FINAL PROJECT REPORT

Project Title: Evaluating use of sterile codling moth in apple IPM programs


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Total Project Request: Year 1: $41,106

Other funding sources

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|---|---|
| Agency Name: | California Walnut Board |
| Amt. requested/awarded: | $19,000 |
| Notes: | Funding to support CA project only |

Budget 1 History

| Item | 2011 |
|---|---|
| Salaries (M. Doerr – one month) | 5,278 |
| Benefits (M. Doerr ) | 1,684 |
| Salaries (Research Assoc. - five months) | 12,900 |
| Benefits (Research Assoc.) | 6,024 |
| Wages | 4,800 |
| Benefits | 720 |
| Equipment | 0 |
| Supplies | 1,000 |
| Travel | 1,000 |
| Miscellaneous | 0 |
| Total | 33,406 |

Budget 2 History: Okanogan Kootenay SRI

| Item | 2011 |
|---|---|
| Salaries | 0 |
| Benefits | 0 |
| Wages | 0 |
| Benefits | 0 |
| Equipment | 0 |
| Supplies (SIRP moths - $4/dish) | 7,200 |
| Travel | 500 |
| Miscellaneous | 0 |
| Total | 7,700 |

Objectives:

1. Establish a mechanism for the SIRP to move moths across the US/Canada border.
2. Determine the best method(s) for releasing SIRP moths to achieve desired results.
3. Evaluate the capability of SIRP moths to control codling moth in selected orchard situations – bin piles, orchard borders, hot spots in orchards, and late season orchard treatments.

SIGNIFICANT FINDINGS:

- Due to regulations on moving insects across international boundaries we were not able to obtain permission for the Okanogan Kootenay SIRP facility in Osoyoos to bring sterile codling moths across the US/Canada border. We relied in the existing USDA-APHIS permit to bring moths across the border on a weekly schedule. While this process worked well for the current project if there was any interest from the industry in accessing sterile CM for commercial purposes a different method of transport would need to be worked out.
- We did not achieve a high sterile to wild moth ratio in traps at most of our SIR release sites, only four of eleven and two of these were sites where no mating disruption was used.
- Most of the sites selected were good tests of border problems in orchards dealing with immigrating codling moth.
- Fruit injury data at harvest was highly variable and more injury occurred on average in blocks where SIR moths were released. While these results could have been influenced by how we set up our study sites it is not very encouraging result.
- There was no difference in moth activity, number recaptured, at different distances from release sites. This would allow for SIR moths to be more rapidly distributed in the orchard should this technique be developed into a commercial venture.

Methods

Insects: Sterile Codling moths were produced at the Okanogan Kootenay SIRP facility in Osoyoos, British Columbia. The first moths were received in Washington state on June 1, 2011 and released at SIR trial sites on June 1 and 2, 2011. The last release date was August 31, 2011. The codling moths were packaged and shipped in Petri dishes (Fig. 1 - left) inside of Styrofoam coolers with ice packs to keep them from damaging themselves during transport. Each Petri dish was filled by weight and contained approximately 800 moths. The codling moth caterpillars were reared using a diet with red dye, which provided a fast way to tell wild moths from sterile moths captured in traps during these studies.


Figure 1. Sterile codling moth were obtained from the Canadian SIR facility in petri dishes of 800 moths (left) and were released by dumping the cooled moths into a release cup that protected the moths and allowed them to exit through holes (right).

Traps: Both treatment (SIR release) and control (no release) orchard blocks were monitored using white delta type traps baited with codling moth pheromone lures. At the beginning of the season we used 0.1 mg codlemone lures, but due to low trap catches in mating disruption treated orchards we changed to Trécé L2 lures, commonly referred to as a 1x lure. Trap catches improved after this lure change.

