FINAL PROJECT REPORT
WTFRC Project Number: AE-04-428 (WSU Project 3643-8366)

Project Title: The importance of dispersal in biological control and IPM

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Budget History:

Item	**Year 1:** 2004	**Year 2:** 2005	**Year 3:** 2006
Salaries	20,487	21,306	15,215
Benefits	6,146	6,392	5,170
Wages	11,000	11,000	6,667
Benefits	1,760	1,760	733
Equipment	0	0	0
Supplies	3,200	3,200	3,200
Travel	3,200	3,200	2,303
Miscellaneous			
Total[a]	45,793	46,858	33,288

[a]Years 1 and 2 split with Pear Commission (2/3 apple, 1/3 pear); year 3 separated into two projects with different names and budget numbers.

Objectives:

1. Examine the area of influence (“active space”) of a rose/strawberry garden used to bolster parasitism of leafrollers.
2. Examine the movement of insect pests from areas of high population density to surrounding managed areas.

Significant findings:

- Rose gardens influence at least 7.2 acres of surrounding orchard.
- The movement of *C. florus* from the gardens to the surrounding orchard is not well synchronized with pest leafroller abundance in the orchard; it is likely driven by population dynamics of strawberry leafroller in the gardens themselves. More work on this area is required.
- The number of CM moving into a managed orchard from an adjacent abandoned area drops off quickly with distance but can still encompass the entire managed block. Damage tends to be more restricted to the border, but pockets of damage do occur throughout the managed area.
- The use of Surround® on the border between the abandoned area and the managed orchard greatly diminished damage and moth capture in the managed section. This may be a good tactic to reduce damage from migrating moths.
- Movement of both CM and OBLR appears to be directional and is likely based on prevailing wind conditions. We found that a low level population in one orchard may contribute more moths to an adjacent orchard with high levels of the pest than the converse.
- CM moved >1200 feet within three days of the application of our markers.

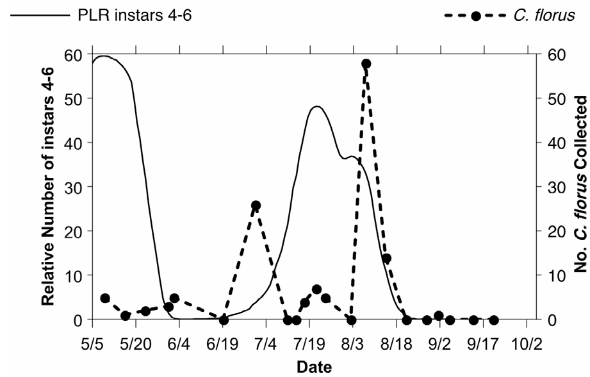
Objective 1. Examine the area of influence (“active space”) of a rose/strawberry garden used to bolster parasitism of leafrollers.

We monitored two sites this year, one at Wenatchee Valley College (WVC) and one on the south side of Frenchman Hills. At the Frenchman Hills site, we only collected six *Colpoclypeus florus* (two positive for the soy marker) from early May to late August, and all of those collections occurred in May. Because of the low catch, the discussion will focus on the WVC site. At both sites, we used the methods developed last year where we used fine netting placed over the garden and then applied soy flour using a fertilizer spreader. This had the advantage of heavily coating the leaves and foliage of the strawberries and roses as well as the netting (the holes in the netting were much larger than the parasitoids) so that emerging parasitoids were well marked. We then used our traps, which consisted of a infested shoot placed through a hole in a sticky card and into a 100-ml vial of water. The shoots and sticky cards were changed each week. Both the larvae and the sticky cards were examined for *C. florus*; if any were found, they were tested with ELISA to see if there was any soy protein present.

At WVC, the garden was adjacent to a block of organic Fuji apples and all trapping was done in the Fuji block. The block had extremely low leafroller population levels in the orchard. We collected low numbers of *C. florus* in early May but had two large peaks during the season. The first peak occurred on 30 June and the second from 2 August to 14 August (Fig. 1). The first peak occurred when most of the leafrollers were in instars 1-3 (only 5% were in instars 4-6 which is the time the parasitoids can successfully attack the leafrollers), but the second peak occurred when virtually all PLR were in the susceptible stages (instars 4-6). However, the population of PLR was decreasing at this time.

