FINAL PROJECT REPORT
WTFRC Project Number: CP-08-804 (WSU Project #13C-3643-5092)

Project Title: Management of codling moth and leafrollers in apple orchards

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Other funding sources

Agency Name: Washington Commission on Pesticide Registration
Total amount awarded: $48,324

Agency Name: Private Chemical Companies
Total amount awarded: ≈ $85,000
The financial information provided in addition to sponsor support simply communicates research program support costs vs. specific project cost-share commitment.

WTFRC Collaborative expenses: None

Total Project Funding: $61,002

Budget History

Item	2008	2009
Salaries [1]	18,170	18,879
Benefits [1]	7,240	7,563
Wages [2]	3,000	1,500
Benefits	471	270
Equipment	0	0
Supplies [4]	1,000	1,000
Travel [3]	1,000	1,000
Miscellaneous	0	0
Total	30,881	30,212

Footnotes:
[1] Kathleen Pierre (3 months - Associate in Research) and Mike Doerr (2 months - Administrative Professional).
[2] Temporary or hourly workers.
[3] Pays for a vehicle used part-time on this project plus fuel and maintenance costs.
[4] Leafroller diet components, plastic Petri dishes, glassware.

Objectives:

1. Develop baseline toxicity bioassays for codling moth and leafroller of new insecticides under development.
2. Select populations of leafrollers (in the laboratory) to determine their inherent potential to develop resistance to selected insecticides.
3. Develop molecular markers to use as a tool for early detection of resistance development in leafrollers and codling moth.
4. Survey codling moth and leafroller populations using discriminating concentrations for key insecticides.
5. Characterize cross-resistance in leafrollers between old and new insecticides.
6. Evaluate new insecticides for control of codling moth and leafrollers in field tests.

Significant findings 2008

1. Field-aged bioassays and field trials confirmed previous laboratory results showing that Altacor (rynaxypyr) has activity against codling moth (CM) eggs, primarily when laid on residues. The same effects were not observed for Belt, a new insecticide in the same class, which at least partially explains why this product does not provide control of CM in field tests.
2. Laboratory selection for resistance in obliquebanded leafroller (*OBLR)* to Altacor (rynaxypyr) and Delegate (spinetoram), to insecticides registered for use in 2008, showed that after five or four generations, respectively, resistance to Altacor were seven times that of the susceptible laboratory colony while resistance to Delegate were only 3.5 times that of the laboratory colony.
3. Every population of *OBLR* collected in the field (6) showed significant levels of resistance to Altacor (rynaxypyr) relative to the laboratory colony. Resistance ratios ranged from two to five. There was some suggestion from the data that resistance to Altacor was correlated to resistance to the organophosphate insecticide azinphosmethyl (Guthion).
4. The field collected *OBLR* populations showed the same level of resistance or enhanced susceptibility to Delegate (spinetoram) as they did to Success (spinosad). These data demonstrate that resistance to Success will be conferred on Delegate as was expected.
5. Data from 2008 show *OBLR* populations resistance to Proclaim (emamectin benzoate) for the first time since it was registered in 2005. Previous data had not shown any sign of resistance in field-collected populations of leafrollers.
6. An international effort to characterize baseline resistance in CM to Altacor did not reveal any concerns for resistance, though there was considerable variation in the response of different populations to discriminating concentrations.
7. Field trials with Delegate and Altacor confirmed earlier studies, which showed them to be highly effective leafroller control products.

Significant findings 2009

1. Laboratory *OBLR* populations selected for resistance to Altacor and Delegate reverted to susceptibility in five and six generations, respectively, after selection pressure was removed.
2. The heritability of Altacor and Delegate selected *OBLR* populations declined over five of six generations, respectively, indicating that most of the genetic variation had been selected against.
3. Evaluation of Altacor and Delegate selected OBLR populations showed different biochemical mechanisms were at work. Esterases were elevated in Altacor selected populations while oxidases were elevated in Delegate selected populations.
4. A measure of the speed of resistance development suggested that the evolution of resistance would be slower in Delegate compared to Altacor.

5. Field trials confirmed that the application of residual ovicides at petal fall provided a delay in the onset of CM fruit injury by approximately 100 DD, therefore allowing first cover sprays to be delayed by this same period.
6. New formulations of malathion did not extend the longevity of residues against CM.
7. Delegate did not show ovicidal activity against CM eggs but when it was used at the petal fall timing it delayed the onset of CM injury much like residual ovicides.

