Dispersal of NOW and Prediction and Prevention of NOW Damage in Almonds

Project No. : **07-ENTO1-Burks**

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Objectives:

1) Quantify the association of the number of NOW in traps with subsequent NOW damage to almonds

2) Examine the effect of pheromone permeation on the movement and mating status of NOW females in large mating disruption blocks

3) Examine the effect of Intrepid® on male response to virgin-baited flight traps

Interpretive Summary:

1) Association of number of NOW in traps with subsequent damage.

Overview: A preliminary comparison of data from 2006 and 2007 suggests that egg traps may track year-to-year variation in NOW abundance and damage better than pheromone traps. Between 2006 and 2007 there was a 74% reduction in NOW damage to Nonpareil in the study plots, and an 89% reduction in Monterey. In the first two flights the total number of males captured in 2007 was equal to or greater than in 2006, whereas significantly fewer eggs were found in egg traps in flight 2 in 2007 compared to 2006. We also found that, while 10% crude almond oil (CAO) increases the number of eggs deposited per trap, it does not increase the number of traps on which egg are deposited. Bootstrap analysis suggests that the number of oviposition traps used to make decisions may be more important than the addition of attractants such as CAO.

More information: The 2007 field season was the second year of an experiment in which sticky traps baited with virgin females as a pheromone source and 2 egg traps were placed in the center of 1 of 41 40-acre plots spread across the Kern County. In 2007 one of the egg traps at each plot had 10% crude almond oil (CAO) added, whereas the other did not. Two delta traps with almond meal as a bait for females were also included at each plot, one with and one withot 10% CAO. A central 2. 1 acre area of these plots was flagged to prevent application of insecticides targeting NOW, and harvest samples of Nonpariel and Monterey almonds totaling 1,000 to 3,000 nuts was collected from each plot and evaluated for almond damage.

NOW damage to almonds in the test plots was 1. 1% in 2007 v. 4. 2% in 2006 for Nonpareil, and 0. 5% v. 4. 4% in Monterey. In contrast, the total number of males captured per plot per flights was significantly greater in 2007 compared to 2006 for flight 1 (Table 1), and not significantly different for flight 2. Only in flight 3 was the number of males captured in pheromone traps significantly less in 2007 compared to 2006. The timing of males captured in pheromone traps also differed between the years, with more males captured early in flights 1 and 2 in 2007 compared to 2006 (Fig. 1A). We have not yet examined the 2007 data using regression analysis; that analysis will be included in the final report for 2007.

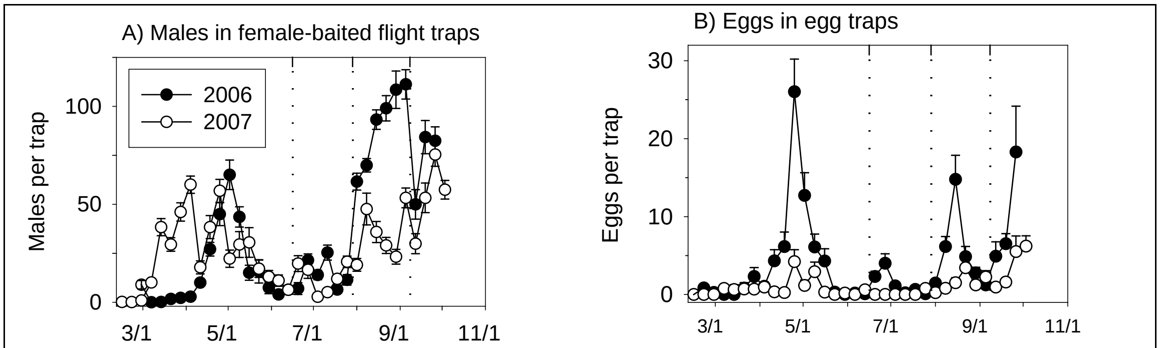

Fig. 1. Weekly number (mean ± SE) of (A) males in pheromone traps and (B) eggs on egg traps in 41 almond plots in 2006 (dark cirles) and 2007 (open circles). Vertical dashed lines show divisions between flights.

Table 1. Comparison of cumulative counts (mean ± SE), over flights, of males in pheromone traps and eggs per plot (2 egg traps per plot)

	Males in pheromone traps		Eggs on egg traps	
Flight	**2006**	**2007**	**2006**	**2007**
1	15. 9 ± 1. 14	23. 7 ± 1. 18	3. 6 ± 0. 38	0. 9 ± 0. 16
2	14. 2 ± 1. 23	12. 8 ± 1. 27	1. 4 ± 0. 26	0. 1 ± 0. 06
3	90. 0 ± 2. 82	34. 5 ± 2. 22	5. 3 ± 0. 67	1. 6 ± 0. 28

Unlike males in pheromone traps, there were nominally fewer eggs in egg traps in 2007 compared to 2006 in all three flights (Tables 1, 2). As is implicit in Table 2, distribution of eggs per trap over flight 1-3 in either year is a significant departure from a normal, a Poisson, or a negative binomial distribution. Mixed models ANOVA indicates that there were more eggs per plot in flight 1 in 2006 than in 2007, but a residuals plot from that analysis indicates that the assumptions for ANOVA were violated. Contingency table analysis using chi-square statistics (nonparametric) did not find a significant difference in flight 1 between the number of eggs or traps with eggs in 2007 v. 2006. However, by any analysis there were significantly fewer plots with eggs detected in flight 2 in 2007 compared to 2006.