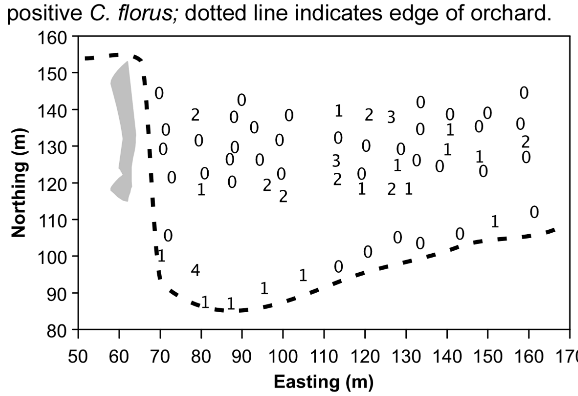
Our markers were detected only during the two large peaks described above. For those three collections, we found that an average of 40% of the parasitoids were marked, indicating they were coming from the strawberry/rose garden. When we examined only the positive parasitoids, we collected them as far as 316 feet from the edge of the soy treated areas, with 75% being collected within roughly 225 feet. If we use the 316-foot figure, the area of influence is a minimum of 7.2 acres. We did catch multiple individuals at the furthest distance so the effect of the rose garden is likely to be larger. Interestingly, there is not a uniform decrease in *C. florus* with distance from the garden; instead, the positively marked parasitoids appeared to follow the edge of the orchard and were more commonly collected 40+ meters (≈130 feet) from the garden (Fig. 2).

Fig. 1. Trap capture of *C. florus* over time at WVC orchard in 2006 with the relative number of PLR instars 4-6 as predicted by the PLR model.



While some of the population trends we observed were undoubtedly influenced by the spray program (and overspray on the garden), particularly in the early season and midseason, our data suggest that further investigation of the interrelationships between strawberry leafroller, PLR or OBLR in the orchard and *C. florus* is warranted. The fact that our first peak in trap catch occurred well before suitable hosts in the orchard were present suggests that *C. florus* movement into the orchard occurs when available strawberry leafroller hosts within the garden are rare and are likely not driven simply by the presence of pest leafrollers in the orchard. The data from 2005 was more restricted in time, but the peak in late season occurred when the relative number of larvae in instars 4-6 was extremely low, again suggesting a poor synchrony with the PLR population. It is clear that without a better understanding of the relationship of *C. florus* and the strawberry leafroller in the strawberry/rose gardens, the utility of the gardens as a supplement to BC of our pest leafrollers within the orchard will always be difficult to predict or understand.

Fig. 2. Map of trap locations and soy treated area (gray area). Numbers indicate locations and numbers of soy positive *C. florus;* dotted line indicates edge of orchard.



Objective 2. Examine the movement of insect pests from areas of high population density to surrounding managed areas.

This year we performed four studies under this objective, three with codling moth and one with OBLR. Two of the codling moth experiments were able to measure the movement of CM from abandoned blocks to adjacent managed blocks. In both blocks, the distance was roughly 40 feet from the managed sections. The other CM experiment was two large orchards that were again separated by a road (≈40 feet) but both sides were managed, with one having a large CM population and the other a relatively low population level. The OBLR study was to investigate movement from a young heavily infested cherry orchard to an infested adjacent apple block in late season.