Methods:

Methods used in this project were outlined in last year's new project proposal and have not changed significantly enough to warrant their repetition here. If there are specific questions with regard to methods, consult the 2007 new proposal or contact the PI for more information.

Results and Discussion:

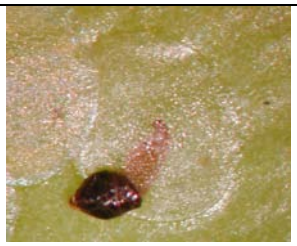
Baseline Bioassays: Laboratory bioassays help to characterize the inherent toxicity of insecticides against pests and, therefore, establish baseline data on susceptibility for future reference when questions of resistance arise. Table 1 summarizes results of laboratory bioassays for several registered and experimental products evaluated against CM and *OBLR* in 2008-09.

Table 1. Summary of baseline bioassays conducted in 2008-09.

Chemical	Year	Source	n	Slope (SE)	LC_{50}-ppm (95% CL)
CM larval screening (fruit injury)					
Malathion	2009	LAB	400	1.6 (0.4)	24.3 (7.3-45.6)
CM ovicidal screening – Egg dip test (topical application)					
Delegate	2009	LAB	2557	0.7 (0.04)	10.9 (6.5-1635)
Cyazypyr	2008	LAB	1541	0.4 (0.8)	955.7 (n/a)
CM ovicidal screening – Apple dip test (residual application)					
Delegate	2009	LAB	3689	1.4 (0.7)	141.8 (110.6-181.1)
Cyazypyr	2008	LAB	1431	2.1 (0.2)	27.7 (19.8-36.8)
CM larval screening – Diet incorporation (larval mortality)					
Delegate	2008	LAB	210	2.2 (0.6)	0.04 (0.02-0.07)
Success	2008	LAB	210	2.9 (0.8)	0.26 (0.12-0.39)
Altacor	2008	LAB	210	2.0 (0.5)	0.07 (0.01-0.13)
Altacor	2008	LAB	245	2.1 (0.4)	0.05 (0.03-0.08)
Cyazypyr	2008	LAB	210	3.5 (0.8)	0.07 (0.03-0.11)
Cyazypyr	2008	LAB	280	3.0 (0.6)	0.06 (0.04-0.08)
CM adult screening – Laboratory reared adults (adult mortality)					
Delegate	2008	LAB	366	0.6 (0.09)	471.9 (239-966)
Guthion	2008	LAB	125	2.5 (0.4)	232.0 (144-4000)
Success	2008	LAB	226	1.0 (0.2)	770.6 (485-1871)
Lorsban	2008	LAB	102	1.8 (0.4)	206.1 (108-684)
OBLR adult screening – Laboratory reared adults (adult mortality)					
Delegate	2008	TF LAB	198	1.5 (0.2)	12.9 (n/a)
Guthion	2008	TF LAB	71	3.0 (0.7)	148.2 (100-228)
Success	2008	TF LAB	194	1.4 (0.9)	45.0 (n/a)
Lorsban	2008	TF LAB	95	3.4 (1.0)	116.1 (53.8-165.2)

The combined ovicidal, ovi-larvicidal and true larvicidal activity (Fig. 1) of different products helps explain their potency against this CM. In previous studies Altacor (rynaxypry) was shown to be highly toxic to CM eggs as a residue (LC_{50} - 6.1 ppm) but less toxic when applied topically (LC_{50} - 55.2 ppm). Another experimental insecicide, cyazypyr, in the same class showed activity similar to rynaxypry, that is it was more toxic to CM eggs as a residue than when applied topically (Table 1). Another insecticide, Belt, showed poor ovicidal activity against CM eggs, which at least partially explains why it does not provide robust control in the field. Delegate showed more toxicity when applied topically to CM eggs compared to when eggs were exposed to residues, LC_{50} values or 10.9 ppm and 141.8 ppm, respectively. At the field rate it was estimated that 63% of eggs would die when treated topically (sprayed) versus 18% if eggs were deposited on a residue. Bioassays were also conducted against different formulations of malathion designed to extend the life of this insecticide. Results showed no improvement of longevity compared to a standard malathion formulation.

Figure 1. Examples of the effects of insecticides on the egg, ovicidal, or the larval stage, ovi-larvicidal or larvicidal, of codling moth.

