FINAL PROJECT REPORT YEAR: 3 of 3

WTFRC Project Number: CP-07-708

Project Title: Interaction of dispersal and management of CM and OBLR

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Total project funding request: Year 1: $60,112 Year 2: $62,452 Year 3: $65,213

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Budget 1:

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Item	Year 1: 2007	Year 2: 2008	Year 3: 2009
Salaries[1]	$28,332	$28,332	$29,151
Benefits	$10,200	$11,049	$11,660
Wages	$12,000	$12,480	$12,979
Benefits	$1,380	$1,959	$2,336
Equipment	$0	$0	$0
Supplies[2]	$6,000	$6,300	$6,615
Travel[3]	$2,200	$2,332	$2,472
Total	$60,112	$62,452	$65,213

Footnotes:

[1] Tawnee Melton 0.75 FTE

[2] Supplies include general lab supplies and ELISA-specific supplies, field supplies including traps, lures, markers, cell phone charges

[3]Travel costs are within-state travel to field sites and vehicle costs

Objectives:

1. Evaluate methods to age-grade CM caught in traps throughout the season. This will be used to evaluate times of peak reproductive potential during which control measures should be optimized.
2. Determine the effect of flight of specified distances on the reproductive ability of CM and OBLR males and females using laboratory assays.
3. Evaluate the effects of different cover sprays on dispersal of CM using protein markers and investigate the effects of border sprays of kaolin on movement patterns.

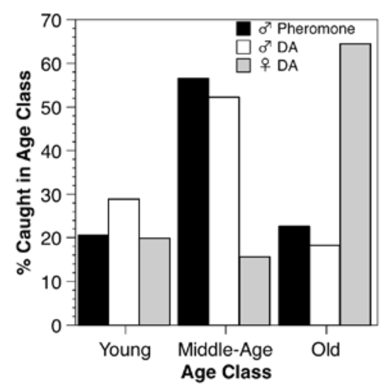
Significant Findings:

- We developed a method to age-grade CM males and females collected in traps that is based primarily on the condition and appearance of the reproductive system.
- OBLR age-grading was not possible because there was no significant variation in appearance of any character.
- Our CM age-grading showed in the overwintering generation that the middle 50% of young moths occurred in a relatively short interval, while middle-aged and older moths were captured over a much longer period. These differences were largely not present during the first summer generation.
- CM males and females were completely unaffected reproductively by flights of ≈ 6,200'.
- OBLR reproduction was heavily affected if neither sex was flown, reducing reproduction ≈2.5 fold compared to when either one or both sexes were flown before mating.
- Our field tests of cover sprays on dispersal of CM were highly variable and showed no statistically significant differences between the Assail and Guthion treatments. Flight mill studies were shown to be cheaper and a more sensitive method to evaluate effects of cover sprays.
  - Flight mill studies showed that sublethal (LD_{10}) doses of Assail significantly reduced average flight distance, number of flights, and flight duration of CM females and males.
  - OBLR females exposed to sublethal doses of Assail and Guthion showed significant reductions in flight distance, number of flights and flight duration. Males were unaffected.
- Our kaolin studies showed that a three tree border can reduce CM migration significantly, even in the face of high population pressure.

Results and Discusssion:

Objective 1. We used a combination of statistical procedures to classify all the males and females caught in our 2007-2008 seasons as young, middle aged, or old. For each moth, we evaluated mating status, size of fat body cells, amount and color of the fatbody, size of the abdomen and color of the reproductive tract. Our initial clustering analysis indicated that female classification required the size of fatbody cells, the amount of fat body, color of the fat body, and color of the reproductive tract for accurate classification. Male classification required the same variables, but also used the size of the abdomen. Using these factors, we age-classified each moth and then used discriminant analysis to evaluate the error rate. Our data showed that the error for females was only 3%, male error rate was 1.5% when moths were collected using the Trécé DA Combo lure and 0.3% when males were collected using pheromone traps. There were only minor differences in the percentage male age classes caught between the pheromone and DA Combo lures, with >50% the males being in the middle age group (Fig. 1). However, for females captured in Combo DA lures baited traps, only 35% of the were in the young or middle group, with 65% being old. These

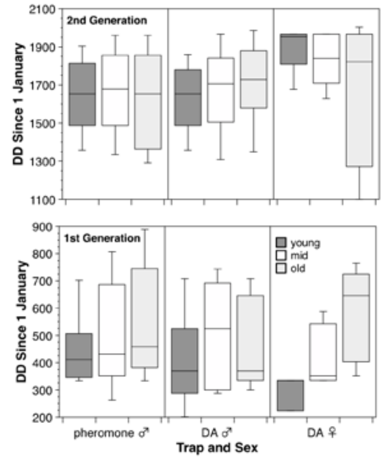
Fig. 1. Age classes of moths captured in 2007-2008 by trap type.



data show that the DA Combo trap has a bias towards sampling primarily older females.