Sterile moth release devices: Release devises where constructed from 16 ounce clear plastic deli cups, by cutting four 1 inch diameter holes in the sides and attaching a wire for hanging them from trees (Fig. 1 - right). These release devices gave the moths a somewhat protected area to become acclimatized to the release site and fly out when they were ready. Moths are released using a blower from the back of a 4-wheeler in British Columbia. This method is efficient for the delivery of large numbers of moths, but was method for the relatively small number of moths released in this study. Using the release devices also provides a degree of consistency across the different treatment areas which otherwise might have had very different moth survival rates due to differences in ground cover, irrigation practices, and orchard structure. One entire Petri dish of moths, containing approximately 800 moths (400 males), was released into each release device every week.

Study sites: It was originally intended that there be four different categories of sites for this study: 1) bin piles, 2) orchard borders adjacent to external CM problems, 3) internal orchard hot spots, and 4) late season orchard treatments. When orchardists were contacted to locate good candidate sites for this study, the most commonly described problem areas were borders adjacent to problem areas, usually neighboring orchards or in one case a bin pile. Sites were chosen in eight orchards in central Washington. Three of these orchards contained two different problem areas treated as separate sites for this study. Orchards were located near Brewster, Chelan, Manson, Selah, Wapato, Buena and Royal City. The Brewster site was the last one to be set up and releases began on June 22, 2011. The second Manson site (Buck) was set up two weeks later than the other sites and releases started at this location on June 15, 2011. All of the orchards included in this study employed mating disruption for the management of codling moths, with one exception: the Wapato Orchard. One of the study sites was so small that a separate treatment and control block could not be established with any expectation that sterile moths would not totally infiltrate the control block. This site, the second Manson area site, therefore, had no control for comparison.

Site descriptions: The Brewster location had historically been a problem area for codling moth due to the strange long narrow shape of the orchard. It is situated between a railroad and the Columbia River and is between one and four rows wide and nearly half a mile long. This has made it difficult to manage and made insecticide treatments less cost effective. This orchard is essentially one long border with nearby backyard orchards, which in general have notoriously high codling moth populations. The year prior to this study very high codling moth damage noted, especially in the northern half of the orchard, which was at least partly due to a lack of management for the second half of the season.

The first Manson location (Fry) is a relatively small plot of older red and golden delicious trees which is bordered very closely on three sides by apple orchard and also interspersed with homes, making it difficult to manage for codling moth. Historically this orchard has had trouble along the northwestern border which is where the SIR moth releases were focused.

The second Manson location (Buck) is the northernmost edge of a large orchard. It is also the highest edge of the orchard, which is on a slope. Historically this edge has had high codling moth damage, possibly due to moth immigration from neighboring yards or feral apple trees. Inspection of this orchard found it to be a mixture of varieties and sizes of trees with gaps between trees and evident

horticultural problems. The trap catch in this orchard prior to the first release showed that there was a large number of codling moths present.

The Chelan location was the only site we found representing the bin pile category. The orchard was near to and uphill from the Chelan Fruit warehouse bin pile and has reportedly suffered effects from codling moth due to it close proximity to the bin pile. Bin piles are notorious for causing difficult codling moth management situations for nearby apple growers because codling moth larvae are not killed during storage in controlled atmosphere storage (CA), and they emerge from diapause after being removed from storage. These moths are continuously emerging from bins that are processed and moved to the bin pile area. Moths are also not typically in sync with the natural life cycle of the codling moth making it difficult or impossible to correctly time insecticide treatments for management. Unfortunately there were no trees or sites for placing traps between the bin pile and the orchard, but release cups were attached to metal fence posts and placed along the edge of the bin pile. The edges of the orchard nearest to the bin pile were monitored with traps and sterile moths were released there as well (Fig. 2A).

The Selah location contained two separate sites where codling moth had been of concern. One site was bordered by residences and backyard apple trees (Fig. 2B - Selah West) and the other was a section of the orchard with large old golden delicious variety trees (Fig 2B - Selah East). Both of these sites had histories of high codling moth damage and trap catches.