		
True ovicidal activity. The larva died within the egg.	Ovi-larvicidal activity. The larva died in the process of exiting the chorion.	True larvicidal activity. The larva exited the egg, fed briefly, and died in close proximity to the egg.

Selecting for Resistance: One way to determine the risk of resistance development is to select populations in the laboratory over successive generations and determine if and at what rate tolerance to a chemical develops. We selected 2,000 OBLR leafroller neonates with an LC_{70} concentration each generation. The concentration (LC_{70}) of insecticides increased as the tolerance of the selected populations increased. Selection with Altacor resulted in a significant increase in the LC_{50}, resistance ratio of more than 2, while after five generations the LC_{50} value had increased almost seven fold relative to the unselected laboratory colony (Table 2). After four generations of selection with Delegate the LC_{50} value had increased only about 3.5 times (Table 2) but this represented a significant resistance ratio.

Table 2. Results of probit analyses for diet incorporation bioassays with *C. rosaceana* neonate larvae from Altacor and Delgate selected populations.

Selected Generation	Chemical	n	Slope (± SE)	χ^2	LC_{50} (ppm) (95% FL)[1]	LC_{90} (ppm) (95% FL)[1]	LCR-LC_{50}[2] (95% CL)[3]
1	Altacor	450	1.02 (0.39)	20.74	0.16 (0.07-0.32)	2.94 (1.41-8.37)	2.2 (1.02-4.65)*
3	Altacor	350	1.72 (0.17)	17.10	0.26 (0.20-0.34)	1.46 (1.00-2.43)	3.1 (2.12-4.43)*
5	Altacor	210	1.19 (0.17)	10.31	0.77 (0.31-1.48)	9.26 (4.40-33.02)	6.6 (3.27-13.24)*
6	Altacor	180	1.88 (0.36)	7.71	1.03 (0.50-1.66)	4.93 (2.88-14.19)	6.6 (3.68-11.79)*
1	Delegate	450	2.56 (0.37)	4.18	0.10 (0.07-0.12)	0.31 (0.23-0.48)	1.26 (0.86-1.85)
2	Delegate	350	2.53 (0.33)	3.96	0.12 (0.09-0.15)	0.39 (0.29-0.59)	2.3 (1.59-3.26)*
4	Delegate	350	3.63 (0.58)	2.98	0.17 (0.14-0.20)	0.38 (0.30-0.56)	3.5 (2.37-5.09)*
6	Delegate	210	3.01 (0.48)	2.52	0.22 (0.17-0.29)	0.59 (0.43-1.02)	3.64 (2.42-5.46)*

The heritability (h^2) declined in the Altacor selected population after only five generations indicating that much of the heterogeneity in the population has been selected against (Fig. 2). The heritability (h^2) had not declined in the Delegate selected population by the fourth generation indicating that there was more heterogeneity in the population yet to be selected against, but by the sixth generation heritability had declined to levels similar to that of the Altacor selected population.

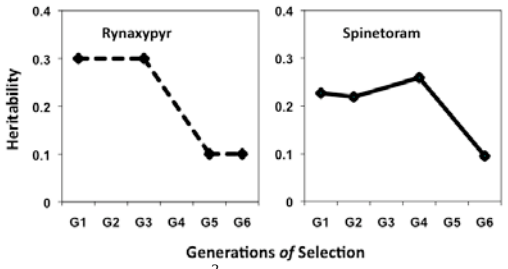


Fig. 2. Heritability (h^2) of Altacor (left) and Delegate (right) resistance in a laboratory population of *OBLR* selected for resistance.

The mean values of the response quotient (*Q)* for resistance against Altacor and Delegate were 0.11 and 0.07, respectively (Fig. 3). These results indicate that resistance evolution would be slower against Delegate than that against Altacor, and thus Delegate would be more durable than Altacor against this particular population of *OBLR*.

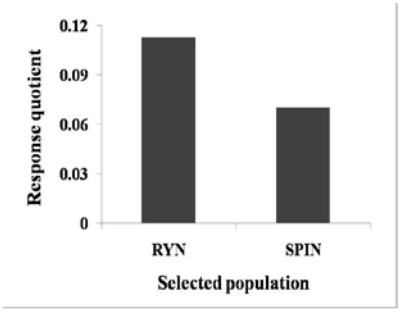


Fig. 3. Response quotients of the Altacor and Delegate selected populations of *OBLR*.