With the classification system applied, we were able to determine the DD at which moths of different ages were caught throughout the season (Fig. 2). We found that in the first generation, the middle 50% of the distribution of young adult males was caught between 350 and 500 DD for pheromone baited traps and 290-525 DD for traps beited with DA combo lures (Fig. 2). The same values for moths classed as middle aged or old are greatly expanded particularly towards the end of the generation. Interestingly, if we target the center 50% of the collection of young adults, that would be near the timing of the delayed first cover if an ovicide or oil is used early in the season (525 DD since 1 January or 350 DD since first moth). Females tended to show a much greater separation in capture of the different age classes.

Fig. 2. DD at which the different age classes were caught in 2007-2008 by trap type, sex and generation. The boxes show the point at which 25 and 50% of moths were caught. The line in the middle shows 50% catch and the whiskers show 10 and 90% emergence.



Trends in emergence of the different age classes during the second generation do not show the large differences in spread of emergence seen in the first generation, but the tendency of slightly increasing median and broader spread is seen in the male emergence patterns (Fig. 2). The emergence of females in the second generation as measured by the DA Combo lures is considerably distorted by low number of females caught that were in good enough condition to classify, especially in the young and middle-aged groups (4 and10 moths, respectively). All the other groupings except the old males in the DA Combo lures (70 moths) had between 100 & 1000 moths and likely accurately reflect the emergence patterns in the field.

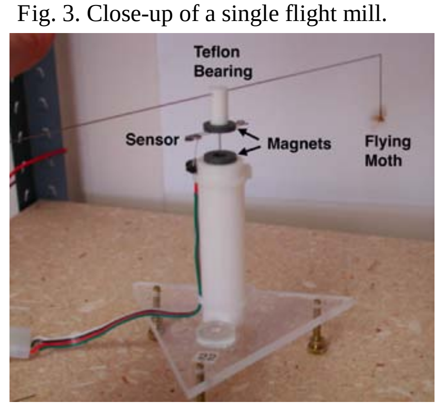
Objective 2. We have built 24 digital flight mills that can be used to evaluate dispersal capabilities of CM and OBLR and the effect of dispersal on reproduction. We are able to run 24 insects simultaneously and the data are recorded by a computer. This data allows us to determine how far and fast they fly, whether they stop and rest, the number of flights, and the duration of flights.

The flight mills use magnetic levitation and Teflon bearings to reduce friction to a minimum (Fig. 3). A one-foot long hollow tube is attached to the bearing and moths are attached to the arm by gluing a small insect pin to their back on the thorax (to prevent interference with the wing motion). The pin is then inserted into the hollow tube. As the moths fly in circles, a sensor detects a small magnet attached near the bearing on every revolution. After flight, the moths are easily separated from the insect pins so that they can be used in our reproductive experiments.

Effect of flight on reproductive output of CM and OBLR

To test the effect of flight on reproductive output, we reared them until the adult stage and the day after emergence, we flew them for roughly 6,200 feet, then paired them in one of four ways: (1) both members of the pair were flown, (2) females were flown and paired with males that were tethered, but not flown, (3) males that were flown and paired with females that were tethered, but not flown, or (4) both pairs were tethered, but neither flown (control group). We then measured their daily mortality, and egg production, and the egg hatch. We used life tables to analyze the data and present the mortality corrected fertility (l_xM_x) as the effect of flight on reproductive rate.

Fig. 3. Close-up of a single flight mill.



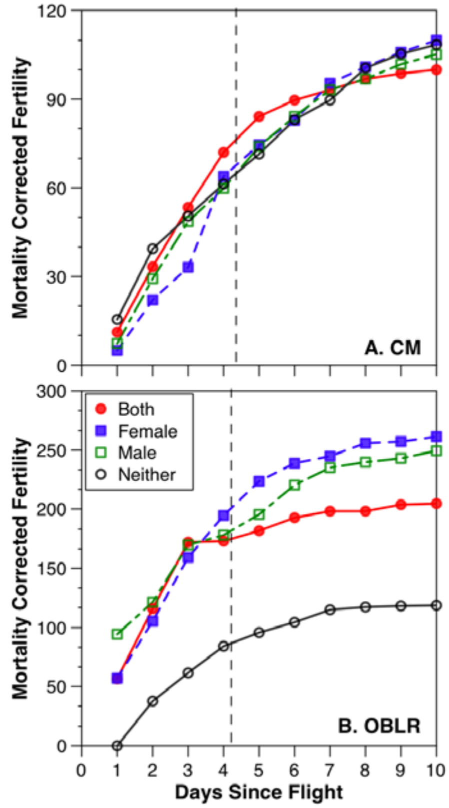


Fig. 4. Effect of flying ♂ and/or ♀ CM and OBLR on reproductive output. A. CM . B. OBLR. Dotted line is average longevity in the field in the summer.

