, showing that it was a good indicator of whether the sprayable pheromone was still working or needed to be reapplied. Early canopy counts showed high codling moth populations and the CM-F with insecticide supplementation kept CM crop damage at acceptable levels as well as the grower standard insecticide treatment program.

Aerosol puffers. At the San Joaquin site, the traps baited with the 1X lure caught no moths after puffers were deployed. "Combo" trap catches provided a good picture of CM generations and peaks in flight (Figures 4 and 5). Canopy counts were performed twice during the season, on June 20 and 21 and again on August 1 and 2. Very little evidence of damage from CM was found during these surveys, with all blocks showing less than 1% damage (Table 6).

Harvest samples included some "unsound" nuts that would probably be discarded during normal pickup and processing operations, so the damage levels found in these samples are likely to be slightly higher than what the grower incurred. Codling moth damage at harvest was reportedly significantly reduced from previous years (Joe Grant, personal communication) and navel orangeworm damage was also very low, with none of the blocks receiving more than 0.5 percent damage (Table 6).

Based on trap catches, codling moth populations at the Glenn County site were quite robust in April and May, with "combo" traps catching as many as 8 moths/trap/day. By late July, the combination of the pheromone puffers and the insecticide sprays had significantly reduced trap catches. Several traps caught only a few moths in all of July and August. The 1X traps were again shut down, once the puffers were all installed. Figure 6 shows 1X and "combo" trap catches from the Glenn site. Very little evidence of damage was found during any of the in-season damage surveys (canopy counts), and the harvest samples contained less than 1% damage, Table 7.

The grower/cooperators at both of these sites are enthusiastic about integrating aerosol puffers into their pest management program. The PMA plans to continue the aerosol puffer trials for up to four more years to demonstrate the long term population reduction and less reliance on pesticides that have been seen in other crops such as pears. In the next few years these trials will rely less and less on pesticide inputs, with the 2005 data acting as a baseline for the comparison of damage data from year to year and a documentation of pesticide reduction in each block.

DISCUSSION

The walnut PMA group will continue to investigate the use of aerosol puffers and ultra low volume application of CM-F pheromone for CM management in walnuts. These two projects represent a narrower focus towards techniques that are effective as well as economical, therefore more likely to be adopted by growers.

Due to input from growers, the PMA team developed the ULV applicator to increase the flexibility and decrease the time and cost needed for four or five sprays of CM-F. The project plans to look more closely at the deposition patterns created by this sprayer and to determine the importance of droplet sizes on the effectiveness of the CM-F. The applicator has gotten a lot of interest from growers because of the possibilities for using the same sprayer to apply materials for walnut husk fly management. The ULV applicator still needs some mechanical refinement.

Another ongoing challenge is the monitoring of CM flights in pheromone-disrupted orchards. 2005 was the second year of using the "combo" lure to overcome this difficulty. The "combo" lure proved to be dependable in the trials, and in some cases, lures were provided to neighboring growers in case the pheromone treatments (especially the puffers) shut down their conventional pheromone-baited traps. In fact, communication with neighboring growers is becoming more important as pheromones are being more widely used for pest management

The walnut PMA maintains a strong alliance between the walnut industry, UC researchers, UC farm advisors, BIOS partners, grower cooperators and PCA's. Insight from these partners helps the project to remain current in its focus. Input from end users, such as PCA's and growers, is especially important as we hope to move towards wider adoption of reduced risk pest management systems.

TABLES AND FIGURES

Table 1. Insecticide applications made to all treatment blocks in CM-F trials, 2005.