These data demonstrate the risk of these two new insecticides to resistance development and underscores the need to follow sound resistance management strategies to at least slow the development of resistance in the field.

Reversion of resistance: A cohort of *OBLR* populations selected for resistance were removed from selection pressure and evaluated each generation to determine if susceptibility would return. Selected populations were susceptible to Altacor (rynaxypyr) after five generations and to Delegate (spinetoram) after six generations (Fig. 4). It is encouraging that reversion to susceptibility occurred with both insecticides as it suggests that resistance can be managed through rotation with each other, or possibly other products with different modes of action.

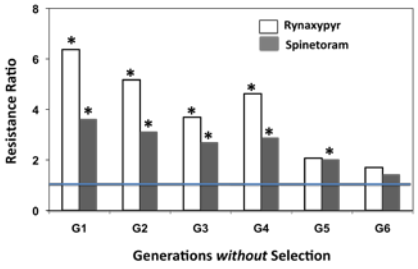


Fig. 4. Reversion of resistance in *OBLR* removed from selection.

Surveys of Field Populations: A survey of CM populations from across the state revealed no concerns with tolerance to Delegate or Altacor. Delegate data were from topically treated adults using technical spinetoram dissolved in acetone. The demonstration that this method can provide reliable and repeatable dose-response lines will allow us to use moths captured in pheromone traps to assess more codling moth populations than is possible if bioassays are restricted to larvae.

We have participated in an international project looking at susceptibility of CM to Altacor. This has been a very good collaborative experience and data thus far shows no major difference in tolerance between field and laboratory (susceptible) populations (Fig. 5).

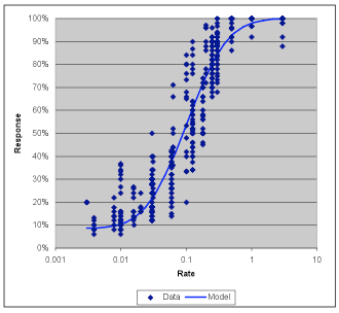


Fig. 5.

Field populations of *OBLR* were collected from six different orchards. Populations were reared in the laboratory and tested using a diet incorporation bioassay to determine their susceptibility to Delegate and Altacor. Results of these bioassays are shown in Fig. 6. Every population of *OBLR* collected in the field showed significant, though low, levels of resistance to Altacor (rynaxypyr) relative to the laboratory colony. Populations showed varying levels of resistance to Delegate (spinetoram) with some populations being resistant while other were more susceptible than the laboratory colony. The response of *OBLR* populations to Delegate mirrored that of Success (spinosad), indicating cross-resistance between these products. These data demonstrate that resistance to Success will be conferred on Delegate as was expected. These data did not suggest any correlated cross-resistance between Altacor or Delegate and the organophosphate insecticide Guthion (azinphosmethyl). Low levels of resistance to Proclaim (emamectin benzoate) was documented for the first time since its registration in 2005. Previous data had not shown any sign of resistance in field-collected populations of leafrollers.

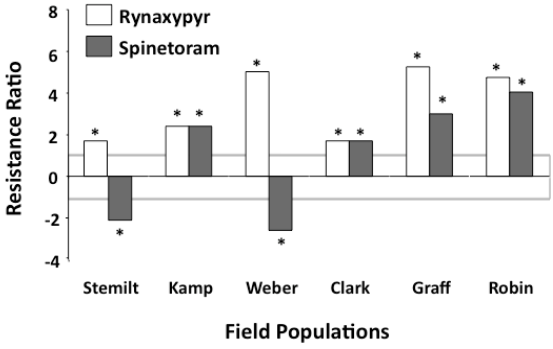


Fig. 6.

A new chemistry in the same class as Altacor was evaluated for toxicity to five field populations of CM. Results showed a high level of toxicity to all populations and LC_{50} values similar to those from a susceptible laboratory population.

Field-collected populations will continue to be reared in the laboratory and used in further experiments to determine if the mechanism of resistance noted from the selected laboratory population (see below) are also expressed in the field populations. It is possible that two different mechanisms are functioning in these populations.