Because moths can only take in a limited amount of energy by feeding on honeydew in the orchard, we had hoped to see that moths that flew would have had reduced survivorship, reduced sperm packet sizes (males) or egg production (females). However, what we found was that there were no significant differences in reproductive rate or mortality between CM pairs that flew and those that did not (Fig 4A). This is one of the worst case scenarios from the standpoint of population biology. Basically, if moths fly 6,200 feet, their reproduction and longevity is completely unaffected, meaning that moths migrating into the orchard can easily affect population dynamics in the new location. The 6,200 foot figure indicates that moths may move and infest >2,772 acres without an reproductive disadvantage.

OBLR had a different response to flight than CM, with the individuals that were not flown having the lowest reproductive rate, followed by those pairs where both members of the pair were flown (Fig. 4B). There were no differences between the pairs where ony one sex was flown. This sort of result is nearly as bad as the response from CM - basically, migrating individuals have unimpared reproduction (as with CM). The only bright side is that if moths within the field do not fly much, they will have a lower reproductive rate. Unfortunately, that means the impact of the migrating moths is proportionally greater (≈ 2-2.5 fold higher) on population growth when they arrive at a new location compared to moths that do not fly before mating. Thus migrating indivduals carrying a gene for pesticide resistance should be able to easily pass that on in the area where they settle.

Objective 3. Cover Spray Effects on CM Fligth Distances: Methods (field studies)

2007. We concentrated on evaluating the effects of Assail and Guthion on CM movement using the protein markers. Two plots were set up in a large Brewster, WA orchard. In the first plot, trees were planted on a 12 x 18' spacing, and were 24 x 18' spacing in the second. The trapped area of both plots was roughly 12.6 acres, but the first plot was longer and narrower (1476' x 360') than the second (1115' x 492'). We placed 60 traps in the first plot and 44 in the second; in both plots, we used the Combo DA lures in standard LPD traps. Both plots were under mating disruption using a full rate of Isomate C+ dispensers.

Traps were placed uniformly throughout both blocks and checked 3 times per week during a three-week period of the first and second flights. All moths captured were dissected to determine mating status and age of the moth using the classification scheme reported in objective 1.

We applied 150 gallons of a 10% egg whites solution to the center 1.5 acres in both plots on the same dates. Egg whites were applied once per generation at roughly 25% adult emergence. In the first generation, Assail was applied to plot 1 and Guthion to plot 2. During the second generation, the treatments were reversed, so that Assail was applied to plot 2 and Guthion to plot 1.

During the first generation, we had a small amount of rain one week after treatment, and then an additional 0.3" fell (according to the Brewster Flat PAWS station) during the third week, that would have affected the data. In the second generation, 0.2" fell two days after our treatments were applied, again potentially affecting marking throughout the experiment.

2008. We set up two different plots to evaluate the effect of Assail and Guthion cover sprays on the dispersal of codling moth. The first plot was set up in Manson during the first generation, but only 14 moths were caught in 120 traps. The second plot was set up during the second generation in Quincy, and we captured 1,651 moths, of which roughly 10% (171) were positively marked.

The second plot consisted of two blocks: one was 19.5 acres (≈ 1487' long x 560' wide) and treated with Guthion and the second was 12.9 acres (≈794' long x 687' wide) and treated with Assail. Treated areas in each block were 350' long by 112' wide and situated on one end of the block, thus the furthest distance outside the marked area that could be recorded in each block was 1375' in the Guthion block and 575' in the Assail block - after those distances, there was a wide road (85'-105') between the blocks and adjacent orchards. We set up four transects in each plot away from the marker treated areas with equal distances for the full length of the Assail block; in the longer Guthion block, we added a lower density of traps out to the end of the block. For comparison of dispersal in the two plots, we initially only looked at the moth captures in the transects out to the 575' in the Guthion block, then compared the dispersal in the full range of traps with the understanding that any trap capture beyond 608' in the Guthion block would a priori cause higher mean dispersal distances.

We used the Trécé DA Combo lures so that we would obtain at least a small number of female moths and to have consistency in trap catch as both blocks were under mating disruption. Each moth captured was sexed and then dissected to determine moth age and mating status.

Results - 2007 Cover Spray Effects: We caught 333 moths in the two plots over both generations; 144 in plot 1 and 189 in plot 2. In plot one, 137 (95%) were caught in the first generation. In plot 2, 61% were caught in the first generation. The overall sex ratio was 89.2% males, which is similar to other studies we've performed with the Combo DA lures.

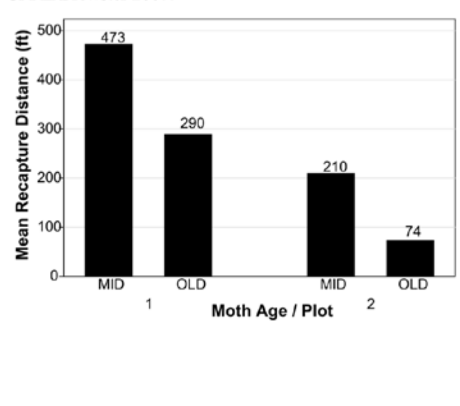
We caught 29 marked moths, 13 in plot 1 and 16 in plot 2. The low percentage marking is likely a result of the rain and restricted the complexity of the analysis that we could perform. We found that there were no significant differences in dispersal distances related to the pesticide. This likely related to the low power of the test caused by the low marking rate.

