FINAL PROJECT REPORT
WTFRC Project Number: AE-05-504 **(WSU Project No. 13C-3643-3190)**

Project Title: Management of leafrollers in apple orchards

PI: Jay F. Brunner
Organization: WSU-Tree Fruit Reseach & Extension Center
Telephone: 509-663-8181
Address: 1100 N. Western Ave.
City: Wenatchee
State/Province/Zip: WA 98801
Email: jfb@wsu.edu
Cooperators: Mike Doerr, WSU-TFREC; Steve Garzinski USDA-ARS Yakima; John Dunley, WSU-TFREC

Other funding Sources

Agency Name:	**Washington State Commission on Pesticide Registration**
Amount awarded:	**$56,593** (two years funding)
Notes:	These funds were used primarily to support a Ph.D. Student working on resistance issues in leafroller and codling moth.
Agency Name:	**Private chemical companies** (Dow, Valent, DuPont, Syngenta, Cerexagri)
Amount awarded:	**$75,000** (funding over three years)
Notes:	These funds were used to maintain leafroller colonies and conduct field surveys of resistance and establish baseline data for some new products.

Total Project Funding: ***2005:*** 25,898 ***2006:*** 26,922 ***2007:*** 27,631

Budget History

Item	**Year 1:** 2005	**Year 2:** 2006	**Year 3:** 2007
Salaries [1] (AR-0.25); (AP-0.083)	 7,048 (AR) 4,603 (AP)	 7,401 (AR) 4,817 (AP)	 7,512 (AR) 4,898 (AP)
Benefits[1] (AR-46%); (AP-34%)	 3,242 (AR) 1,565 (AP)	 3,626 (AR) 1,638 (AP)	 3,456 (AR) 1,665 (AP)
Wages [2]	5,400	5,400	6,000
Benefits	540	540	600
Equipment	0	0	0
Supplies [3]	1,500	1,500	1,500
Travel [4]	2,000	2,000	2,000
Miscellaneous	0	0	0
Total	25,898	26,922	27,631

Footnotes:

[1] **Ph.D. student**. Funding provided by the Washington Commission on Pesticide Registration (WSCPR) was not used because the student did not arrive until January 2006. WSCPR has authorized funds already allocated to be used in 2006 for the student. **Kathleen Pierre (AR Associate in Research)** - rearing and maintenance of leafroller colonies; **Mike Doerr (AP Administrative Professional)** – management of project and bioassay efforts.

[2] Summer labor to assist with rearing of leafrollers.

[3] Leafroller diet components, plastic Petri dishes, glassware. Cell phone charges are allowed under this grant.

[4] Pays for a vehicle for six months used part-time on this project plus fuel and maintenance costs.

Objectives:

1. Develop a dose-mortality bioassay method for insect growth regulators (IGRs) and other new insecticides to establish baseline toxicity data for codling moth and leafroller.
2. Develop discriminating concentrations for key insecticides.
3. Use molecular methods as a tool for early detection of resistance development in leafrollers and codling moth.
4. Evaluate levels of resistance in leafroller populations from orchards suspected of having resistance issues with insecticides.
5. Characterize any 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:

1. Baseline susceptibility data for several new insecticides (some not yet registered) have been developed for leafrollers and codling moth (Table 1). These include baselines for insect growth regulators, which do not conform to the typical baseline approaches of measuring mortality.
2. For codling moth we have developed ovicide bioassays. This method allows us to determine if an insecticide has efficacy against the egg stage and which exposure method, topical or residual, is most efficacious. This approach has also been used to develop baseline concentration-response curves on codling moth eggs for new insecticides (Table 1).
3. A new artificial diet has been used to establish dose-response curves using a diet incorporation method. This approach allows evaluation of resistance when fruit or foliage is not available. It also provides a good system for selecting codling moth or leafroller populations by exposing them to insecticides each generation (Table 1). This method can also be used to determine the potential of a pest species to develop resistance to a particular class of insecticide by exposing a population to a diet laced with insecticide that will kill about 70% each generation.
4. Sublethal effects for some insecticides against leafrollers have been characterized. These effects are especially important for insect growth regulators. Understanding the sublethal effects helps in explaining the impact of insecticides that do not have fast killing power, for example, insect growth regulators.
5. In field-aged residue bioassays have been used to estimate the activity periods of different insecticides against leafroller and codling moth (Table 2). This bioassay method has been used to characterize longevity of residues against larvae and egg (of codling moth). These data represent an additional set of baselines against which we can test populations suspected of being resistant. It might be that the LC_{50} values do not shift to a great degree but that larvae are able to overcome residues in a shorter time than susceptible populations.
6. Field trials have demonstrated the efficacy of several new insecticides against codling moth larvae and eggs and leafroller larvae. Field trials are how rates and re-treatment intervals are established for new insecticides. These data form the basis for recommendations WSU publishes in the Crop Protection Guide for Tree Fruits in Washington.