CM movement from Abandoned to Managed Orchards:

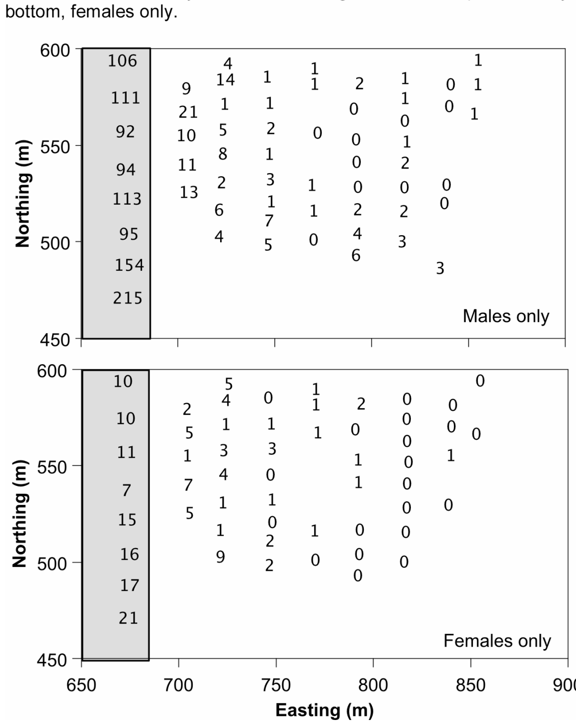
Methods: We applied our egg protein marker to about 1.5 acres of the abandoned orchard blocks immediately adjacent to the managed areas. All sprays were applied at roughly 25% adult emergence in the second generation on 18 July. Both of the managed blocks were not under mating disruption and were under a conventional CM program. The first block (Y1) was about 4 acres in size and planted with Gala apples and the adjacent abandoned orchard was comprised of Red Delicious apples. The second block (Y2) was 8 acres and was predominately Fuji with some Red Delicious apples intermixed; the abandoned block was Red Delicious. We placed one row of pheromone traps in the egg-treated area (eight traps) and 60 in each of the managed orchards. All traps were baited with Trécé's Combo/DA lure which attracts males and a lower number of females; all moths were identified to sex and processed by ELISA to determine whether they had picked up the protein marker in the abandoned areas. We geocoded (using GPS) every trap so that we could determine the exact distances flown from the edge of the protein marked block.

We also evaluated fruit injury in both the abandoned areas (in the center of the treated areas) and throughout the managed orchards just before harvest. All samples were geocoded so that we could determine the exact location of all samples with respect to the abandoned areas. Our sampling density was roughly 25 trees per acre (60 fruit/tree) with the edges adjacent to the abandoned orchards being sampled more heavily (every row for the first five tree rows, samples ≈40 feet apart) to determine exactly how far damage extended into the managed orchards.

Analysis*:* We analyzed the moth catch data using the total marked moths caught as well as separated by sex. Because we geocoded all samples, we calculated how far the marked moths flew and plotted the data as distance from the edge of the marked areas. Similarly, we analyzed the fruit damage in the same fashion.

Results*:* We captured 3,372 moths in the Y1 plots over a two-week period with 2,398 being caught in the eight traps in the abandoned area and 974 in the managed area. Of those caught in the managed area, 230 (24%) were positive for the egg marker indicating that they definitely had visited or originated from the abandoned orchard. However, our abandoned area had 1,102 (46%) marked moths. The percentage marked is quite low compared to other studies we have run, which suggests that a large number of moths originated deeper in the abandoned area than our treated zone. If this is true, then the number in the managed areas originating from the abandoned area was higher than 24% (roughly 2x higher likely) because moths from deeper in the abandoned areas bypassed our marked area and would not have acquired the mark.