	CM-F block	GS block	Untreated
Butte-D	4/21 CM-F 5/25 CM-F[1] 6/24 CM-F[1] 7/06 Lorsban 7/25 CM-F + Lorsban 8/22 CM-F	5/06 Asana 6/25 Lorsban 7/06 Lorsban	
Butte-A	4/21 CM-F 5/24 CM-F[1] 6/24 CM-F[1] 7/23 CM-F + Imidan 8/19 CM-F + Lorsban	6/06 Lorsban 7/14 Imidan 8/24 Lorsban	
Tehama	4/23 CM-F 5/26 CM-F[1] 6/24 Imidan 6/26 CM-F[1] 7/28 CM-F 8/28 CM-F	6/24 Imidan 8/20 Asana + NuLure	
SJ-P	5/12 CM-F 6/10 CM-F 7/22 CM-F[1] 8/11 CM-F[1] 8/23 Lorsban + NuLure	7/06 Lorsban + Apollo 8/23 Lorsban + NuLure	
SJ-R	5/05 CM-F 6/10 CM-F 7/09 Penncap-M + Vendex 7/22 CM-F[1] 8/25 Malathion + NuLure 8/31 CM-F[1]	6/03 Lorsban 7/09 Penncap-M + Vendex 8/25 Lorsban + NuLure	8/25 Lorsban + NuLure

[1]Indicates CM-F applications made using Ultra Low Volume applicator.

Table 2. Selected descriptive information for SJ Puffer trial production blocks

Block	Variety*	Acres	Planted	Historic codling moth pressure/damage**
1	Tulare	20	2001	L
2	Serr/Chandler	27	1965/1995	H/M
3	Chandler	27	1992	L
4	Chandler	23	1984	H/M
5	Serr/Chandler	23	1964/1985	H/M
6	Tulare	36	2001	L
7	Howard	28	1995	L/M
8	Serr/Chandler	25	1965/1990	M
9	Serr/Chandler	50	1969/1984	H
10	Vina/Serr	23	1985/1967	H
11	Howard	20	2002	L
12	Serr/Chandler	27	1969/1995	M/H
13	Chandler	23	1993	L
14&15	Serr/Chandler	49	1969/1992	H/M
18	Serr/Chandler	6	1969/1992	M/H
19	Hartley	28	1967	L/M
20	Chandler/Howard	28	1995	L
22	Chandler	23	1987	L
23	Howard	10	1992	L/M
24	Vina	51	1980	H
25	Serr/Chandler	17	1969/1990	M/H

Table 3. Supplemental Insecticides at San Joaquin puffer site in 2005.

Block	Variety	Date	Material
1	Tulare	8/24	Malathion + NuLure
2	Serr	5/17 8/08 8/24	Lorsban Malathion + NuLure Malathion + NuLure
3 & 20	Chandler		
4	Chandler	5/24 7/02 8/24	Lorsban Warrior Malathion + NuLure
5	Serr & Chandler	5/19 7/04 8/05 8/24	Lorsban Warrior Malathion + NuLure Malathion + NuLure
7	Howard	8/12 8/15 8/17	Malathion + NuLure Warrior Warrior
8	Serr & Chandler	5/18 8/13	Lorsban Malathion + NuLure
9	Serr & Chandler	5/21 7/01 8/05	Lorsban Warrior Malathion + NuLure
10	Vina & Serr	5/24 8/08 8/24	Lorsban Malathion + NuLure Malathion + NuLure
12	Serr & Chandler	5/17 7/02 8/13	Lorsban Warrior Malathion + NuLure
13 & 22	Chandler	8/16	Warrior
14 & 15	Serr	5/17 8/12	Lorsban Malathion + NuLure
18	Serr	5/20 8/08	Lorsban Malathion + NuLure
19	Hartley	5/24 8/08	Lorsban Malathion + NuLure
23	Howard	8/24	Malathion + NuLure
24	Vina	5/18 8/08 8/24	Lorsban Malathion + NuLure Malathion + NuLure
25	Serr & Chandler	5/20 8/08	Lorsban Malathion + NuLure

Table 4. Supplemental insecticides at 2005 Glenn puffer site.