Methods:

Concentration/dose-response bioassays – Apples (CM) or leaves (LR) or artificial diet were dipped into known concentrations/doses of an insecticide and allowed to dry. After an appropriate period (7 to 14 days) the eggs or larvae were assessed for mortality. Data were ran through a software program that generated a linear relationship between concentration/dose and mortality providing estimates of LC_{50} values among other useful statistics.

Diet incorporation bioassay – Insecticide was incorporated into a new artificial diet as a water mixture. A small amount of diet was placed into a small cup and newly hatched CM or LR larvae were introduced. After an appropriate period (7 to 14 days) the eggs or larvae were assessed for mortality. Data were ran through a software program that generated a linear relationship between concentration/dose and mortality providing estimates of LC_{50} values among other useful statistics.

Survey of field-collected populations - In 2006 only two populations of OBLR larvae were collected. They were reared to the second generation (F2) in the laboratory, and neonate larvae were used in a leaf-disk bioassay to determine their susceptibility to azinphosmethyl (Guthion 50WP, Bayer CropScience) and spinosad (Success 2SC, Dow AgroSciences). Another population was collected from Mattawa where spinosad seemed to fail in summer, but sufficient larvae have not been reared to conduct bioassays.

Reversion of resistance - Field-collected populations that had demonstrated resistance to azinphosmethyl, spinosad and methoxyfenozide were reared through successive generations without selection pressure from insecticides. These populations were periodically evaluated for resistance levels using established bioassay methods to these three insecticides.

Field-aged bioassay – A field-aged bioassay was used to assess the residue longevity of new insecticides. Trees were treated with candidate insecticides and at regular intervals leaves or fruit were collected. Leafroller or codling moth larvae were placed on the leaves or fruit and mortality assessed after appropriate periods to determine the efficacy of aged residues.

Field trials – Field tests were conducted evaluating the efficacy of new insecticides against leafrollers and codling moth. Treatments were applied either by hand-gun or airblast sprayer in replicated deigns. Assessment of leafrollers was made by counting live and dead larvae following treatment and for codling moth the number of injured fruit after each generation.

Results and discussion:

Baseline toxicity data – Over the past several years we have conducted bioassays with new insecticides against codling moth eggs and larvae and leafroller larvae. These bioassays establish levels of susceptibility in laboratory colony populations that serve as baselines for comparing to field collected populations allowing us to assess if populations are developing resistance. These data also provide insights into the inherent toxicity of a new insecticide to a pest.

Table 1. Summary of bioassay results for several new insecticides using susceptible laboratory colonies of codling moth eggs and larvae and leafroller larvae.