Using the age classification system, old moths dispersed an average of 160' and middle-aged moths averaged 364'. In each plot, the average dispersal distance was significantly lower for older individuals compared to middle aged ones (fig. 5). Only 3 marked females dispersed out of the area treated with egg whites, and they showed similar results to the males, with the two mid-aged females dispersing an average of 567' versus 154' for the single old female.

The evaluation of mating status also suggested that mated moth fly further than unmated ones. The results were especially pronounced in the first plot (higher tree density plot) with mated moths flying twice as far.

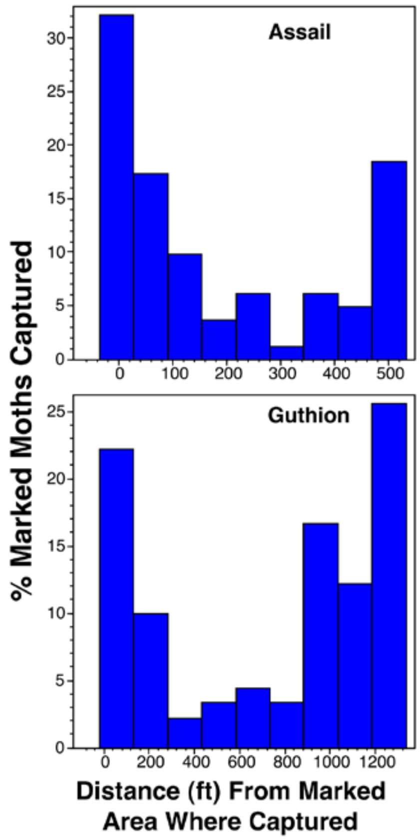
In terms of plot differences, the average dispersal distance in the first plot (395') was significantly higher than the second plot (142') (Fig. 5). This was consistent between generations and age classes, regardless of which treatment was applied. The reasons for these differences are unclear, but may be related to tree density. The first plot was planted at roughly 2x the density of the second plot and it was not on flat ground (it sloped downward from east to west roughly 82'). Our previous studies have shown that wind velocity in higher density orchards tends to be lower than in low density orchards, suggesting that moths may be able to fly a greater percentage of the time (our studies in another project showed flight at wind speeds > 3.3 mph is rare and that moths are unable to locate lures at those wind speeds). The

Fig. 5. Average recapture distance for middle-aged and old CM in Brewster 2007.



potential difference in the amount of time moths are flying would tend to allow them to move further in the high-density orchard where wind velocity would be < 3.3 mph a greater percentage of the time.

Fig. 6. Percentage of marked moths captured at different distances from the marked area. In both plots, moth captures rose sharply at the end of the plot where a wide drive row was present.



Cover Spray Effects 2008

As usual, there was a strong bias towards males (91% males) in the DA Combo lures with no significant difference in sex ratio between the two treatments. Because of the low percentage of females captured, unless mentioned, all analyses are restricted to male moths. Analysis of the age distributions of marked moths captured in each block also showed no significant differences between the blocks and averaged 11% young, 54% middle aged, and 35% old. This ratio is similar to that of unmarked moths caught in the plots.

In terms of the average distance moved, there were no significant differences resulting from either pesticide ($p = 0.3$) or age ($p = 0.08$) when the Guthion plot data were restricted to the same trapping grid size as the found in the Assail plot.

Probably the most interesting factor in the data was the differences in trap capture within the plot (Fig. 6). When evaluating the data for moth capture in both treatments, individuals dispersing from the edge of the plot tended to be found at high levels near the marking area and at the furthest edge of the block. Moth behavior is apparently strongly affected by the wider drive rows found at the end of the block. A possible explanation might be the trap density (and hence competition between traps) is effectively lower at the ends where traps are not found outside the plot, but our larval distribution studies performed a few years ago for improving the Taiwan sampling program showed the same trends of heaviest populations being found on the borders in roughly 80% of the orchards sampled.