Mechanisms of Resistance: We used colorimetric microplate assays to assess the activity of detoxification enzymes in resistant (selected) as well as susceptible (unselected) populations of *OBLR* in order to determine the mechanisms of resistance. We used a total of 30 third instar larvae from each of the selected and unselected populations to determine total proteins using Bio-Rad protein assay, and the activity of non-specific esterases, mixed-function oxidases, and glutathione-*S*-transferases using α-naphthyl acetate (α-NA), *3,3′,5,5′*-tetramethylbenzidine (TMBZ), and *1*-chloro-*2,4*-dinitrobenzene (CDNB) as substrates, respectively. The results of detoxification enzyme assays indicate that the activity of esterases was significantly increased in Altacor (Fig. 7 - left) selected population *(p = 0.004)* whereas the level of oxidases was significantly increased in the Delegate (spinetoram) selected population *(p = 0.039)* (Fig. 7 - right). There was no increase in glutathione-*S*-transferases activity for Altacor selected populations but Delegate selected populations showed an increase in activity though not significantly different from unselected populations *(p = 0.054)*. These results indicate that the laboratory selected populations that showed resistance to Altacor and Delegate do not share resistance mechanism. It further suggests that these two reduced-

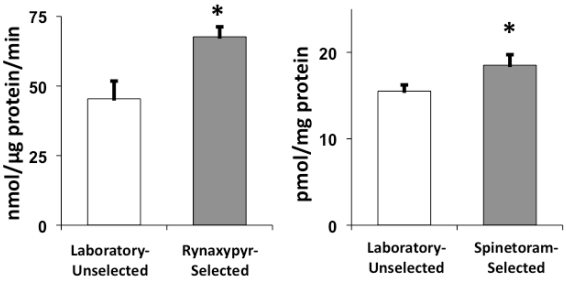


Fig. 7.

risk insecticides can be used in resistance management program involving the use of these products in rotation. Further studies will examine field-collected populations to determine if they show the same levels of enzyme activity as the laboratory selected populations. It is always possible that field populations will have a different pattern of biochemical resistance than the selected populations.

Development of Molecular Markers: No progress has been made in developing molecular markers for resistance in *OBLR* to Altacor or Delegate. It was likely too ambitious of a goal to set to be able to identify molecular markers within the scope of this project. However, now that we have resistant populations it should be possible with additional time and funding to move forward with this objective. We will not be asking the commission to fund this work.

Efficacy Evaluations: Twenty field trials to evaluate new insecticides for efficacy, timing and rates against CM and *OBLR* were conducted in the 2008-09 period. Most of these efforts were supported through gift grants from private chemical companies. Data from these trials form the basis for recommendations in WSU Extension Bulletin EB-0419 "Crop Protection Guide for Tree Fruits in Washington".

A key finding showed that Altacor had ovicidal activity, which provides flexibility in its use pattern in apple and the opportunity to coincidentally control CM eggs and leafroller larvae early in the season. Cyazypyr, a new chemical made by the same company that developed Altacor, showed similar activity against CM (eggs and larvae) and *OBLR* in field trials. However, a closely related product, Belt (flubendiamide), was shown not to have ovicidal activity against CM and most likely accounts for its lower level of efficacy against this pest.

Table 3 is a summary of numerous field trials over the last 5 years comparing control of CM based on insect growth regulators (IGRs) with programs based on neonicotinyls (Assail or Calpyso) and azinphos-methyl (AZM - Guthion). IGRs worked well when directed against the first CM generation but were never as good as the neonicotinyls or Guthion, even though they were applied three versus two times. The level of control with the IGRs declined in the second CM generation, especially for

Table 3. A summary of insect growth regulator and oil programs for control of CM compared to those using neonicotinyl or azinphos-emthyl programs.

				Avg Reduction in Codling Moth Injury Relative to UTC (SEM)		
	Rate (gm	Timing (DD[a], + Retreatment Interval)		1st	2nd	
Insecticide	AI/A)	1st Generation	2nd Generation	Generation	Generation	n
Rimon	95	100, +14d, +14d	1000, +14d, +14d	85.9 (4.7)	81.9 (3.4)	7
Intrepid	113	100, +14d, +14d	1000, +14d, +14d	88.0 (2.9)	77.1 (2.3)	4
Esteem	50	100, +14d, +14d	1000, +14d, +14d	73.7 (9.2)	55.5 (4.8)	3
Mineral Oil	1% v:v	200, +14d, +14d	1200, +14d, +14d	74.9 (6.7)	55.2 (10.8)	4
Neonic.[b]	Various	250, +21d	1250, +21d	96.5 (6.4)	84.5 (1.3)	6
Guthion	454	250, +21d	1250, +21d	96.9 (1.1)	94.8 (1.4)	9

[a], Timing reported as accumulated codling moth degree-days (Celsius) from biofix unless followed by 'd' indicating the calendar day interval between applications.