Chemical	Year	Source	n	Slope (SE)	LC50-ppm (95% CL)	LC90-ppm (95%CL)
Obliquebanded leafroller larval screening						
emamectin	2005	LAB	350	3.0 (0.5)	0.04 (0.03-0.05)	0.10 (0.08-0.16)
rynaxypyr	2005	LAB	350	1.6 (0.2)	2.9 (1.6-4.4)	18.6 (11.7-38.7)
rynaxypyr	2005	LAB	350	2.0 (0.3)	2.4 (3.5-6.7)	10.2 (6.7-20.0)
novaluron	2005	LAB	350	1.1 (0.2)	27.2 (14.9-44.1)*	438.0 (228.9-1273.9)*
novaluron	2005	LAB	350	1.6 (0.3)	5.8 (2.4-9.7)**	36.7 (22.7-73.2)**
methoxy	2005	LAB	350	2.6 (0.4)	2.9 (2.2-3.6)	8.8 (6.6-13.4)
spinosad	2005	LAB	350	2.8 (0.6)	0.4 (0.2-0.5)	1.0 (0.8-1.7)
azinphos	2005	LAB	350	4.1 (1.1)	11.9 (8.0-14.6)	24.7 (19.5-44.2)
Obliquebanded leafroller larval screening (Diet incorporation)						
spinetoram	2003	LAB	175	1.2 (0.3)	0.2 (0.01-0.39)	
rynaxypyr	2006	LAB	250	1.9 (0.3)	0.31 (0.18-0.44)	1.47 (1.04-2.59)
rynaxypyr	2007	LAB	250	2.6 (0.4)	0.33 (0.24-0.77)	1.03 (0.77-1.60)
rynaxypyr	2007	LAB1	400	5.0 (1.3)	0.09 (0.06-0.11)	0.17 (0.14-0.23)
rynaxypyr	2007	LAB2	400	5.3 (1.8)	0.09 (0.04-0.12)	0.16 (0.13-0.27)

Table 1. Continued.

Chemical	Year	Source	n	Slope (SE)	LC50-ppm (95% CL)	LC90-ppm (95%CL)
Codling moth larval screening – Apple test (larval mortality)						
spinetoram	2003	LAB	700	1.2 (0.4)	0.04 (0.0004-0.13)	
rynaxypyr	2006	LAB	300	2.2 (0.6)	0.8 (0.3-1.3)	3.0 (1.9-6.7)
flubendiamide	2006	LAB	350	2.4 (1.0)	35.0 (7.2-55.8)	117.8 (77.7-324.4)
Exp 1	2007	LAB	300	1.7 (0.3)	3.0 (1.3-4.9)	17.3 (11.2-34.8)
flubendiamide	2007	LAB	300	0.8 (0.2)	72.1 (20.4-190.8)	2577.9 (659.4-$1.4\text{x}10^5$)
Exp 2	2007	LAB	300	1.6 (1.0)	3.4 (no limits)	22.0 (no limits)
Exp 3	2007	LAB	300	0.7 (0.2)	22.7 (2.8-65.1)	1360.1 (348.9-70090.0)
Exp 4	2007	LAB	300	1.7 (0.6)	41.5 (3.8-81.2)	246.4 (132.0-1460.0)
Codling moth larval screening – Diet incorporation (larval mortality)						
rynaxypyr	2006	LAB	350	4.6 (1.3)	0.13 (0.08-0.18)	0.25 (0.18-0.51)
Codling moth ovicidal screening (Topical method)						
Mineral oil	2005	LAB	1350	4.2 (0.2)	3.7 (2.8-4.3)	
flubendiamide	2006	LAB	3207	0.7 (0.04)	519.6 (196.8-4018.5)	38568.0 (4674-$1.1{*}10^9$)
rynaxypyr	2003	LAB	1044	0.6 (0.1)	55.2(27.3-116.0)	
emamectin	2006	LAB	2100	No dose response		
Codling moth ovicidal screening (Residual method)						
flubendiamide	2006	LAB	3207	1.8 (0.08)	148.4 (125.7-175.3)	773.2 (573.0-1173.6)
rynaxypyr	2003	LAB	1872	0.6 (0.1)	6.1(0.6-21.3)	
emamectin	2006	LAB	2100	No dose response		

Resistance surveys 2007: Rynaxypyr (Altacor, DuPont) is a new insecticide due to be registered for use on tree fruit in 2008. We have worked with the company to develop methods and baseline data on the susceptibility of codling moth and leafrollers to this product. In 2007 we conducted an extensive study using these methods to assess the susceptibility of codling moth to this new product. Enough larvae were collected and reared to the adult stage to develop complete concentration response curves for six populations allowing the estimation of LC_{50} values (Table 2). There was no indication from these data of resistance in field populations. Because it is difficult to obtain sufficient larvae from commercial orchards to generate complete concentration response curves, two diagnostic concentrations were selected based on susceptibility of laboratory colonies.

Table 2. Results of resistance screening bioassays for different field collected codling moth populations in 2007.