The Wapato location had some unique problems. The orchard was a mix of tree crops including pears, cherries and peaches and different varieties of apples planted in several different planting layouts. The orchard was on a hill with significant elevation differences between the different apple plots, making it difficult to evaluate degree days and timing of pesticide treatments in the different areas. The orchardist reported two specific problem areas. One was a small block of triple row planted Gala apples at the top of the hill (Fig. 2D - Wapato Gala) and the other was a slightly larger area of large Golden Delicious trees (Fig. 2D - Wapato Gold). This was the only orchard in this study that did not use mating disruption, which resulted in higher moths catches compared to the other locations.

The Buena location was larger and more uniform than most of the other locations. This orchard contained two separate border areas that had experienced effects of poorly managed neighboring orchards. Bordering one of the sites, Buena NE (Fig. 2C) was a pear orchard in which there was clear evidence of codling moth damage throughout the season. The other site, Buena SW was adjacent to another apple orchard which showed signs of codling moth damage throughout the season and also had historically received pressure from orchards across the road (Fig. 2C). The manager of this orchard reported having to hand remove damaged apples along these border areas before harvesting the previous year because there was so much injury from codling moth.

The Royal City location had a reported border problem along one edge shared with another apple orchard. The bordering orchard was small and did not extend the entire length of the study orchard providing only a small area for a release treatment and a control block.

Damage surveys: Codling moth damage was evaluated in each location two times over the course of the study; after the first codling moth generation and again prior to harvest. Fruit damage was evaluated in each SIR release treatment and control by randomly selecting 40 trees distributed throughout each block and inspecting forty half-fruit on each tree. In cases where there were fewer than forty half-fruit visible on a selected tree the evaluation was continued on neighboring trees until a total of forty half-fruit were counted. The number of codling moth injuries found was recorded for each tree. The trees in the orchard at the Chelan location had very few apples, and the SIR release and control blocks were very small necessitating a smaller sample size of twenty half-fruit per tree.

