FINAL REPORT
WTFRC Project # AE-01-33

Project Title:	Development of feeding attractants for control of moths pests of apple.
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Objectives:
1. Develop formulation for a bait station, to incorporate an attractant, a feeding stimulant, and toxicant.
2. Verify attractant release rates and moth attraction, contact, and mortality in response to bait station.
3. Develop bait station visual characteristics.
4. Conduct flight tunnel, field cage, and field tests with a bait station model.

Significant Findings:
1. A bait station design was used that includes a controlled release dispenser for the feeding attractant (acetic acid and 3-methyl-1-butanol), a permethrin formulation (Teflon grease), and a badminton birdie or shuttlecock as the target (artificial flower visual design).
2. Numbers of male and female Lacanobia fruitworm moths were significantly reduced in apple orchards with bait stations with a feeding attractant as the lure.
3. Reductions in moth numbers can be accomplished with relatively low rates of bait stations per acre (50).
4. Most female moths responding to the lure have not yet laid most of their eggs, supporting the idea that bait stations to kill females will reduce oviposition.

METHODS:
Bait Stations: Bait stations were made of a combination of a physical target, a chemical attractant in a controlled release dispenser, and a toxicant in a suitable formulation. The target in this case was a white plastic badminton birdie or shuttlecock. Controlled release dispensers were 8 ml polypropylene vials, each loaded with 5 ml of a 50:50 mixture of acetic acid and 3-methyl-1-butanol (isoamyl alcohol), onto cotton balls within the vial. Three mm diameter holes were drilled into the vial lids for release of the attractant. The vial was glued into the base of the shuttlecock, replacing the rubber cap which was removed from the shuttlecock. The inside of the shuttlecock was coated with a Teflon grease which contained 6% by weight technical grade permethrin. Bait stations (shuttlecock with lure and coated with permethrin in Teflon) were suspended by wire hangers from branches on apple trees, in the upper half of the canopy.

Bait station efficacy was evaluated with a flight tunnel assay and a contact assay. In the flight tunnel, Lacanobia fruitworm moths were tested for attraction to, contact with, and mortality following contact, after exposure for 2 minutes to a bait station. Moths were captured after 2 minutes in the flight tunnel and were held in vials to determine mortality rates. In the contact assay, used on shuttlecocks exposed in the field, moths held with forceps were lightly touched to the shuttlecock and then held in vials to determine mortality rates in comparison to untreated moths.

Plot monitoring.: Orchards were selected to provide space for four 5 acre plots, with all plots of the same variety and similar canopy structure. Each plot was monitored with one blacklight trap, two pheromone traps, and two feeding attractant traps. Blacklight traps possessed 8 watt blacklight bulbs run off of 12 volt batteries. Pheromone traps were Agrisense Universal Moth Traps (green lid, yellow

cone, white bucket), baited with one mg of a three component sex pheromone applied to a rubber septum. Pheromone lures were placed in a small plastic basket at the center of the inside of the trap top. A one inch square piece of Vaportape was placed within each bucket to kill trapped moths. These same traps were used as feed attractant traps, but were baited with 8 ml vials of acetic acid and 3-methyl-1-butanol with 3 mm diameter holes in the lids. Vials were suspended within the bucket of each trap with a thin wire. When traps were checked, all contents were placed in pre-labled ziplock plastic bags for transport to the lab, and were stored in a freezer until moths were sorted and identified under a dissecting microscope. All female Lacanobia fruitworm and spotted cutworm moths were dissected to determine their reproductive status (mating and egg development).

Experiment 1: Bait Station Density. Five-acre plots in apple orchards were monitored starting at the beginning of the *Lacanobia* flight in mid-May 2002. Where and when trap captures were high enough (several moths per trap per day), experiments were begun. The four treatments were 0, 2, 10, and 50 bait stations per acre. Plots were monitored daily for 6 days prior to bait station deployment and daily for 6 days after bait station deployment. Three replicates of this experiment were conducted from late May into early June, while an additional three replicates of the same experimental design were conducted from mid to late June. Orchards used in the 4^{th} to 6^{th} replicates were not the same as orchards used in the 1^{st} to 3^{rd} replicates. Statistical comparisons were made of numbers of Lacanobia moths captured in traps before and after bait station deployment, to determine if numbers of moths in those plots were reduced with bait stations. Additionally, numbers of moths captured after bait station deployment were compared between treatments to determine if there were significantly fewer Lacanobia moths captured in plots treated with bait stations, compared to untreated controls.

Experiment 2: Efficacy of Bait Station Deployment. Five-acre plots in apple orchards were monitored as described above, beginning the first week of August 2002. When trap catches were high enough experiments were begun. This experiment provided comparisons of unbaited plots with plots treated with 50 bait stations per acre. Plots were paired to provide the same apple variety and canopy structure for both treatment and control. Plots were monitored daily for 6 days before bait station deployment, daily for 6 days after bait station deployment, and then intermittently until mid. In early to mid September, depending on variety and other activities in orchards, trees were sampled for larvae, using a beating technique. A white bedsheet was placed on one side of the tree, starting at the trunk, and all limbs above the sheet were knocked with a pole to attempt to dislodge caterpillars on limbs and foliage. Larvae on the sheet were collected into a paper cup with apple leave and were transported to the laboratory for identification. Early instar larvae were reared to third instar for final identification as to species.