Chemical	Year	Source	n	Slope (SE)	LC50-ppm (95% CL)	RR ratio[1] (95% CL)[2]
Obliquebanded leafroller larval screening						
Altacor	2007	LAB1	400	5.0 (1.3)	0.09 (0.06-0.11)	
Altacor	2007	LAB2	400	5.3 (1.8)	0.09 (0.04-0.12)	1.00 (0.66-1.51)
Altacor	2007	Moxee F1	400	2.2 (0.4)	0.14 (0.04-0.24)	1.54 (0.98-2.41)
Altacor	2007	Donald F1	400	1.4 (0.2)	0.05 (0.02-0.08)*	0.53 (0.31-0.93)
Altacor	2007	NCW Heat F1	300	2.6 (0.7)	0.12 (0.06-0.16)	1.27 (0.78-2.05)
Altacor	2007	Brogan F1	290	3.4 (2.1)	0.10 (no limits)	1.10 (0.47-2.58)
Altacor	2007	Sm. Tract F1	265	1.5 (0.3)	0.09 (0.03-0.16)	0.94 (0.51-1.72)

Field collected populations that did not produce enough individuals to generate complete curves were tested at these diagnostic concentrations to see if there was any difference from the baseline data (susceptible laboratory). Figure 1 shows results from 17 populations collected in Washington and exposed to a 0.2 ppm diagnostic concentration of rynaxypyr. By comparing the percent mortality of the reference population (laboratory colony) to field populations we saw that some has lower percent mortality than would be expected of a susceptible population.

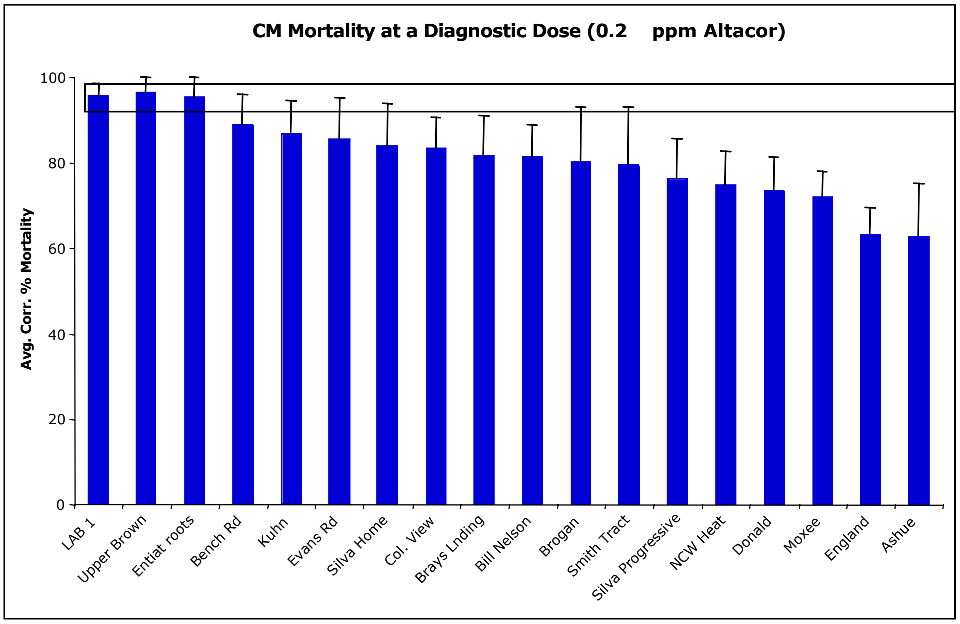
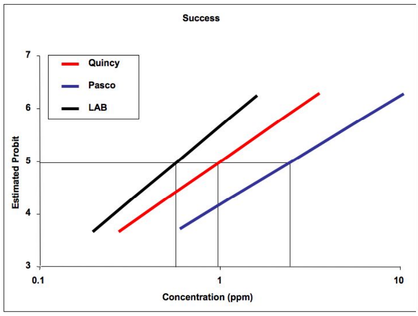
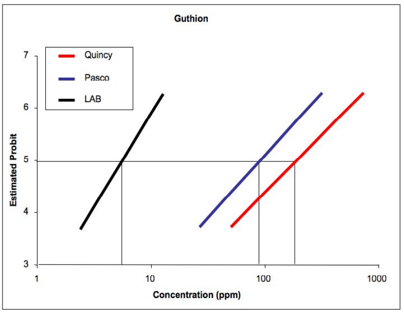


Figure 1. Percent larval mortality of laboratory and field-collected populations of codling moth exposed to a diagnostic concentration (0.2 ppm) of rynaxypyr.