Cover Spray Effects Using Flight Mills:

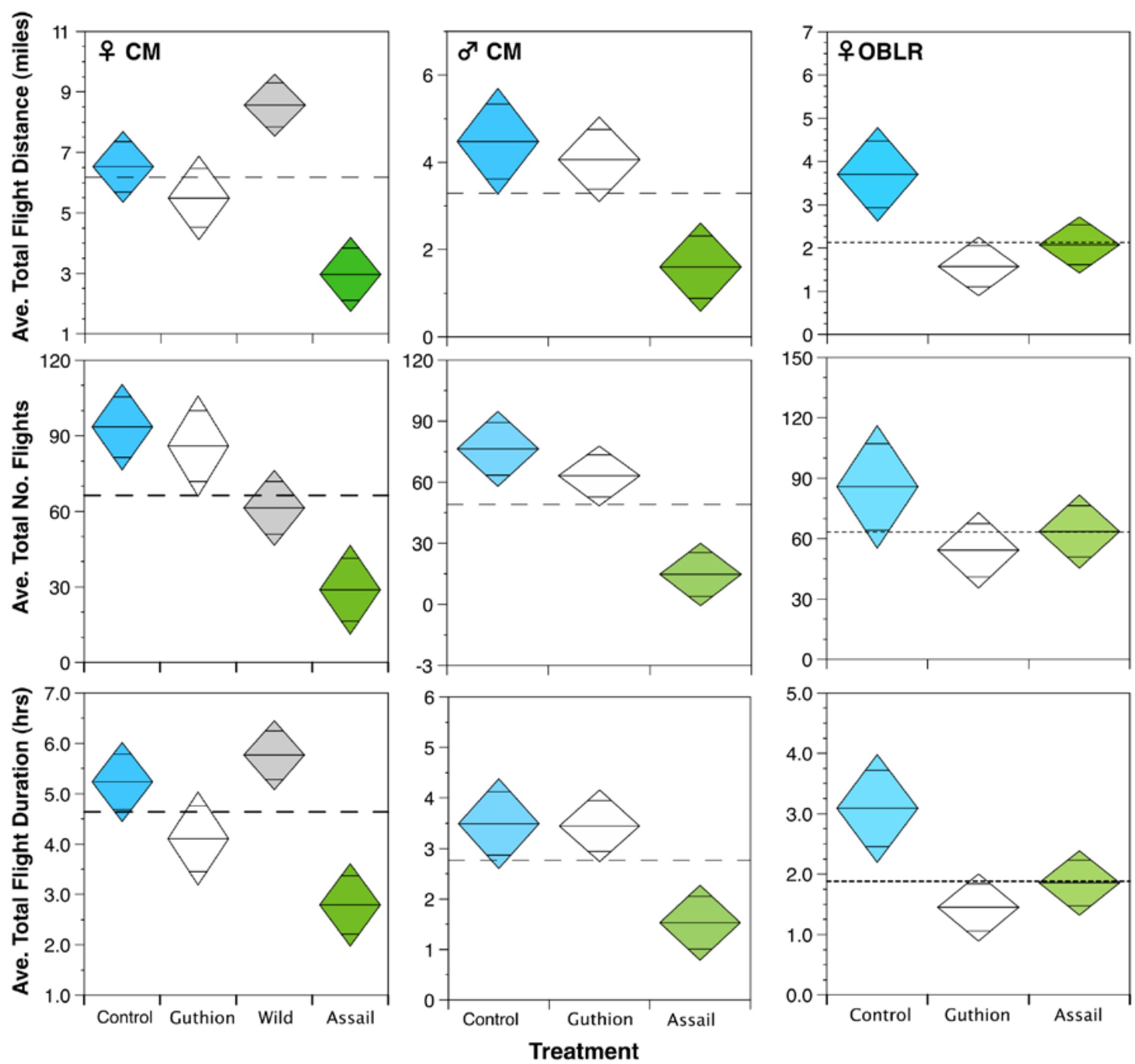
The variability obtained in the field experiments means that it is difficult to show statistically significant differences related to pesticide applications, but does not mean that they don't exist. In the field, we cannot control moth age, weather patterns, trap catch, marking rates, and tree density, size and other factors except within broad limits. The costs of doing the large experiments also preclude doing large numbers of them at any one time. To address these issues, the flight mill technology we developed for objective two seemed like an obvious method to try. In the lab studies, we can control all the different variables, and relatively quickly (and cheaply) determine how sublethal doses affect flight. Clearly, testing moths on the flight mills is extremely artificial and is not indicative of normal behavior in the field. However, flight mill data gives us good information on the physiological capabilities of the moths under a given set of conditions, in our case when exposed to sublethal doses of Assail and Guthion. Being able to evaluate moths in the laboratory means that we have a much less expensive way to test pesticides than using field experiments.

In this study, we applied a sub-lethal dose of guthion or assail to the container the moths were held in for 24 hours before flight. Moths were then attached to the flight mill and flight distances, number of flights, and total flight duration were recorded. In the case of codling moth, we used moths from the USDA-Wapato colony, but also flew female moths that were emerging from bands that had been collected the previous fall. These wild moths can serve as a second control that provides information on how well the Wapato colony reflects wild-type flight characteristics. We flew males and females separately. OBLR tested came from the TFREC colony.