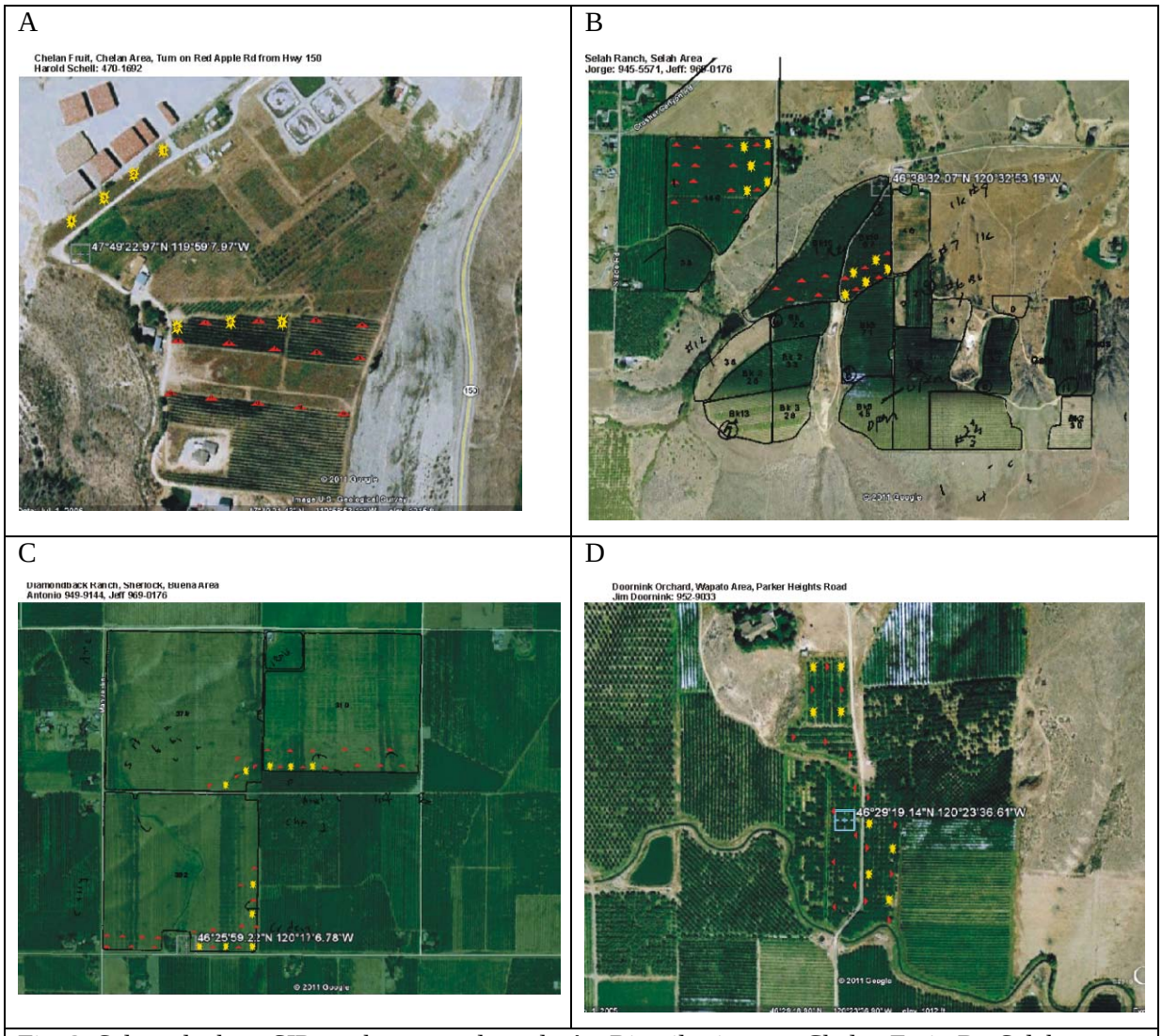
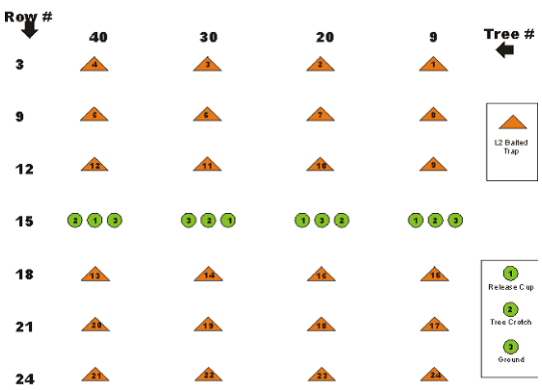



Fig. 2. Selected where SIR moths were released. A - Bin pile site near Chelan Fruit, B - Selah location with two release and control sites, C - Buena location with two release and control sites, D - Wapato location with two release and control sites.

Release method comparison: Moths were colored with florescent powder and released using three different release methods at point sources in an organically managed orchard east of Wenatchee. Pheromone baited traps were placed 60, 120 and 180 feet north and south of these release points (see image to right). Three different release methods were used: the release device described above, pouring the moths onto the ground around the base of a tree, and quickly distributing the moths into the tree itself, mostly in



large crotches of the trees and on horizontal branches. Some of the moths that were place in the trees did end up on the ground, but this simulated the actual results that could be expected using this release method in practice. Moths were released once per week for eight weeks, from July 8, 2011 to September 2, 2011. Traps were checked twice per week at four and seven days after release. Trap bottoms with moths were brought back to the lab and checked with a UV lamp to determine florescent powder color. One wild codling moth was captured during this trial.

## Results & Discussion

Efficiency evaluation: Most of the time and money invested in distributing the sterile codling moths for this study was spent in driving to the moth pickup site and between all of the release sites. This may or may not be an expense included in the implementation of an SIR release for coding moth control depending on the location of releases and method of transportation chosen in the future. Because the moths should be released soon after receipt, efforts to coordinate speedy distribution of moths to release sites and make timely application would be a concern and will probably be the most expensive and complicated part of adopting this management technique. For this study the crew from Wenatchee spent a total of 9 hours driving to the SIR moth drop off site and between release sites each week covering approximately 430 miles. These figures do not include the driving time or miles driven by the person who picked up the moths up in Canada each week and deliver them to the drop off site in Brewster. Relative to the driving time, the time spent actually releasing the moths in the orchards was very small.