For several years we have been evaluating leafroller populations for resistance to insecticides. We have previously shown that field-collected populations of both leafroller species (OBLR and PLR) were resistant to methoxyfenozide (Intrepid) before it was registered, evidently because of cross-resistance to organophosphate (OP) insecticides. However, these populations were not resistant to spinosad (Success) or emamectin benzoate (Proclaim) indicating no cross-resistance. We have also shown that after only 6 years of use some OBLR populations had developed resistance to spinosad. For example, in 2006 OBLR populations near Quincy and Pasco showed resistance to azinphosmethyl (35.6 and 11.3 times), spinosad (1.9 and 7.2 times) and methoxyfenozide (***Pasco only*** - 10.8 times). The spinosad resistance level is the highest we have detected in Washington but our data suggest that this population should still be controlled if using the high field rate; however, methoxyfenozide would likely not provide sufficient control to be commercially acceptable. While we have not yet completed the tests, it is highly likely that OBLR populations resistant to spinosad will also show resistance to spinetoram (Delegate), a newly registered insecticide in the same class.





Because of our concerns about OP mediated cross-resistance in new insecticides we conducted some preliminary evaluations of OBLR populations susceptibility to rynaxypyr. Table 3 shows bioassay results from six field-collected populations using two different methods (leaf-dip and diet incorporation). Four of the six populations show resistance ratios (roughly the LC_{50} of field population divided by LC_{50} of reference or susceptible population) that indicate a low level of resistance to rynaxypyr and the data further suggest that this is likely due to OP mediated cross resistance. What this means in terms of the expected level of control of OBLR populations in orchards is difficult to predict at this time but it is certainly not a positive development.

Table 3. Bioassay results for field-collected OBLR populations showing resistance to rynaxypyr, 2006 and 2007.

Chemical	Year	Source	n	Slope (SE)	LC_{50}-ppm (95% CL)	RR ratio[1] (95% CL)[2]
Obliquebanded leafroller larval screening						
Altacor	2006	LAB	250	1.9 (0.3)	0.31 (0.18-0.44)	
Altacor	2006	Mattawa F_3	250	1.5 (0.2)	0.64 (0.32-1.01)	2.0 (1.1-3.9)*
Altacor	2006	Quincy F_3	250	2.0 (0.4)	1.06 (0.62-1.54)	3.4 (1.9-6.2)*
Altacor	2006	Pasco F_9	250	2.2 (0.4)	0.28 (0.16-0.39)	0.9 (0.5-1.6)
Altacor	2007	Lab	250	2.61 (0.39)	0.33 (0.24-0.77)	
Altacor	2007	Plath-F_2	250	3.06 (0.70)	0.39 (0.19-0.57)	1.18 (0.88-1.59)
Altacor	2007	Jarrel-F_2	250	5.12 (0.99)	1.21 (1.01-1.44)	3.07 (2.19-4.29)*
Altacor	2007	Jones-F_2	250	2.9 (0.37)	1.39 (1.02-1.85)	4.18 (2.91-5.99)*

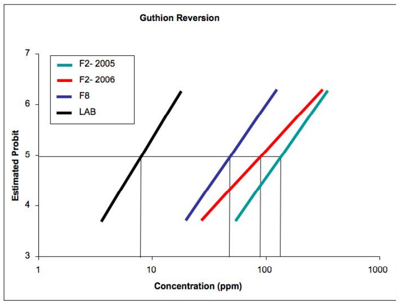
n = number of larvae assayed

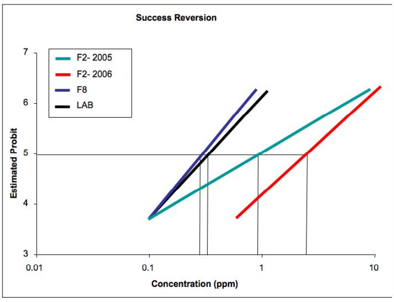
[1] Resistance ratio- LC_{50} field population: LC_{50} lab colony