Table 2. Various statistics for comparison of eggs on egg traps at 41 plots (2 traps per plot) between 2006 and 2007

	%Plots with eggs deposited on traps		Median eggs per plot		Maximum eggs per plot	
Flight	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
1	90	76	67	18	506	148
2	56	15	3	0	179	26
3	93	66	31	8	476	63

For 2007, we also examined differences between traps with and without 10% CAO in numbers of eggs on egg traps and number of egg on traps with eggs. This analysis was also extended to females in sticky traps baited with almond meal with or without 10% CAO. Chi-square tests indicate that the *number* of eggs in flights 1 and 2 from all 41 plots was significantly greater in the 41 egg traps with 10% CAO compared to the 41 without it (Table 3). However, the number of *traps that had eggs* (i. e. , > 0) was not significant different with or without CAO in flights one or two. The addition of 10% CAO also had no effect on either the number of delta traps with females or the number of females per traps. These observations suggest that 10% CAO does not affect the likelihood that a NOW female will oviposit on an egg trap, but does affect the number of eggs that will be deposited if oviposition occurs.

Table 3. Effect of ommission (CAO-) or addition (CAO+) of 10% crude almond oil on eggs on egg traps or moths in Delta traps baited with almond meal in 41 PFC almond plots in 2007

		Sum of Eggs or moths		%Traps w Eggs or Moths	
Trap Type	**Flight**	**CAO-**	**CAO+**	**CAO-**	**CAO+**
Egg	1	418	861	51	54
	2	15	50	7	12
	3	384	388	44	51
Delta	1	19	26	32	29
	2	4	4	7	7
	3	22	33	37	39

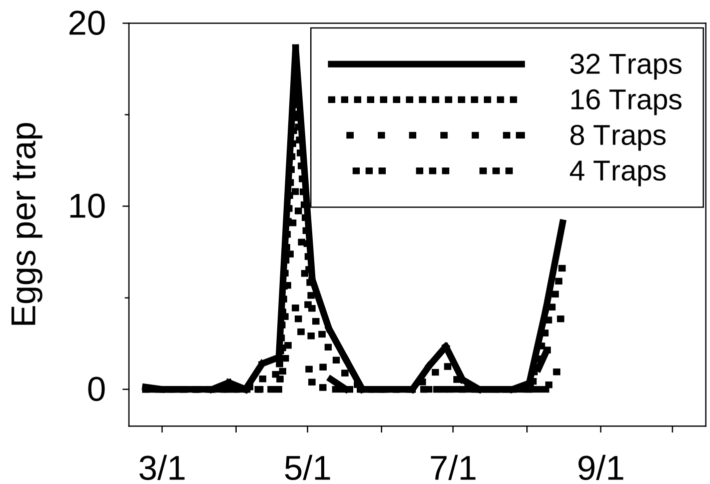

Fig. 2. Weekly 10th percentile trap means observed with bootstrap analysis using 2000 random samples with replacement using sample sizes of 4, 8, 16, or 32 traps. These results indicate a >90% probability of detecting the second flight with 16 or 32 traps, but not with 4 or 8.

Bootstrap analysis was used to examine the egg trap data from 2006. Random sampling with replacement was used to examine the range of the estimated mean eggs per trap, and the 10% percentile weekly estimate was plotted for each sample size (Fig. 2). The results indicate that, for 2006, one would have had a ≥90% chance of detecting the peak for the second flight with 16 or 32 traps, but not with 4 or 8. This finding, in combination with the previous observations concerning the effect of 10% CAO on traps with eggs and eggs per trap, suggests that the number of egg traps used is likely more important for the detection of NOW activity than the use of 10% CAO to make traps more attractive.

2) Movement of NOW females in large mating disruption blocks.

Overview: The pattern of NOW harvest damage to Nonpareil was examined at 200 foot intervals along 1000-foot transects. These data were compared to past mark-release-recapture experiments and laboratory data on lifespan and daily reproductive capacity. The results of this comparison indicate that, while individual NOW of both sexes can travel great distances, in tree nut orchards most oviposition and damage occurs closer to where NOW females emerge from pupae to adults.

More information: Female movement and activity was monitored in three 320 acre sites comprising adjacent 160 acre blocks under conventional and mating disruption treatment for control of navel orangeworm treatment. Female activity and movement was monitored using a protein mark-capture technique and blacklights. We have not yet processed those data; they will be reported in the final report for 2007. However, since these experiments depending on capturing females, the low NOW abundance in 2007 (as indicated by the damage data and the trapping data for eggs and females reported in the previous section) do not bode well for obtaining useful data from these experiments.

We examined 6 1000-ft transects, (as described) beginning at even intervals around the edge of one of the 320 acre blocks. The transects on the north and east had uniform NOW damage of ≤5%, whereas those on the south and west (two from the conventional and one from the mating disruption plot) had damage ranging from 15 to 20% on the edge and declining to ≤5%.