As discussed above the moths were release into release cups and the lid was replaced, so this took more time than applying them onto the ground would have, but either way most of the time was spent walking between the release point. Subtracting the time spent checking the monitoring traps in the treated areas, releasing sterile moths into the release devices at a rate of one device per acre took approximately 15 to 20 minutes for each plot with between five and seven release devices in each. Extrapolating these values gives a figure of between 3 and 4 minutes per acre. If the applicator were driving a four-wheeler and/or distributing the moths on the ground or directly onto the trees instead of putting them in release devices this time could be shorter.

The components of the release devices themselves are inexpensive but they are time consuming to assemble using the current method. This process could be streamlined and made much more efficient for mass production if necessary.

Trap catches: Sterile moths were consistently captured in traps baited with either the 0.1 mg or L2 lure in the control blocks (Fig. 3). Due to the small size of the orchard plots used for this study this result was understandable and expected. When averaged over the 11 test sites the number of sterile moths captured was lower in control compared to the SIR release blocks (Fig. 3). The average ratio of sterile moths to wild moths in the SIR release blocks was 8.7 and 11.3 when using the 0.1 mg lure

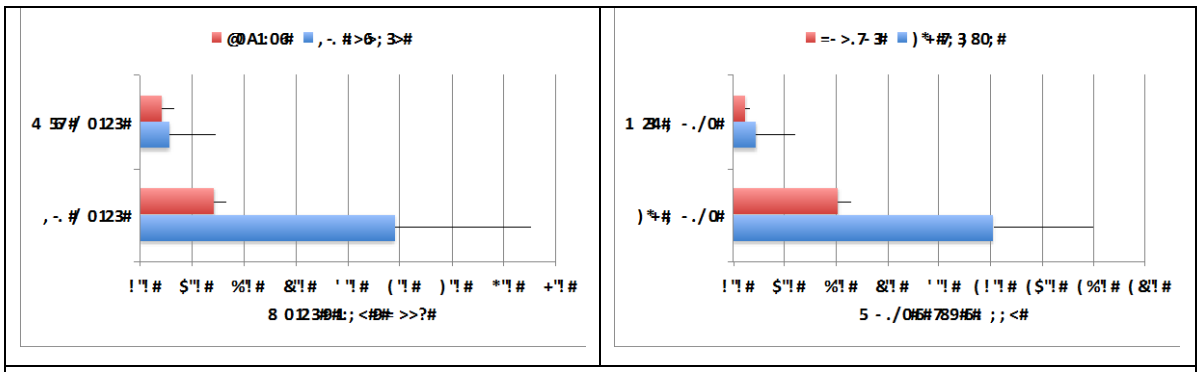



Figure 3. Average moths per trap per week captured in 0.1 mg lures (June) and L2 lures (July-Aug.) in sites with releases of SIR moths and in control (no release) sites (N=11).

result was understandable and expected. When averaged over the 11 test sites the number of sterile moths captured was lower in control compared to the SIR release blocks (Fig. 3). The average ratio of sterile moths to wild moths in the SIR release blocks was 8.7 and 11.3 when using the 0.1 mg lure and the L2 lure, respectively. In the control blocks the average ratio was 3.4 and 8.8 when using the 0.1 mg lure and the L2 lure, respectively. The target ratio for using SIR to control codling moth is 40:1, however, this ratio is usually determined without the influence of mating disruption which we know reduces the efficiency of monitoring traps. In the SIR release blocks four of the 11 had ratios of sterile to wild moths greater than 40:1 (50:1-127:1), with two of these being the Wapato sites where no pheromone mating disruption was used. An additional SIR release block had a ratio of 36:1 (Chelan bin pile site) and another a ratio of 18:1 (Manson Fry). In the control blocks only two of 11 had a sterile to wild moth ratio greater than 40:1, 137:1 and 104:1, one of which was a Wapato site and the other Wapato site had a ratio of 28:1. These data suggest that there should have been some impact of the SIR releases on codling moth.