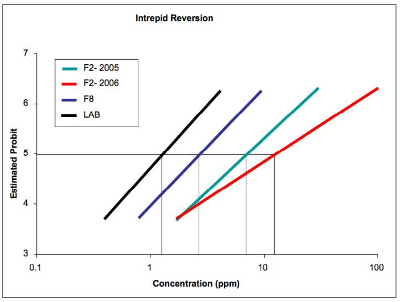
[2] 95% Confidence limits (Lethal Ratio Significance Test, Robertson and Priesler, 1992)

* LC_{50} of field collected population significantly different than the laboratory colony

Reversion of resistance - We have shown that at least for one insecticide, spinosad, it is possible that resistance will revert to susceptible levels if selection pressure is eliminated. For example, OBLR populations collected from Pasco in 2005 and reared in the laboratory on artificial diet through eight generations showed a decline in resistance to spinosad to a level the same as the susceptible colony. By contrast these same populations, while showing some decline in resistance to methoxyfenozide and azinphosmethyl, did not show reversion to susceptible levels suggesting their mechanisms of resistance are linked.



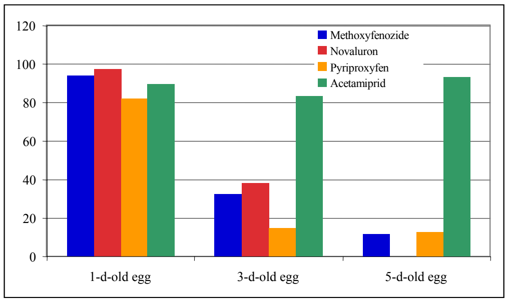




Field-aged bioassay – In 2006, field-aged bioassays residues of novaluron (Rimon) were not as long lasting as those of methoxyfenozide for PLR or OBLR. Rynaxypyr (Altacor) and spinetoram (Delegate) showed a long residual activity against OBLR larvae, similar to spinosad (Success) (Table 4). Against CM larvae rynaxypyr (Altacor) showed very good residual activity, lasting as long as azinphosmethyl and longer than spinosad (Success). In an ovicidal bioassay novaluron had slightly better residual activity than methoxyfenozide. In 2007, flubendiamide (Belt) showed long residual activity against OBLR larvae as did to experimental insecticides (Table 4). Against codling moth residues of spinetoram (Delegate) were of similar duration as those of acetamiprid (Assail), while residues of flubendiamide (Belt) and two experimental insecticides were not as effective as acetamiprid. Residues of rynaxypyr were more effective and lasted longer than those of pyriproxyfen against codling moth eggs (Table 4).

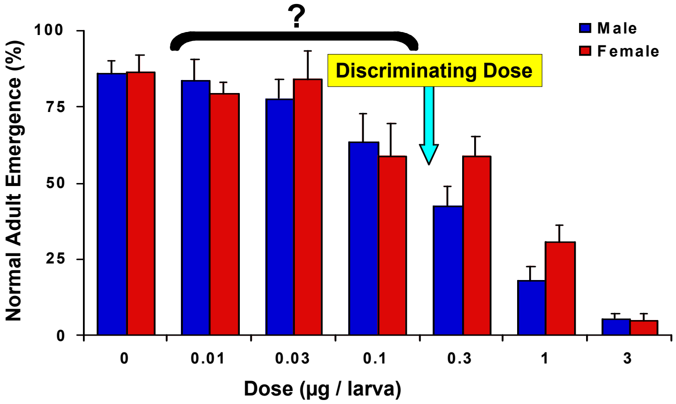
Table 4. Corrected percent mortality of leafroller and codling moth exposed to residues of insecticides for different periods, 2006 and 2007.