Results: The wild CM female moths flew significantly further than the Wapato female control moths; there were fewer flights, but they were longer duration on average (Fig. 7). The guthion-treated female moths showed a non-significant reduction in the total flight distance, number of flights and average flight duration compared to the control moths. However, the assail treatment significantly reduced all three parameters 54, 69 and 47% for flight distance, number of flights, and flight duration, respectively. Clearly, Assail even at low doses strongly affected moth flight. Effects on male CM were similar in terms of the effects and significance of them (Fig. 7).

The OBLR females treated with either guthion or assail had significantly lower flight distances, duration and number of flights compared to the control moths (Fig. 7). There were no significant differences between female moth flight parameters between the two pesticide treatments. In complete contrast, the OBLR males showed no significant differences between control, guthion or assail treatments in any flight parameter.

Fig. 7. Mean diamond plots for CM and OBLR flight distance, number of flights, and flight duration. Dotted lines on plots indicate the overall mean for a comparison, the line in the middle of the diamond is the mean, the upper and lower lines indicate where if ther is no overlap that treatments are signficantly different at $p = 0.05$.



These studies clearly show that migratory ability and movement in the field can be affected by the pesticide used, even when applied at very low levels. Evaluating a range of differnet pesticides could be used to help manage codling moth and OBLR, particularly when movement into the plot from an outside source is a key factor in a particular management situation. In situations where high levels of movement are suspected, Assail would be a much better choice than guthion for codling moth, either material would reduce flight of female OBLR.

Cover Spray Effects: Kaolin

2008. We set up two different trials to evaluate the ability of a three tree row barrier to reduce CM movement from high population to low population areas. In the first trial, a large abandoned orchard was removed adjacent to a commercial block. Although the grower applied a Surround treatment to the border, it was only applied once at a low rate and washed off completely within a small amount of time. We sampled 795 trees at the orchard, but in all plots, damage was less than 0.05%, so no analysis was possible.

The second trial was run in a small planting at WSU-TFREC with extraordinary levels of codling moth pressure, coming from surrounding infested blocks as well as present within the block. Early in the first generation, we started treating the bottom half of the plot with insecticides and left the top part of the plot untreated. A three-row barrier of surround was applied twice to the center of the plot and to one edge (Fig. 8). We sampled every tree in the block by evaluating 60 half-fruit per tree for CM damage at the end of the first and second generations. There were no sprays applied during the second generation. We compared the damage found on either side of the surround barrier, looking at both overall damage in each subplot, and looking at the differences within a plot in the three tree rows adjacent to the surround barrier and then the three rows furthest from the surround barrier.

2009. We set up two studies, one at WSU-TFREC that had high pest pressure and one in east Wenatchee where two plots occurred side-by-side with one of the growers complaining that high pressure was coming from his neighbor for the past several years.

The plot at WSU-TFREC was treated with Kaolin at 50 lbs/acre a total of three times so that we had a clearly demarked area from what we felt was the direction of movement. We sampled the plots three times (1st, 2nd generation, harvest), evaluating ≈ 53,000 fruit for damage over the three periods. Unfortunately, we made the mistake of not treating the entire plot for first generation CM, because we knew it had been treated the year before (but obviously not well!). This resulted in very high damage that occurred early on that masked any movement restriction by kaolin treatments.

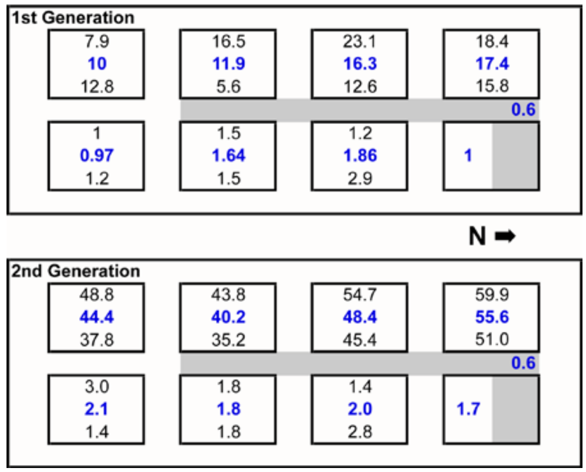
The test in east Wenatchee consisted of three apple blocks of 14.5, 18, and 17.5 acres (Fig. 9). The experiment was set up so that we had areas where kaolin was applied between the different plots so that we could see if migration from one plot was limited and egg laying occurred. We used 28 pheromone traps to evaluate flight and sampled >189,000 fruit over the three sampling periods (1st, 2nd generation, harvest). Kaolin was applied three times in the first generation and three times in the second to portions of the presumed moth source block (grey boxes in figure 9). The idea was to see if we could stop movement and damage in the areas across from the kaolin treated two rows. We treated two rows within the source block and in the lower right quadrant, the two rows across from the source block; the idea being to test if we could hold populations within the source block versus keep them in the outer two rows in the bottom right block.

2008 Results*:* The heavy insecticide treatments of the lower four plots in the first generation resulted in very low damage levels in those plots compared to the top four plots that were untreated (Fig. 8). Overall, damage was highest on the north (right) border of the block and decreased in each successive plot to the south (left). There were no significant differences between the upper and lower three rows, except in the second plot from the left in the top row.