Block	Date	Material
Vinas	May 6 June 25 July 7 Aug. 10	Asana, every other row Warrior Penncap-M Asana
Tehamas	May 6 July 7 Aug. 10	Asana, every other row Penncap-M Asana
Chandlers	July 7 Aug. 10	Penncap-M Asana

Table 5. Percent Damage at Harvest from Codling Moth and Naval Orangeworm in 2005 CM-F trials.

	CM-F		Grower Standard		Untreated Control	
Site	% CM	% NOW	% CM	% NOW	% CM	% NOW
Butte-D	1.2	2.6	1.4	0.4	-	-
Butte-A	6.0	15.6	5.7	2.4	8.4	3.6
Tehama	0.0	1.2	1.6	0.2	2.6	1.2
SJ-P	5.4	2.3	4.9	4.8	7.4	4.6
SJ-R	1.0	0.2	0.4	1.2	3.3	4.2
Average	2.7	4.4	2.8	1.8	5.4	3.4
St. Dev.	2.8	6.4	2.3	1.9	2.9	1.5

Table 6. Percent damage found at canopy counts and harvest at San Joaquin site.

		Canopy Counts % CM		Damage at Harvest	
Block	Variety	June 20-21	Aug. 1-2	% CM	% NOW
1	Tulare			0.2	0.0
2	Serr	0.0	0.2	2.0	0.0
3 & 20	Chandler			0.6	0.0
4	Chandler	0.1	0.2	0.4	0.2
5	Serr & Chandler	0.7	0.5	Serr 2.4 Chandler 0.0	0.0 0.8
7	Howard	0.2	0.1	0.2	0.0
8	Serr & Chandler	0.0	0.5	Serr 1.2 Chandler 0.4	0.0 0.4
9	Serr & Chandler	0.0	0.3	Serr 2.4 Chandler 0.0	0.0 0.0
10	Vina & Serr	0.0	0.3	1.6	0.2
12	Serr & Chandler		0.3	Serr 1.2 Chandler 0.0	0.0 0.0
13 & 22	Chandler			2.0	0.4
14 & 15	Serr		0.7	2.6	0.4
18	Serr	0.0	0.2	2.8	0.4
19	Hartley	0.4	0.1	1.0	0.0
23	Howard	0.2	0.5	0.0	0.0
24	Vina	0.1	0.4	2.8	0.0
25	Serr & Chandler	0.1	0.5	Serr 0.0 Chandler 1.1	0.0 0.3

Table 7. Percent damage found at canopy counts and harvest at Glenn site.

	Canopy Counts % CM		Damage at Harvest	
Location	June 15	Aug. 17	% CM	% NOW
Vinas NW	0.2	0.1	0.4	0.2
Vinas NE	0.1	0.1	0.4	1.0
Vinas SW	0.1	0.2	0.4	0.6
Vinas SE	0.1	0.1	0.6	0.4
Tehamas W	0.0	0.1	0.2	0.6
Tehamas E	0.0	0.3	0.0	0.4
Chandlers W	0.4	0.3	0.2	0.0
Chandlers E	0.1	0.1	0.4	0.0