Table 1. Percent fruit injury in different treatments at each study location after the first CM generation and prior to harvest.

| Location | Treatment | 1st gen | Harvest |
|---|---|---|---|
| Chelan | SIR release | 0.00% | 0.00% |
| Chelan | Control | 0.00% | 0.00% |
| Manson Fry | SIR release | *0.17%* | *0.17%* |
| Manson Fry | Control | *0.00%* | *0.00%* |
| Manson Buck | | 3.33% | 9.00% |
| Brewster | SIR release | *0.83%* | *0.33%* |
| Brewster | Control | *0.00%* | *0.17%* |
| Selah W | SIR release | 0.00% | *0.67%* |
| Selah W | Control | 0.00% | *0.17%* |
| Selah E | SIR release | 0.00% | 0.00% |
| Selah E | Control | 0.00% | 0.00% |
| Wapato Gala | SIR release | | **1.17%** |
| Wapato Gala | Control | **1.83%** | **1.83%** |
| Wapato Golden | SIR release | **0.00%** | **1.00%** |
| Wapato Golden | Control | **2.50%** | **1.67%** |
| Buena SW | SIR release | 0.17% | **0.33%** |
| Buena SW | Control | 0.17% | **0.50%** |
| Buena NE | SIR release | 0.00% | *4.83%* |
| Buena NE | Control | 1.50% | *2.50%* |
| Royal Slope | SIR release | 0.00% | *0.50%* |
| Royal Slope | Control | 0.00% | *0.17%* |

At some sites the capture of SIR moths was very low relative to the wild moths. At these sites it is highly likely that grower spray programs could have negatively impacted the survival of sterile moths. We are still working on getting spray records from the cooperating locations to assess their possible impact on SIR released moths. At the Manson Buck location the average capture of wild moths was high, 5.9 moths/trap/week, which was essentially the same as captures of sterile moths. At the Buena location the ratio of sterile to wild moths was very low, 1.5:1 and 2.8:1 in the two SIR release sites and there was little difference in ratios on the control sites.

The primary goal of this project was to see if release of SIR moths could help problems sites within apple orchards. The bottom line for this determination is to see if fruit injury was reduced in locations where SIR moths were released.

Table 1 summarizes the fruit injury results from each orchard site. After the first generation it was found that there was more injury in two study sites, Manson Fry and Brewster, in the SIR release blocks than the control blocks. The Brewster site was set up late and was very small and injury was in the northern part of the orchard where it had been the worst the previous season. The fruit injury was lower at harvest in the SIR release block while injury in the control block had increased.

At the Mason Fry location fruit injury in the SIR release area was higher than the control treatment after the first generation but did not increase by harvest.

At the Buena SE site the SIR release blocks had lower levels of injury than the control blocks but at the Buena NE site the SIR release block at harvest had higher fruit injury than the control block.

At the Royal Slope location the SIR release block had a higher level of fruit injury than the control blocks at harvest.

At the Wapato location the SIR release block has less injury than the control blocks, though injury overall was high at this location, likely because no mating disruption was used.

Fruit injury data would not support the value of releasing SIR moths using the methods in this study. We did select sites with high codling moth pressure, which was the intent of the project. In some of the locations it was difficult to get a good control to compare with the SIR release area and this more than anything could have skewed the fruit injury results. Often we set up the SIR release area where most of the external pressure would be felt while the control block was typically more removed from the area of highest codling moth pressure.

Release method comparison: When SIR moths were marked with florescent powder and released using different methods there was a definite and consistent pattern. The further monitoring traps were from the release locations the fewer moths were recaptured and fewer moths were recaptured upwind of the release sites (Fig. 4 all data pooled).