			Corrected percent mortality (DAT)				
Insecticide	Rate/a	Year	1	7	14	21	28
Pandemis leafroller (7-d evaluation)							
novaluron	32 fl oz	2006	90.3	88.6	50.0	72.7	
methoxyfenozide	16 fl oz	2006	100.0	100.0	100.0	100.0	
Obliquebanded leafroller (7-d evaluation)							
novaluron	32 fl oz	2006	91.7	86.1	64.4	62.0	
methoxyfenozide	16 fl oz	2006	100.0	100.0	100.0	100.0	
rynaxypyr	4.0 oz	2006	98.1	100.0	100.0	100.0	100.0
spinosad	6.0 fl oz	2006	100.0	100.0	92.5	95.7	100.0
spinetoram	6.4 oz	2006	100.0	100.0	100.0	100.0	100.0
Codling moth neonates (7-day evaluation)							
rynaxypyr	4.0 oz	2006	100.0	72.2	93.8	91.1	86.2
azinphosmethyl	2.0 lb	2006	100.0	94.4	91.7	82.3	89.6
spinosad	6.0 fl oz	2006	85.0	72.2	33.3	67.7	41.3
spinetoram	6.4 oz	2006	100.0	94.4	41.7	91.1	65.5
Codling moth ovicide (10-day evaluation)							
novaluron	32 fl oz	2006	74.4	87.2	82.3	87.4	
methoxyfenozide	16 fl oz	2006	78.4	76.1	72.2	79.5	
			Corrected percent mortality (DAT)				
Insecticide	Rate/a	Year	1 or 4	7	14	21	28
Obliquebanded leafroller (7-d evaluation)							
Experimental #1	119.2	2007	87.3	79.1	75.4	87.5	55.7
Experimental #2	70.9	2007	100.0	97.0	96.9	97.9	100.0
flubendiamide	70.9	2007	100.0	100.0	100.0	100.0	100.0
Codling moth neonates (apple test live cm)							
acetamiprid	67.5	2007	92.6	100.0	76.7	70.8	86.7
acetamiprid	67.5	2007	88.9	95.5	90.0	91.7	73.3
spinetoram	49.7	2007	100.0	86.4	83.3	91.7	76.7
Experiment #1	119.2	2007	29.7	42.1	48.7	50.0	8.6
Experiment #2	70.9	2007	73.0	81.6	82.1	76.7	60.0
flubendiamide	70.9	2007	59.5	57.9	76.9	80.0	57.1
Codling moth ovicide (apple residue test)							
pyriproxyfen	50.0	2007	47.3	32.7	37.1	32.3	35.7
pyriproxyfen	50.0	2007	47.0	40.6	46.3	37.6	36.8
rynaxypyr	40.0	2007	81.0	76.5	76.4	77.3	78.6

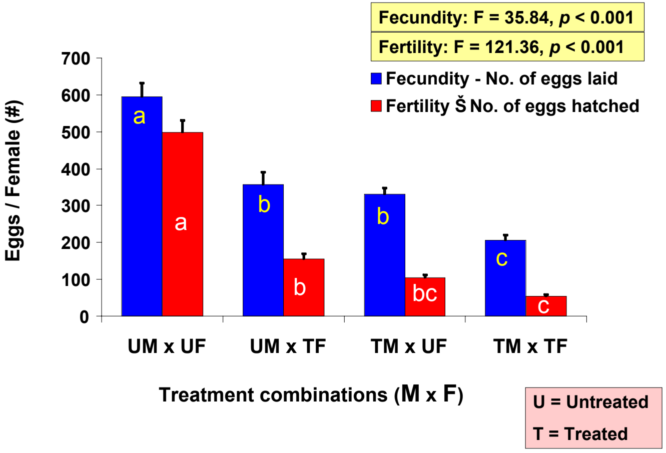


The ovicidal activity of insecticides against codling moth is becoming an important consideration in the management of this pest. We have shown in Table 3 that several insecticides have topic and/or residual effect on codling moth eggs. We have tests of evaluating the residual activity of these insecticides as new eggs are laid on them (Table 4). However, we have not shown previously the impact of egg age on topical applications of insecticides. We developed a method for doing this and the results are of great interest. Some insecticides (methoxyfenozide, novaluron, pyriproxyfen) that have a high effect topically against new eggs had little or no effect against older eggs. Of note was the strong ovicidal effect of acetamiprid against young and old codling moth eggs. This impact is likely a reason contributing to acetamiprid's efficacy against codling moth.