Figure 1. Map of San Joaquin Puffer test site

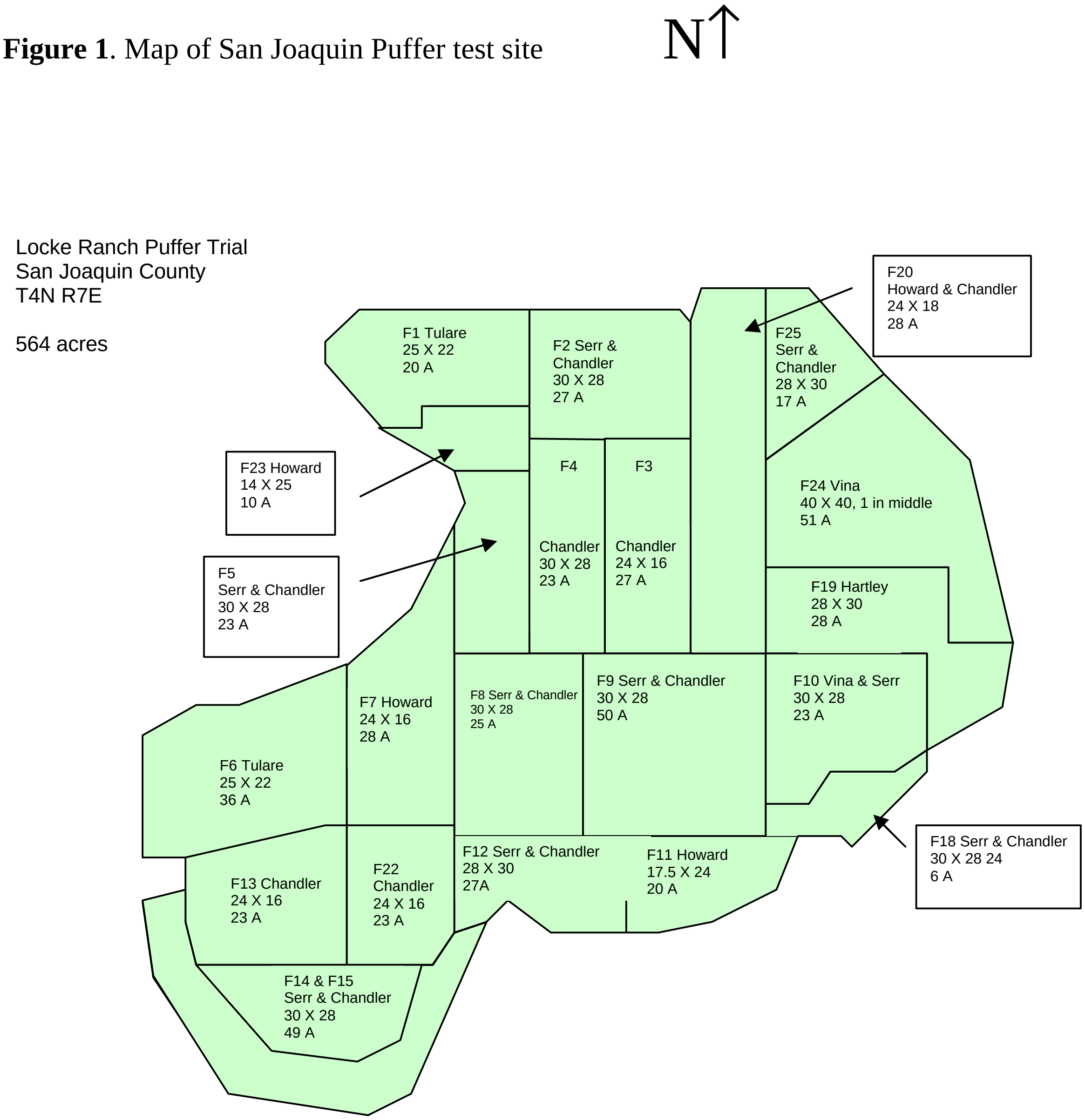
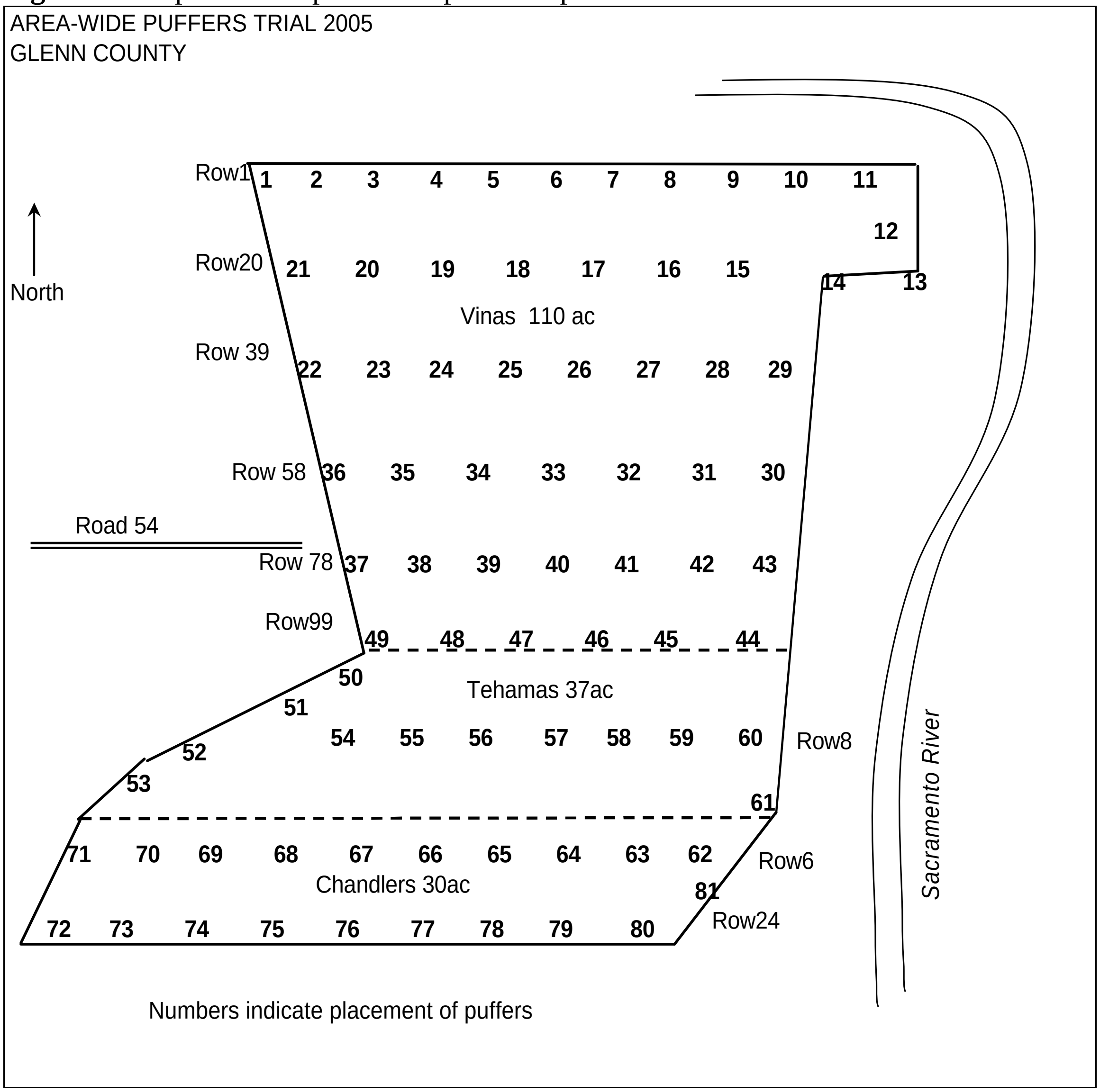