Distributions often used for examining insect dispersal include inverse regression (y = *a* + *b*/dist), negative exponential (y = *a**exp(-*b**dist), or the Cauchy distribution. These are all long-tail distributions—they predict a few individuals travel relatively far and most don't travel very fair.

We fit the former two models to these three transects. The results are shown in Fig. 3. Using either model, the predicted values indicate that half the difference between the "dirty" edge and the lower intererior plateau level of damage was achieved at 200 feet (~8 rows) and the lower plateau was reached at 400 feet.

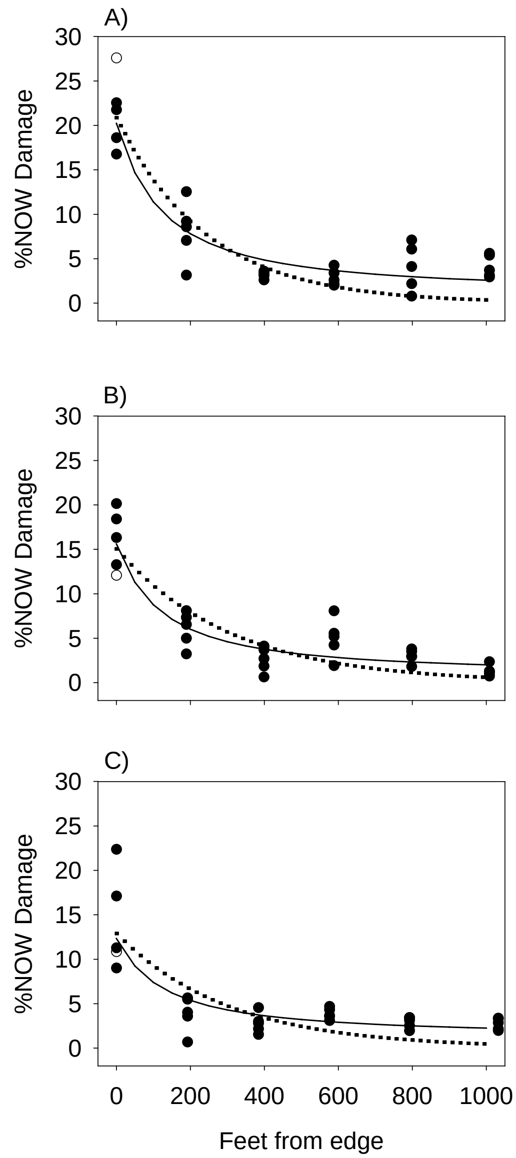

Fig. 3. Comparison of observed NOW damage in Nonpareil almonds (black dots) with predictions using inverse (solid line) and negative exponential (dotted line) regression models along 1,000 foot transects starting on the west (A) and southern (B, C) edges of a 320 block of almonds.

The foregoing observations are consistent with other research results. In 2006 we found a similar distribution over the first several days of a mark-capture experiment with newly-eclosed females. In the laboratory we have examined longevity and fecundity of NOW under of temperature/photoperiod regime typical for June 20 in Kern County. We found that, while female with access to sugar solution live 13 ± 0. 7 d (mean ± SE), and 44 ± 8% of fertile eggs were deposited by the end of the second night after eclosion. Thus, while NOW are capable of traveling considerable distances, various lines of evidence indicate that, in tree nut orchards, most oviposition and most damage occurs fairly near the location where the female emerges from the pupa.

3) Effect of Intrepid® on male response to virgin-baited flight traps.
Overview:Field experiments examined the effect of Intrepid on the ability of NOW males to locate virgin females in flight traps. The results provide possible evidence that reduced ability to find females is greater with exposure to this insect growth regulator than with exposure to Imidan, a neurotoxin. If so, Intrepid might be have a more synergistic effect when used in conjuction with mating disruption.

More information: A randomized complete block experiment was conducted in 40-acre almond plots centered on either side of four 160 acre blocks. In each plot, four virgin-baited traps were arranged in a square, 165 feet apart and near the center of the plot. Males were monitored for 2 weeks before and after applications targeted at the first and second flights (Table 4). In the first application the "Imidan" plots received no pesticide, whereas in the second they received Imidan. The "before-after" difference was significantly different from 0 for Intrepid but not for Imidan on the second application, and was not significantly different between the Intrepid plots and the untreated control (i. e. , "Imidan plots") for the first application. It is therefore possible that, under the hotter mid-summer conditions, sub-lethal effects of Intrepid have greater impact on reproductive performance of NOW males compared to Imidan.

Table 4. NOW per virgin-baited trap (mean ± SE) averaged by plot over the two weeks before and after insecticide treatments on May 1 and July 5

Application	Period	Imidan	Intrepid
May 1	Before	22. 5 ± 1. 00	23. 3 ± 2. 72
	After	20. 0 ± 2. 60	21. 2 ± 3. 67
July 5	Before	12. 2 ± 5. 15	11. 7 ± 4. 28
	After	4. 5 ± 1. 22	1. 1 ± 0. 52