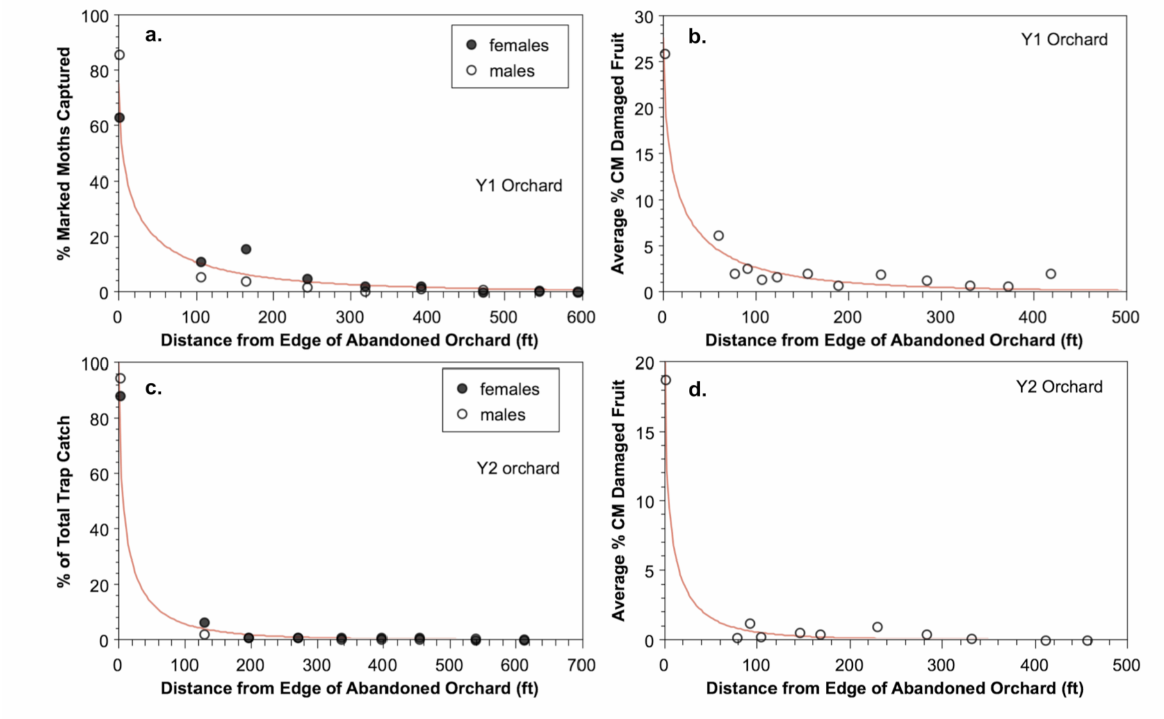
Fig. 3. Trap catch of marked moths in the Y1 orchard. Gray area is the abandoned orchard adjacent to the managed orchard. Top Males only, bottom, females only.



When we examined only the marked moths, we found that they were in the highest numbers closest to the abandoned orchard but were found at virtually all distances, both males and females (Fig. 3). Roughly 29% of all the marked moths caught within the orchard were females. When plotted as the percentage trap catch vs. distance from the abandoned orchard, both sexes had a similarly shaped drop off with distance (Fig. 4a).

The damage in the plot fit a similarly shaped curve as the dispersal into the orchard, where the damage was highest closest to the border and

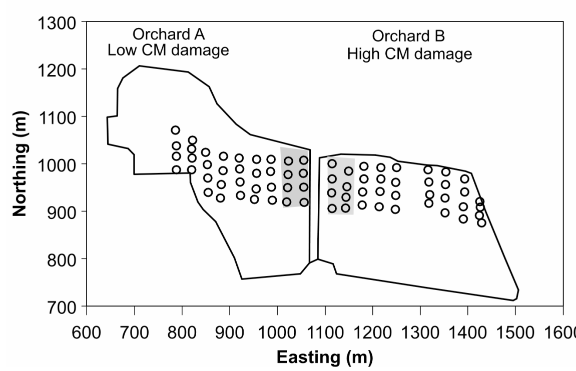
Fig.4. Percentage marked moths and fruit damage versus distance from abandoned area for orchards Y1 and Y2. Solid lines are predicted values based on non-linear regression. Orchard Y2 was sprayed with Surround before we treated the area.



decreased as we moved away from the edge (Fig. 4b). We also found that the damage tended to be slightly higher on the top and bottom of the orchard where it appeared that moths flew around the edge for a short distance.