In the second generation, the average damage in the top plots increased significantly (3-4 fold) over the levels in the first generation, but the lower block damage levels did not increase significantly from the first generation. The greatest increase was in the lower left plot which was not protected by the surround barrier, but that still remained very low (Fig. 8).

The data show that the surround barrier is very good at reducing migration between plots. The three plots on the bottom right were unaffected by the high populations on the top side of the Surround border. The bottom left plot that was not protected by the barrier is the only question. It appears that the TFREC blocks to the north of our test block were the source of pressure and the kaolin border stopped migration from those blocks and then funneled the moths down the tree rows in the upper plots. However, it is still a question why moths that laid eggs on the top left block did not move down into the unprotected block below in greater numbers.

Fig. 8. Layout of kaolin experiment at WSU-TFREC. Each square represents a plot; gray areas were treated twice with Surround in the first generation. The three numbers represent the average % damage for the plot (center number) and the three rows furthest and closest to the Surround border. The one number in the lower right plot is the average for the plot; not enough trees were present to tabulate.



2009 Results: The moth catch was heaviest in the presumed source block with relatively low levels occuring in the other two apple blocks. Damage did not correspond precisely to the trap catch, where the highest catches occurring near the kaolin treated areas in the presumed source block (Figs. 9 and 10). Overall, the damage was extraordinarily low (no damage to the apple block to the south west, and 0.7 and 0.4% damage in the source and north east block, respectively).

In regards to the kaolin treatment in this experiement, we did not see a reduction in damage that could be directly attributable to the kaolin treatments, other than in the kaolin treated rows, which had no damage present. The orchard block to the south west had no damage occur within it, despite some high moth counts and high damage in the adjacent presumed source block. This shows that CM treatments in conjunction with mating disruption can reduce or prevent damage when used correctly.

The lack of results in this situation is perplexing compared to the work the pervious year where we found the kaolin treatments allowed us to strongly channel moth movement away from parts of the plot, even on a relatively small scale and in the face of heavy pressure. Hindsight suggests that it might have been better to have modified the spray so that we would have prevented moths moving north -south from cutting behind the treated rows by placing additional treated strips (dotted boxes in Fig. 10) **-** this would not be needed in a normal commercial application where treated rows would not be broken up as our experimental protocol dictated.

Overall, the use of kaolin sprays as border treatments to reduce codling moth movement from a high level area to a low level area still needs more work, but the results from our studies last year and in 2005 strongly suggest that it can stronly reduce movement and damage with only a few boarder rows needing treatment. The most difficult aspect of this project is finding plots where damage is sufficient to show differences and where other aspects of orchard design (e.g., row spacing, different tree sizes, row direction differences) do not potentially complicate the results or mask the effects when applied on an experimental scale.

Fig. 9. Kaolin plot in East Wenatchee; numbers indicate the number of CM adults captured season long in the 28 traps spaced between the different plots. Gray boxes show where kaolin was applied.

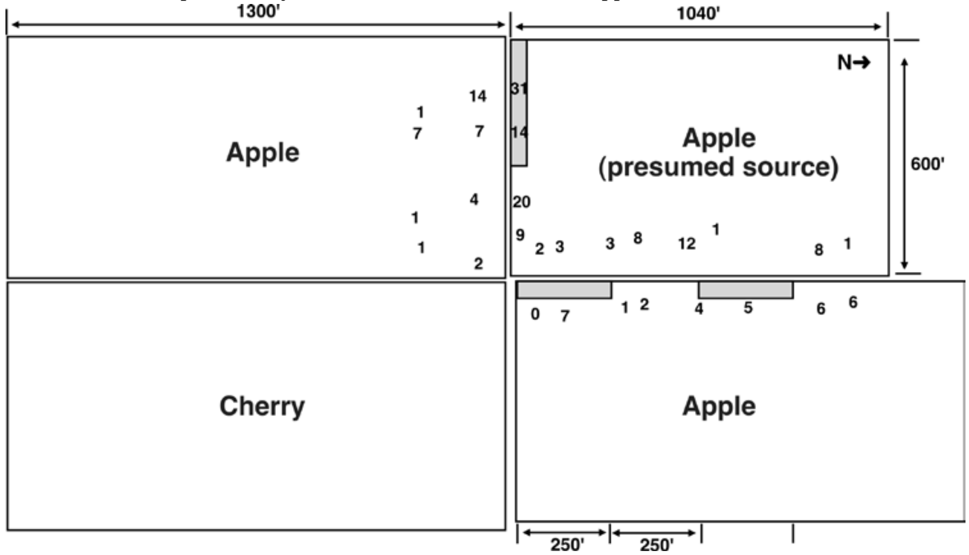
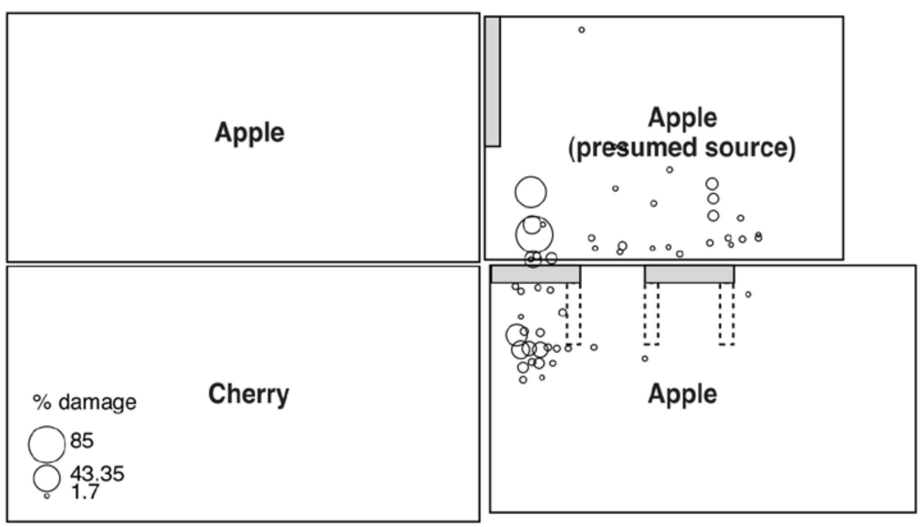