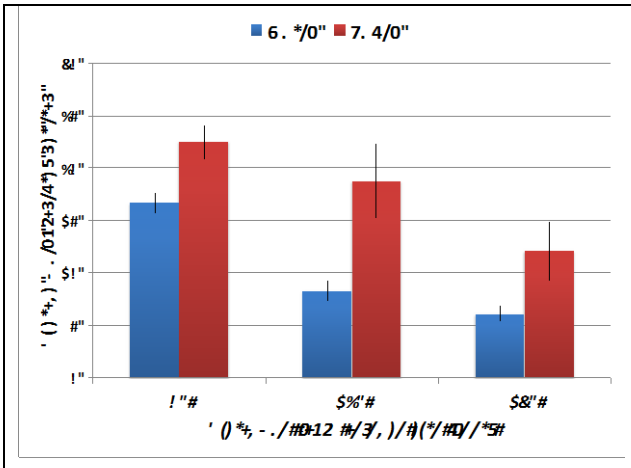
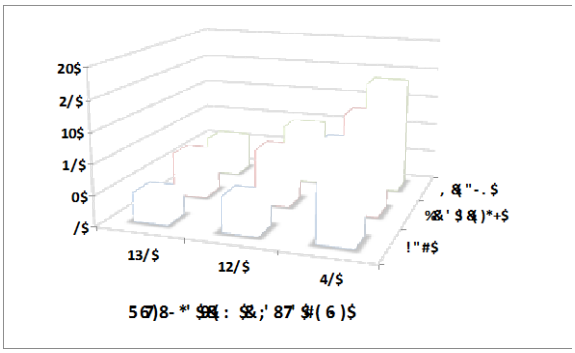


Figure 4. Average sterile moth capture in traps placed at different distances from the release site.

The average number of moths recaptured from the three different release methods was similar at each distance from the release locations (Fig. 5). These data suggest that releasing SIR moths by dumping them on the ground or putting them in the crotch of a tree would not hinder their activity. These releases were done in summer so the temperatures were warm and dew on the ground cover would not have been an issue. There were overhead irrigation in the block that was used in this study but if there was any effect from this practice it impacted all moth activity from all release methods the same.

A

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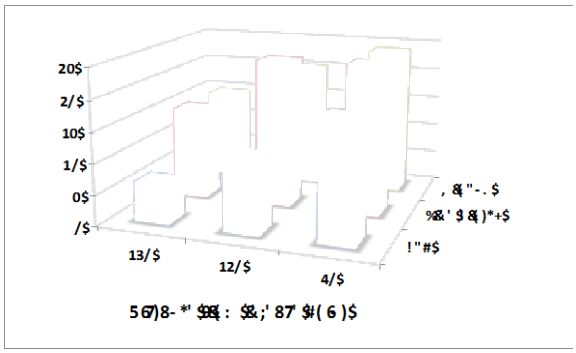


Figure 5. Average sterile moth capture in traps placed at different distances from the release site. A - moth capture to the north of the release sites and B - moth capture to the south of the release sites. Wind direction tended to be north to south.

**Executive Summary**

Moving insects across international boundaries for the Okanogan Kootenay SIRP facility in Osoyoos was found to be fraught with difficulty. The personnel at the Okanogan Kootenay SIRP facility were excellent to work with and they produced a very good product. We, therefore, relied on the existing USDA-APHIS permit to bring moths across the border on a weekly schedule. If there were interest from the industry in accessing sterile CM for commercial purposes a different method of transport would need to be worked out. We did not achieve a high sterile to wild moth ratio, 40:1 being the target, in traps at most of our SIR release sites, only four of eleven achieved this ratio and two of these were sites where no mating disruption was used. Most of the sites selected were good tests of border problems of orchards dealing with immigrating codling moth. Fruit injury data at harvest was highly variable and more injury occurred on average in blocks where SIR moths were released than the "control" blocks at the same location. While these results were likely influenced by how we set up our study sites it is not a very encouraging result. There was no difference in moth activity, number of moths recaptured, at different distances when we released moths using different methods, release cup, dumped on ground and placed in the crotch of a tree. These results would allow SIR moths to be more rapidly distributed in the orchard should this technique be developed into a commercial venture.