In the Y2 plots, we captured 1,177 moths in eight traps in the abandoned area and 193 in the 60 traps within the orchard. In the abandoned area, 654 moths were marked, and within the orchard only 42 (21%) were marked. Considering the magnitude of the trap catch within the abandoned area and the relatively short distance (40 feet), the low trap catch surprised us, especially after the numbers we found in the Y1 plots. However, the big difference was that the Fuji block was sprayed with Surround® for sunburn protection and previous studies by Tom Unruh have shown that CM tend to avoid Surround treated areas. The drop off with distance of moth capture was considerably quicker than we saw in the Y1 plot (that was not treated with surround) (Fig. 4a vs. Fig. 4c). Damage in the plot dropped off very quickly, similar to the way that trap catch dropped off with distance from the abandoned area (Fig. 4d), again faster than in the Y1 orchard (Fig. 4b vs. 4d). These data suggest that even a single treatment of Surround on a few border rows may be a good management tactic adjacent to a source of high levels of CM (*e.g.*, bin piles, abandoned orchards, etc.).

Fig. 5. Trap locations (circles) and treated areas (gray boxes) at the two adjacent managed orchards. Orchard A treated with milk marker, Orchard B with egg marker.

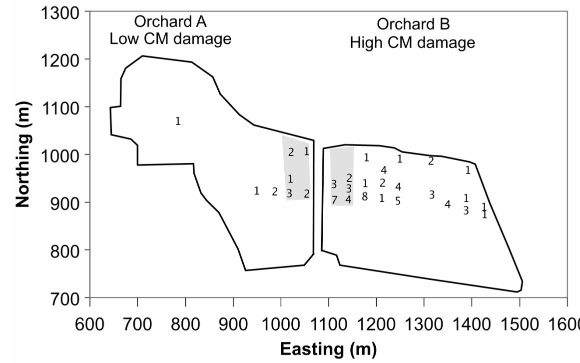


Two managed orchards with different damage levels

***Methods**:* We chose two side-by-side orchards that had differing damage levels the previous year

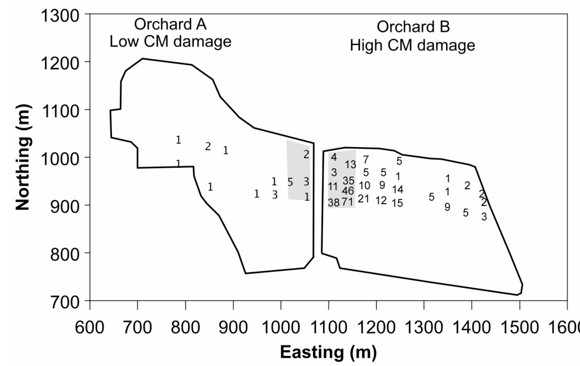
(Fig. 5). We treated 1.5 acres with our protein markers in each block. Orchard A received a milk treatment and Orchard B an egg treatment. Both treatments were applied on 18 July when roughly 25% of the summer generation had emerged. We placed 36 traps on a regular grid in both orchards and followed the movement for 2.5 weeks, which is roughly the time where our markers have sufficient residue to mark moths that just walked on treated leaves. We used the Trécé DA/combo lures so that we could collect data on male and female movement patterns.

Fig. 6. Trap catch over two weeks for moths that tested positive for the milk marker. The milk treated area is in grey in Orchard A.



***Results**:* Because we treated the two orchard areas with different markers, we could distinguish the origin of the moths. At harvest, Orchard A had the lower levels of damage (0.09% over 361 trees, 60 fruit/tree) and Orchard B had 0.9% damage over 489 trees. We caught 186 moths in Orchard A and 1,394 in Orchard B. However, looking at marked individuals, we found that only 27 from Orchard B were detected in Orchard A, while 63 from Orchard B came from Orchard A (Figs. 6, 7). The trap catch is the opposite of what we would predict by marker efficiency (the egg marker in Orchard B allows marking at roughly 2x the rate of the milk marker used in orchard A). Part of the discrepancy is likely simply a directional movement from east to west; when we examined movement patterns of the marked moths, 12.9% of the milk-marked moths moved east from the treated area, while 16.7% of the egg-marked moths moved towards the east. The reason for the directed movement may be the prevailing wind direction or some other factor.