Fig. 10. Kaolin plot in East Wenatchee; circle size is proportional to damage (scale shown in lower right corner), samples with no damage are not shown for clarity. Gray boxes show where kaolin was applied; dotted boxes are where we should have added to the barrier to prevent moths moving north-south from slipping behind the kaolin barrier.



Executive Summary – Significance of This Project to the Industry.

Objective 1. The classification system provides us with information that is useful in understanding the overall population dynamics of codling moth. For example, it suggests an additional reason why the delayed first cover strategy is effective. Our data suggests that targeting the period when young moths ocurr in the first generation might be a useful tactic, but that tactic probably is considerably less useful in the second generation, in part because of the rapid aging that occurs during the summer because of high daily DD accumulations. The large number of old moths caught late in each generation suggests that control measures applied at that time are relatively less useful because the reproductive potential of older moths is so low compared to younger or middle age moths.

Objective 2. The 6,200 foot flight was chosen as one that would be a reasonable distance for moths to fly based on our studies from the pesticide effects study (objective 3). Our data in the reproductive effects sections show that for both CM and OBLR moths within a fairly large area can be considered to be a single interacting population, although clearly the probabilility of mating between moths decreases as the distance between them increases. For CM, flying the 6,200 feet did not affect population growth. For OBLR, non-flying pairs had a lower reproductive rate than those were either sex or both sexes of the pair were flown. This may mean that migrating individuals that carry a gene for resistance will be able to easily pass it on to the population in the area where they finally establish; their growth rate is roughly 2.5 fold higher than the non-migrating pairs.

Objective 3. Our field studies were highly variable and did not provide statistically significant differences in the flight distances of CM between plots treated with guthion or assail. This is likely caused by variability between blocks, small elevational differences, low capture rates, and a range of other factors inherent in field studies. However, use of our flight mills showed that it was easy to detect effects of sub-lethal doses on flight duration, distance, and number of flights. CM males and females were both strongly affected by Assail, but not Guthion. OBLR females were strongly affected by Assail and Guthion, while OBLR males were unaffected. Choice of Assail for CM cover sprays would greatly reduce movement potential for either CM or OBLR.

Kaolin barriers were shown in 2008 to be highly effective in channelling migrating moths around areas and reducing damage significantly. In 2009, we did not see this, primarily because of poor choices in the layout of our experimental plots. The 2008 data along with data from a previous project results strongly suggest that 2-3 rows around the border adjacent to a source of migrating moths will significantly reduce damage from migrating individuals.

Future Studies

Objective 1. The classification system is complete and will likely play a role in helping us understand how to focus our control programs for better efficacy or to evaluate current programs more effectively. Further focused studies are not needed for this objective.

Objective 2. The reproductive effects studies are complete and strongly suggest that both CM and OBLR flying ≈6,200 feet are not sacrificing either longevity or reproductive output to fly that distance. These data mean that control of these migrating individuals is necessary. Further studies on this area are not needed.

Objective 3. Our flight mill studies showed that pesticide choice can strongly effect the flight behavior of both CM and OBLR. Further studies in this area would be very productive and reasonably priced, if only to evaluate the current suite of insecticides as to their effect on migration.

Kaolin studies would also be worthwhile if performed on a very large scale (e.g., muliple plots per year for multiple years). These studies are expensive, and difficult to set up and highly dependent upon the likelihood of true migration coming from a particular direction versus a person’s tendency to “blame the neighbor” for damage within a particular orchard.