Experiment 3. Evaluation of pheromone baited and feeding attractant bait stations. This experiment was not conducted due to a lack of time. Because of difficulties with early season weather contributing to variance in the data, it was decided to repeat the first experiment during the latter half of the first Lacanobia flight rather than conduct this experiment, which was scheduled for that time period.

Results and Discussion:

A total of 48 moths were tested to the final bait station design in the flight tunnel. 22 were attracted, 20 contacted the bait station, and 18 died in the assay. The other two were paralyzed During field tests, bait stations were brought in from the field and tested with the contact assay after 6 days exposure and after 3 weeks exposure. Mortality of Lacanobia moths that were touched to bait stations was 80% and 68% for bait stations that were 6 days and 3 weeks old respectively, with the majority of the remainder paralyzed.

Bait Station Density.

Data from monitoring traps are summarized below in Table 1.

Numbers of male and numbers of female Lacanobia fruitworm moths that were captured in traps baited with the feeding attractant were reduced in plots for the 6 day period following treatment (bait station deployment) compared to the 6 day period before treatment, for the 0, 2, 10 and 50 bait stations per acre treatments. For the 6 day period of monitoring following bait station deployment (post-bait), numbers of male and numbers of female Lacanobia fruitworm moths in traps baited with the feeding attractant were significantly reduced in plots with 50 bait stations per acre, compared to untreated plots.

The reductions in captures of moths from pre to post-baiting appear to be due to changes in weather, and are not attributable to the deployment of bait stations. Experiments were begun when a threshold of several moths per trap per day was reached, which probably was when night time temperatures were relatively warm. The warm weather in May and June did not last longer than the five day pre-baiting period, and cooler weather prevailed for the post-baiting period. However, the post-baiting reductions in moths in traps in treated plots (50 bait stations per acre) compared to control plots can be attributed to the deployment of bait stations and supports the hypothesis that numbers of Lacanobia fruitworm moths in plots were reduced by the bait stations.

Numbers of male and numbers of female Lacanobia fruitworm moths that were captured in blacklight traps were also reduced in plots for the 6 day period following treatment (bait station deployment) compared to the 6 day period before treatment, for most treatments as well as the controls. For the 6 day period of monitoring following bait station deployment (post-bait), numbers of male and numbers of female Lacanobia fruitworm moths in blacklight traps were significantly reduced in plots with 50 bait stations per acre, compared to untreated plots.

These data support the discussion above, that bait station deployment reduced the presence of Lacanobia in plots with 50 bait stations per acre, but that there was a strong reduction in moth activity following the dates of baiting in all plots, probably in response to changes in weather. It is encouraging that similar results were obtained with blacklight and feeding attractant traps, because a reduction in captures of moths in feeding attractant traps might be interpreted as evidence of disruption of moth ability to find lures in baited plots, rather than evidence of mortality of moths at bait stations. It is less likely that odors from lures of bait stations would effect moth response to blacklight.

Numbers of male Lacanobia moths captured in pheromone traps were reduced during the post baiting period compared to the pre-baiting period, in control and treated plots. During the 6 day post-baiting period, numbers of males in baited plots (2, 10, or 50 bait stations per acre) were not significantly different than in unbaited plots.

It is generally assumed that male response to female sex pheromone involves much greater distances than moth responses to either blacklight or feeding attractant. Also, males are more likely to be wide-ranging in their search for mates, compared to moths searching for food. Thus, it is not surprising that the any mortality of males from bait stations in 5 acre plots did not significantly impact numbers of males in pheromone traps.

Table 1. Numbers of Lacanobia fruitworm moths captured in monitoring traps in 5 acre apple plots treated with different numbers of bait stations. May-June 2002. Monitoring traps were baited with acetic acid and isoamyl alcohol (AAIAA), blacklight, or sex pheromone lure (Pheromone).

	Bait Stations per Acre			
	0	2	10	50
AAIAA				
female prebait	0.63 ± 0.15	0.79 ± 0.17	0.64 ± 0.15	2.15 ± 0.56
female postbait	0.22 ± 0.06a	0.25 ± 0.07a	0.21 ± 0.07a	0.04 ± 0.02b
male prebait	0.34 ± 0.09	0.49 ± 0.12	0.45 ± 0.13	1.21 ± 0.26
male postbait	0.11 ± 0.04a	0.15 ± 0.05a	0.13 ± 0.05a	0.06 ± 0.03b
Blacklight				
female prebait	0.24 ± 0.11	0.47 ± 0.29	0.35 ± 0.28	0.63 ± 0.24
female postbait	0.14 ± 0.07a	0.13 ± 0.07a	0.09 ± 0.07a	0.03 ± 0.03b
male prebait	0.13 ± 0.06	0.45 ± 0.32	0.18 ± 0.17	0.63 ± 0.21
male postbait	0.14 ± 0.07a	0.21 ± 0.13a	0.06 ± 0.04b	0.06 ± 0.04b
Pheromone				
male prebait	10.23 ± 1.97	6.71 ± 1.15	8.59 ± 1.47	10.21 ± 1.49
male postbait	5.08 ± 0.96a	2.79 ± 0.44a	3.96 ± 0.66a	4.38 ± 0.71a

Means within a row followed by the same letter are not significantly different at $p < 0.05$ by an lsd test.