[b], Compilation of all trials that relied on season-long applications of Assail or Calypso.

n, Number of trials.

Esteem. Oil alone provided reasonable control of CM by killing eggs in the first generation but the level of control fell in the second generation. It is likely that control with IGRs and oil in the second CM generation would have been high if one more application had been applied to cover the longer

oviposition period. These data show that IGRs and oil can control CM but do not represent the best stand-alone programs for this pest. It is better to incorporate the benefits of IGRs or oil into programs that incorporate lavicides in order to optimize CM control.

Table 4 gives a summary of how characteristics of IGRs and oil can be incorporated into programs with larvicides to control CM. Two different strategies are outlined in this table. In the first strategy an IGR or oil is applied at the beginning of a CM generation to act as an ovicide. In the first generation the IGR coincidentally controls leafroller larvae. The early ovicide treatment is followed by a tank-mix of an IGR and larvicide, which acts to kill larvae hatching from eggs and to kill eggs deposited after the treatment. The value of this approach is to reduce trips through the orchard and it has been a very powerful program against very high CM populations, especially if followed by an additional larvicide 14-17 days after the tank-mix application. The second strategy uses an IGR or oil early in each generation as in the first strategy, but follows it with a delayed (100 DD) larvicide, which is repeated 17 days following the first. This strategy is effective because it puts the most active residues of the larvicides on the target when most of the CM egg hatch is occurring.

Table 4: Summary of field trials that incorporated ovicides and larvicides for control of CM.

Ovicide Class[a] (Timing[b])	Timing (tank-mix[d] or larvicide)	Retreatment (17 days later)	Avg reduction in CM injury relative to UTC (SEM) 1st Gen	2nd Gen	n
Tank mix strategy with delayed first cover					
IGR	IGR + Larvicide[c]		88.8 (3.5)	89.9 (1.3)	8
HMO	IGR + Larvicide		91.6 (3.5)	83.6 (3.6)	9
Ovicide early with delayed first cover larvicide treatments					
IGR	Larvicide[c]	Larvicide	97.7 (1.4)	92.6 (1.4)	3
HMO	Larvicide	Larvicide	75.1 (8.7)	77.1 (5.3)	5

[a], Ovicide class, IGR is either Rimon, Intrepid, or Esteem. HMO is horticultural mineral oil.

[b], Timing for IGR at 100 or 1000 CM degree-days (DD) from biofix. Timing for oil is 200 or 2000 DD.

[c], Larvicide is either Assil, Calypso, Delegate, or Altacor.

[d], Tank-mix timing is delay cover; 350 DD in first generation or 1350 DD in second generation.

n, number of trials.

In 2008 two large plot field trials (un-replicated) Altacor and Delegate provide excellent control of *OBLR*. In 2009 we evaluated five insecticides in large un-replicated field trials against *OBLR* that were applied by a grower. All the insecticides provided very good control in this test (Table 5). We have also conducted several replicated small plot trials in 2008 and 2009 against overwintered and summer *OBLR* that showed very good results for these products.

Table 5: *OBLR* control following a single petal fall application, 2009.

Trt	Insecticide	Rate (form/acre)	Post-treatment Evaluation (20 DAT)- OBLR/100 shoots Feeding sites	Live larvae	Pupae	Dead Larvae
1	Proclaim 5SG	4 oz	20.4	0.0	0.0	4.5
2	Delegate 25WG	6 oz	15.8	0.2	0.0	2.6
3	Altacor 35WG	4 oz	14.1	0.5	0.0	1.8
4	Belt 480SC	5 fl oz	20.8	0.1	0.0	4.8
5	Tourismo*	15 fl oz	15.7	0.1	0.0	2.0

* - Tourismo is a pre-mix of flubendiamide and a buprofezine.

We showed that *OBLR* larvae were controlled by a blossom application of limesulfur. While these data were from a hand-gun applied treatment, and are thus preliminary information that need to be validated using standard airblast equipment, they do show that if a grower is applying limesulfur as a blossom thinner they likely would not need a specific leafroller control at petal fall.