Figure 2. Map of Glenn puffer test plot with puffer locations and numbers



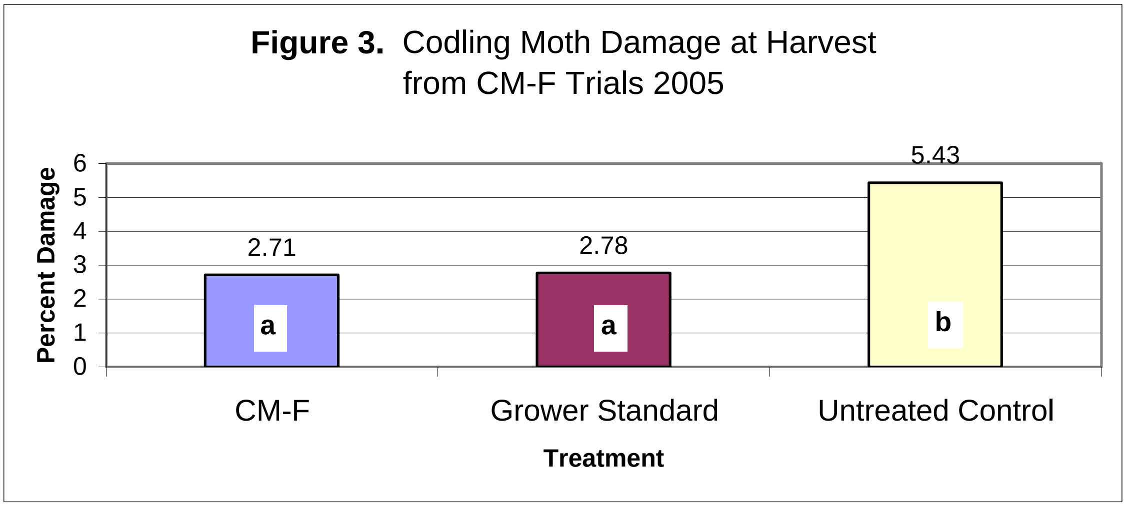


Figure 3. Codling Moth Damage at Harvest from CM-F Trials 2005
Percent Damage
6
5
4
3
2
1
0
2.71
2.78
5.43
a
a
b
CM-F
Grower Standard
Untreated Control
Treatment

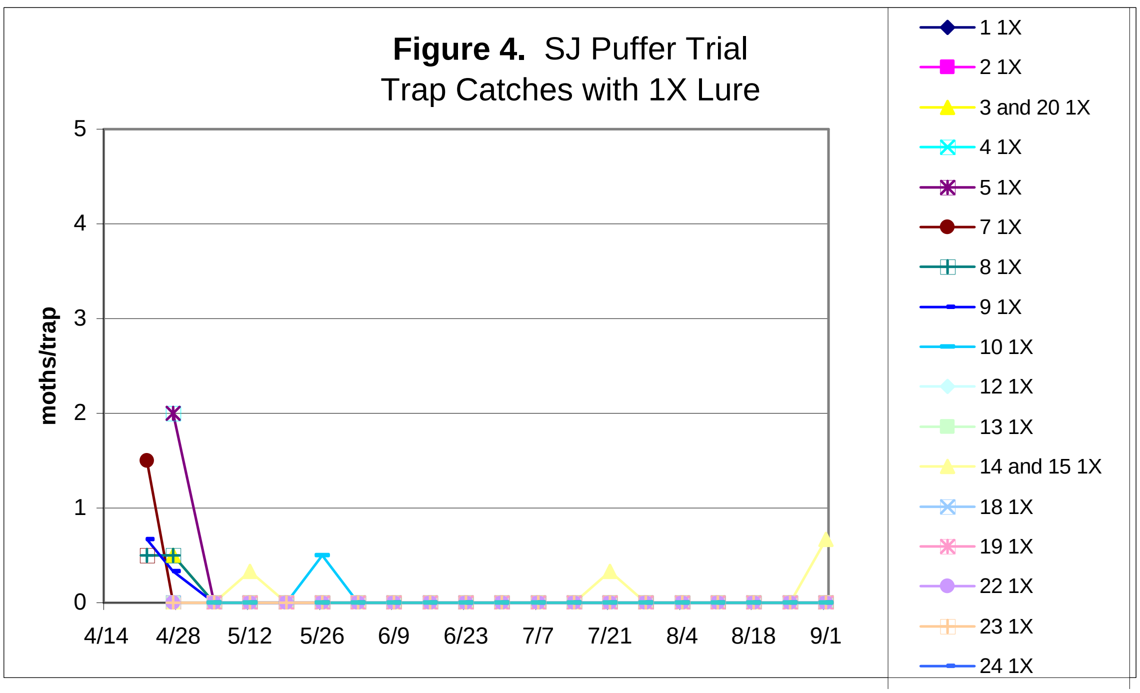


Figure 4. SJ Puffer Trial Trap Catches with 1X Lure
moths/trap
5
4
3
2
1
0
4/14
4/28
5/12
5/26
6/9
6/23
7/7
7/21
8/4
8/18
9/1
1 1X
2 1X
3 and 20 1X
4 1X
5 1X
7 1X
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19 1X
22 1X
23 1X
24 1X