Fig. 7. Trap catch over two weeks for moths that tested positive for the egg marker. The egg treated area is in grey in Orchard B.



The damage in Orchard A was low and scattered in a random fashion over the entire orchard. However, in Orchard B, there was a hotspot, which corresponded to one section adjacent to the marked area that was comprised of Gala apples. This area also had the highest trap catch for individuals that were either marked or unmarked.

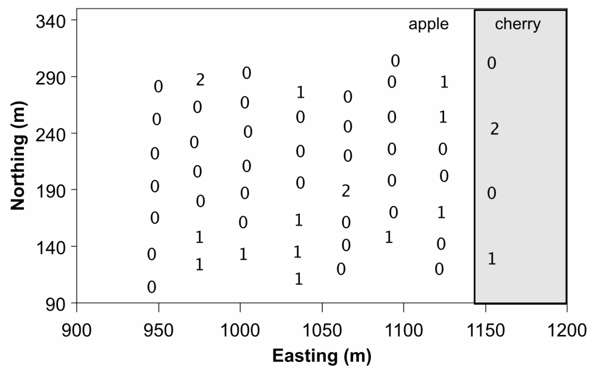
When we examined the distance dispersal curve for moths marked with the egg marker (origin = Orchard B) it appeared similar to the ones found previously in orchards Y1 and Y2. However, damage could not be analyzed the same way because our treated area was likely not the sole source of the moths; as mentioned previously the major source was likely the Gala area adjacent to our marked area. The moths marked with the milk marker (origin = Orchard A) did not show any marked pattern with distance from the area treated (Fig. 6). We found them throughout Orchard A and Orchard B in a random fashion. In marked moths originating from either area, we collected them at the maximum distance where our traps were placed (>1200 feet), all within the initial three days after treatment.

OBLR Movement from Cherries to Apples after Cherry Harvest

***Methods**:* We used a young cherry orchard infested with OBLR adjacent to a large apple block. In this situation, we applied our egg protein to the cherry orchard and placed a grid of traps in the cherry block. We placed 49 pheromone traps in the apples and four in the cherry orchard. We also placed 18 acetic acid traps in the apple orchard in an attempt to collect females, but no moths were captured in the acetic acid traps. Treatments were applied on 4 August, and trapping continued for three weeks after treatment.

Results: We captured 350 moths total, 15 in the cherry and 335 in the apple block. Of those, only 16 marked adults were captured in the apple block. The distribution of the egg-marked captures was relatively random and uniform throughout the block out to more than 450 feet from the cherry block (Fig. 8).

Fig. 8. Trap catch of egg positive OBLR over 2 week period.



We have run at least one experiment per year trying to examine the importance of movement from cherries to apples in late season. In the first year, where young cherries were between two mature apple blocks, we found that movement from the cherries to the apples was strongly directional and accounted for 30% of the moths caught in one block and less than 4% in the other. Last year, we conducted movement studies between an apple and cherry block but found that very little movement occurred between the two blocks; only five moths were found to have moved from the treated area into the other. This year, our results also show little movement between the cherries and apples.

We were also unable to determine the flight ability of female OBLR because they do not respond to the pheromone, and the acetic acid traps caught no moths. Thus, our comments on flight refer only to males and thus the impact of movement patterns of females can only be inferred from male data. If females disperse in a similar direction, distance and frequency as males, even with the relatively low levels found in our studies, the high reproductive rate of OBLR would allow it to spread over a large area and initiate hot spots the following year.

Based on our studies with both OBLR and CM, it is likely that infestation of adjacent orchards is highly dependent on the spatial arrangement of the two orchards, distance between them and environmental factors such as the direction and intensity of the prevailing wind. It appears that the movement is not necessarily a function of high numbers in one orchard moving to the adjacent clean orchard; it is a two-way interaction, but it is not symmetrical. In some cases, the orchard with the lower density may actually be the source of a greater number of dispersing moths, depending on wind patterns or whatever environmental variable influences directionality in movement. However, even if a lower number of moths come from one direction, their high reproductive rate can result in hot spots that may be important the following year as a source for population buildup.