Reduce use of Lorsban (chlorpyrifos) is in response to grower sensitivity to using organophosphate insecticides due to farm worker concerns and because there are many effective alternatives for leafroller control that can be used later in the season, e.g. at petal fall. Some questions have arisen about the impacts of eliminating Lorsban from the pre-bloom control and we conducted a test in 2009 to address some of these questions. The test was a replicated small plot design. The treatments are shown in Table 6. Lorsban and different oils were the primary insecticide treatments. While different tools were used to assess the impact of different treatments the focus of this discussion is on their effects on aphids and their natural enemies. Where Lorsban was included as a treatment there

Table 6: Aphid shoot samples associated with Lorsban and oil treatments, 2009.

			Average number of aphid infested shoots/2 minute sample						
			28-May			15-Jun		30-Jun	7-Aug
Trt	Treat.	Rate (form. per acre)	AGA	GAA	RAA	GAA	RAA	RAA	WAA
1	Citrus Oil Lorsban	2 qrt 2 qrt	1.0a	0.7a	0.0b	3.7a	0.7b	1.0b	1.3b
2	Supreme Oil Lorsban	5 gal 2 qrt	0.0a	0.0a	0.0b	6.0a	0.3b	2.7b	0.0b
3	Citrus oil Supreme Oil Lorsban	2 qrt 2 gal 2 qrt	1.3a	0.0a	0.0b	4.0a	1.3b	0.3b	0.7b
4	MSO Lorsban	2 qrt 2 qrt	2.0a	0.0a	0.0b	6.7a	0.3b	0.0b	0.3b
5	MSO Supreme Oil Lorsban	2 qrt 2 gal 2 qrt	0.7a	0.0a	0.3b	5.0a	0.3b	0.0b	0.0b
6	EXP Oil Lorsban	2 qrt 2 qrt	1.7a	0.3a	0.7b	4.0a	0.3b	3.3b	0.0b
7	Supreme Oil	5 gal	1.0a	0.0a	0.0b	4.3a	0.3b	3.7b	12.0a
8	Citrus oil	3 qrt	0.3a	0.7a	1.0b	5.3a	1.3b	2.0b	12.7a
9	Supreme Oil Assail	5 gal 1.7 oz	0.0a	0.7a	0.0b	9.0a	0.0b	0.3b	25.0a
10	UTC		2.0a	0.0a	5.0a	3.3a	9.7a	13.0a	8.3a

Means in the same column followed by the same letter are not significantly different (P=0.05, Student's t test).

were lower levels of rosy apple aphid (RAA) but not of apple grain aphid (AGA) or green apple aphid (GAA). There were also lower levels of woolly apple aphid (WAA) in the August sample. It appears that Lorsban used in the delayed-dormant had some impact on WAA densities. It is also interesting to note that we could not identify any negative impact on natural enemies, such as, the WAA parasite from Lorsban applications based on limb taps, yellow sticky cards or shoot samples. We did sample fruit injury in this test and found that where Lorsban was included in delayed-dormant treatments San Jose scale infestation on fruit was significantly less than where only oil was applied.

Executive Summary
Baseline toxicities have been established for CM and *OBLR* for all the newly registered insecticides. These data provide an understanding of the inherent toxicity of these products as well as the basis for evaluating suspected resistance development in the field. Additional information on the residual activity of new insecticides has also been developed through field-aged bioassays. These data helped to define the effective residue life of different chemicals and also provides another tool for assessing suspected resistance. Field populations of CM and *OBLR* have been evaluated for their susceptibility to several newly registered insecticides. While no resistance was detected in CM populations most populations of *OBLR* evaluated were found to have low to moderate levels of resistance, in some cases before those populations were exposed to the products. A susceptible *OBLR* population was selected in the laboratory with Delegate and Altacor. After one and four generations *OBLR* showed significant levels of resistance to Altacor and Delegate, respectively. The biochemical basis for resistance in *OBLR* to Altacor and Delegate was due to increased levels of esterases and oxidases, respectively. These findings support the concern that new chemistries will be susceptible to resistance development, especially in *OBLR*, and points to the need for sound resistance management programs. There did not appear to be a strong correlation between resistance to new insecticides and OP insecticides in *OBLR* populations, however, there was strong cross-resistance between Delegate and Success. Numerous field trials have been conducted to evaluate new insecticides for control of CM and *OBLR*, both as individual product comparisons and in programs that mix different products. The results of these trials are represented in WSU recommendations found in EB-0419 and in educational materials associated with the Pest Management Transition Project.