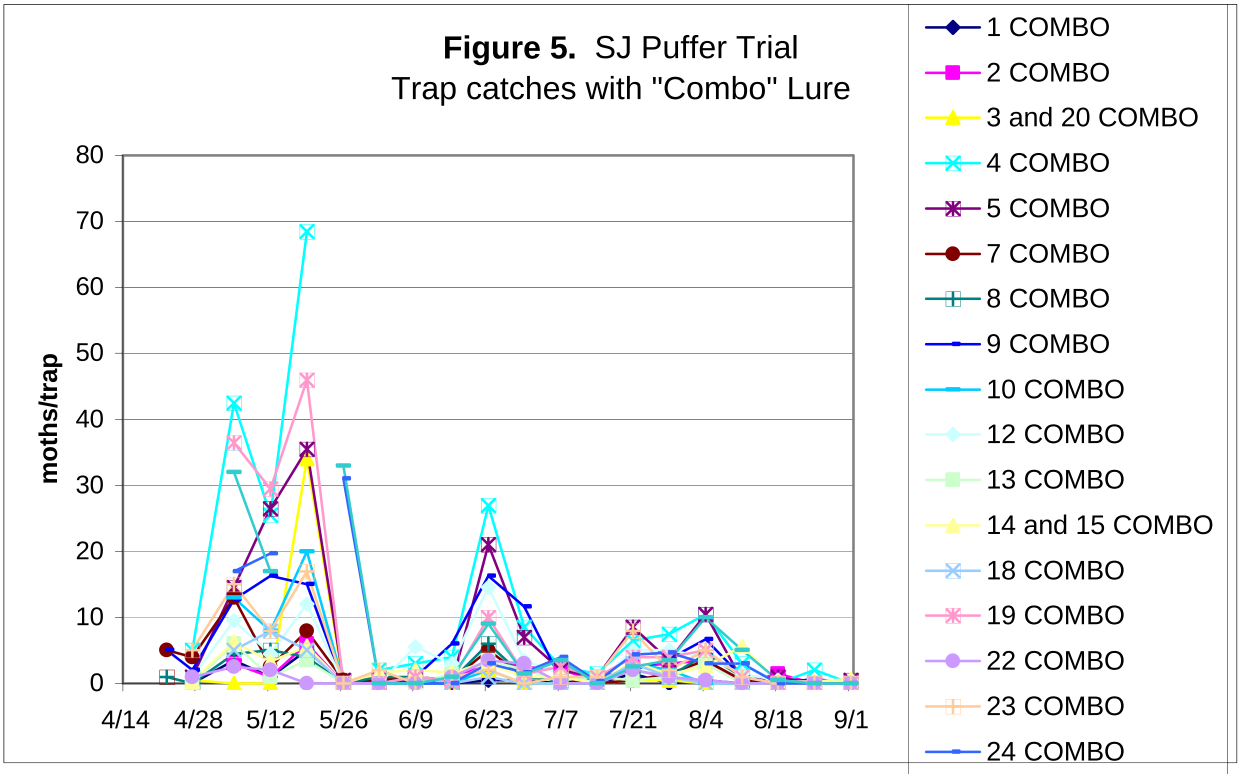
Figure 5. SJ Puffer Trial
Trap catches with "Combo" Lure
moths/trap
0
10
20
30
40
50
60
70
80
4/14
4/28
5/12
5/26
6/9
6/23
7/7
7/21
8/4
8/18
9/1
1 COMBO
2 COMBO
3 and 20 COMBO
4 COMBO
5 COMBO
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22 COMBO
23 COMBO
24 COMBO