Efficacy of Bait Station Deployment

Data from monitoring traps are summarized below in Table 2.

In plots treated with bait stations, numbers of female Lacanobia fruitworm moths that were captured in traps baited with the feeding attractant were significantly reduced during the 6 day period following baiting compared to the 6 day period before baiting. Numbers of males in those plots were numerically but not significantly lower following baiting. For the 6 day monitoring period following baiting, numbers of male and numbers of female Lacanobia in feeding attractant traps were significantly lower in treated plots compared to control plots.

In plots treated with bait stations, numbers of female Lacanobia captured in blacklight traps were significantly reduced during the 6 days after baiting compared to the 6 days before baiting. Numbers of males in those plots were numerically but not significantly lower following baiting. For the 6 day monitoring period following baiting, numbers of male and numbers of female Lacanobia in blacklight traps were significantly lower in treated plots compared to control plots.

Numbers of male Lacanobia in traps baited with pheromone were significantly reduced in baited plots compared to control plots during the 6 day post baiting period. Male numbers were not significantly reduced in baited plots during the post baiting period compared to the pre-baiting period.

This trap catch data supports the hypothesis that the bait stations deployed at 50 per acre reduced populations of Lacanobia fruitworm moths in plots, particularly numbers of females. Numbers of female Lacanobia moths captured in feeding attractant traps were reduced by about 3/4 while numbers in blacklight traps were reduced about ½.

Numbers of Lacanobia larvae collected were not sufficient for statistical analysis. However, all larvae collected were in unbaited plots.

Table 2. Numbers of Lacanobia fruitworm moths captured in monitoring traps in 5 acre apple plots that were treated with 50 bait stations per acre or were not treated (control). August-September 2002. Monitoring traps were baited with acetic acid and isoamyl alcohol (AAIAA), blacklight, or sex pheromone lure (Pheromone).

	Bait Stations per Acre	
	0	50
AAIAA		
female prebait	0.74 ± 0.19ax	0.76 ± 0.14bx
female postbait	1.35 ± 0.23ax	0.32 ± 0.07by
male prebait	0.65 ± 0.17ax	0.69 ± 0.16ax
male postbait	1.10 ± 0.17ax	0.44 ± 0.12bx
Blacklight		
female prebait	3.36 ± 0.45ax	2.79 ± 0.78ax
female postbait	2.08 ± 0.32ax	1.14 ± 0.21by
male prebait	16.91 ± 3.53ax	6.00 ± 2.06ax
male postbait	11.94 ± 2.68ax	3.31 ± 0.78bx
Pheromone		
male prebait	72.79 ± 6.77ax	49.78 ± 6.37ax
male postbait	59.34 ± 5.38ax	36.10 ± 2.66by

Means within a row followed by the same letter (a or b only) are not significantly different at $p < 0.05$ by an lsd test. Means within a column pair followed by the same letter (or or y only) are not significantly different at $p < 0.05$ by an lsd test.

These results provide a possible means of reducing populations of Lacanobia fruitworm below damaging levels without using cover sprays of insecticides. Advantages of such a bait station method are 1) minimal or no contact between pesticide and the commodity, 2) minimal contact between the pesticide and beneficial arthropods, 3) reduced contact between pesticide and workers. Costs of such a system are as yet unknown. Further work needs to be done to determine if reductions in numbers of female moths in orchards is directly related to reductions in reproduction and then in larvae on apple trees in the next generation. Costs of materials for the bait station are low (birdie, grease, pesticide, attractant, vial, wire) but can certainly be reduced.

Project Title: Development of bait stations for control of Lacanobia fruitworm.
Project Duration: 2000-2002.
Current Year: 2002
Project Total (3 years): $84,313

Year	Year 1 (2000)	Year 2 (2001)	Year 3 (2002)
Total	$32,213	$25,000	$27,000
Current year breakdown			
Item	Year 1 (2000)	Year 2 (2001)	Year 3 (2002)
Salaries	$20,800	$22,000	$19,500
Benefits	6,930		2,500
Equipment			
Supplies	4,000	3,000	4,000
Travel	500		1,000
Total	$32,213	$25,000	$27,000

Additional support was provided in 2001 and 2002 by IFAFS/RAMP ($30,165 per annum).