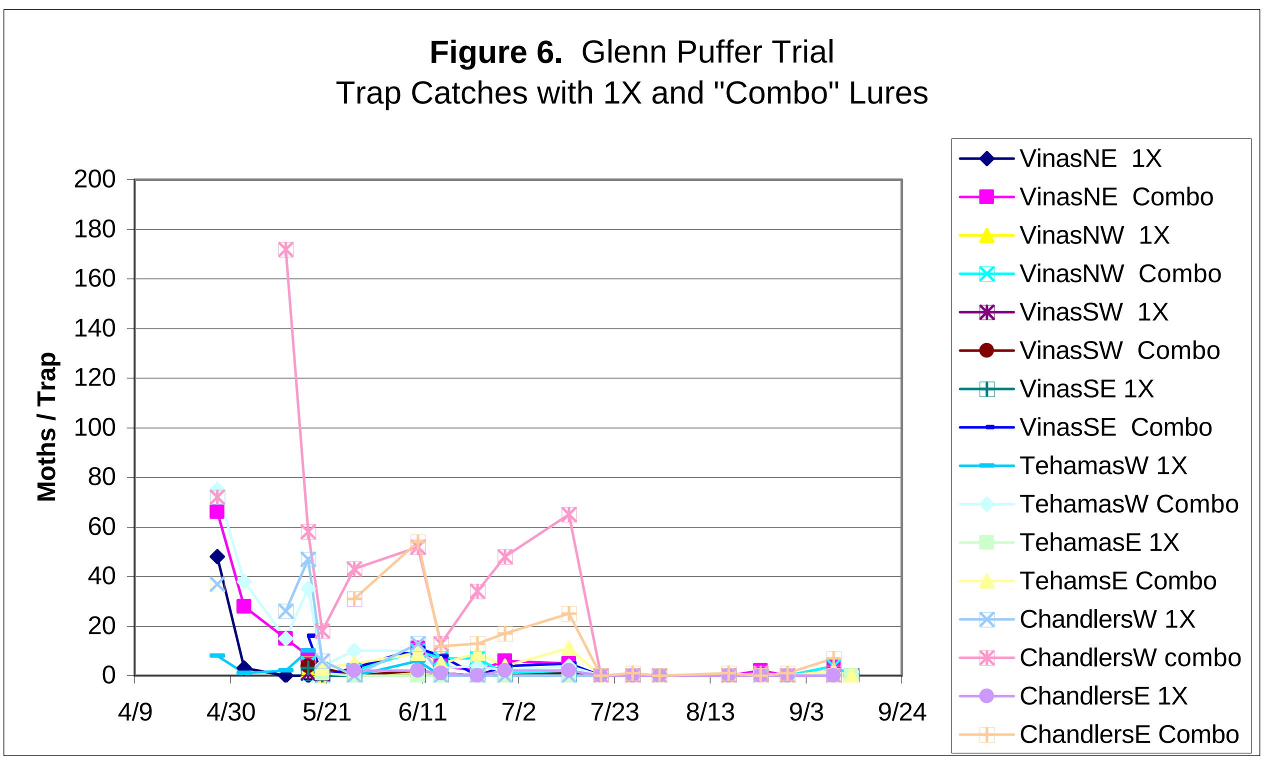
Figure 6. Glenn Puffer Trial
Trap Catches with 1X and "Combo" Lures
Moths / Trap
0
20
40
60
80
100
120
140
160
180
200
4/9
4/30
5/21
6/11
7/2
7/23
8/13
9/3
9/24
VinasNE 1X
VinasNE Combo
VinasNW 1X
VinasNW Combo
VinasSW 1X
VinasSW Combo
VinasSE 1X
VinasSE Combo
TehamasW 1X
TehamasW Combo
TehamasE 1X
TehamsE Combo
ChandlersW 1X
ChandlersW combo
ChandlersE 1X
ChandlersE Combo