Lethal and sublethal effects of IGR -



Developing baseline information for insect growth regulators is a challenge because the target insect stage does not always express exposure through mortality. When pyriproxyfen (Esteem) is consumed by a leafroller larvae it lives longer than normal but expresses intoxication by abnormal structures (see photos to the right). To be able to evaluate potential resistance to pyriproxyfen we set out to define a dose that would provide discrimination if susceptible laboratory populations were compared with field-collected populations. Based on several parameter, like the emergence of adults (Figure below) we believe a discriminating dose is between 0.1 and 0.3 micrograms per larva. From this study, we asked the question about sublethal effects of pyriproxyfen. Larvae that consumed low doses (0.01 and 0.03 micrograms) did not show detrimental effects, at least in external morphology and did not show mortality rates that were different from the untreated controls. We, therefore, exposed larvae to a sublethal dose (0.03 mirograms per larva) and then examined the impact on pupal and adults weight and on the ability of moths to reproduce. The weights of pupae and adult treated with pyriproxyfen were significantly higher than untreated larvae. However, whether male or female destined larvae were treated there was a significant reduction in the number of eggs laid per female, fertility of the eggs (see Figure to right) and the percent of egg hatch. When male larvae were treated and female untreated there was roughly an 80% reduction in egg hatch. When both sexes were exposed to a sublethal dose of pyriproxyfen there was almost a 90% reduction in egg hatch.



Field Trials:

In 2007 we conducted 14 field trials against codling moth and leafrollers involving a total of 53 separate treatments. Over the past 3 years we have conducted 38 separate field trials against codling moth and leafrollers involving a total of 147 separate treatments. Results from these trials fomr the basis for use recommendations used by the industry for pest control that are published in the Crop Protection Guide for Tree Fruit in Washington (EC-0419).

2007 Leafroller Trials: Acetamiprid (Assail) was evaluated as a leafroller control applied pre-bloom in two field trials. In one trial it was compared with chlorpyrifos (Lorsban) (Table 5) as an industry standard and in another with spinosad (Success) (Table 6). In both cases, Assail failed to provide control while the industry standards provided excellent control.

Table 5. Control of overwintering obliquebanded leafroller larvae, 2007.

Insecticide	Rate (gm AI/a)	Timing	Avg live larvae/ 500 shoots (11 May)
Assail 70WP	67.5	Pink	1.8b
Assail 70WP + HMO	67.5 + 1.0% v:v	Pink	2.8b
Success 2SC	42.6	Pink	0.0a
Untreated			2.0b

Means in the same column followed by the same letter are not different (*P*=0.05, Student's *t* test). Statistics were run on transformed data [Log (y+1)].

Table 6. Control of overwintering obliquebanded leafroller larvae, 2007.

Insecticide	Rate (gm AI/a)	Timing	Avg live larvae/ 500 shoots (24 Apr)
Lorsban 4E	908.0	Pink	0.00a
Assail 70WP	67.5	Pink	2.85b
Untreated			2.90b

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

2007 Codling Moth Trials: We typically test unregistered insecticides in partnership with private chemical companies to determine their fit into IPM programs. Recently, we have been examining the efficacy of tank mixes of new insecticides applied at a delayed first larvicide timing. This approach seems to work well against high pest pressure situations where good coverage of the target surface is achieved. Two examples of results of field trials are shown below.

In the first test oil or pyriproxyfen (Esteem) was applied at an ovicide timing followed either by tank mixes of acetamiprid (Assail)+pyriproxyfen, rynaxypyr (Altacor)+pyriproxyfen, or with non-tank mix applications of acetamiprid, pyriproxyfen or rynaxypyr. The tank-mix program of Assail + Esteem, preceded by an oil application at 200DD, had significantly more CM injured fruit than the other two tank-mix treatment programs that were included in this trial (Fig. 1). Altacor + Esteem, preceded by oil or Esteem, provided very good CM control through both generations. There did not appear to be a significant advantage to using Esteem instead of oil as a strategy to delay the tank-mix application; however, Esteem could provide the added benefit of leafroller (LR) control, especially when used at the spring application timing. An oil application at 200DD followed by two applications of Altacor or Assail also provided good CM control in this trial. Using an ovicide, like oil or Esteem, to delay the first larvicide application creates the opportunity to reduce the interval between larvicide applications (ca. 17d) and will be a good strategy for using new larvicides, like Assail and Altacor, that have a shorter active residue life than the OP products that they will be replacing. Oil followed by two applications of Esteem did not provide the same level of CM control. In this case, the Esteem applications were likely too late in the generation to have an optimal effect on eggs in the orchard. This illustrates the importance of application timing with new insecticides that effect specific stages of the CM life cycle.

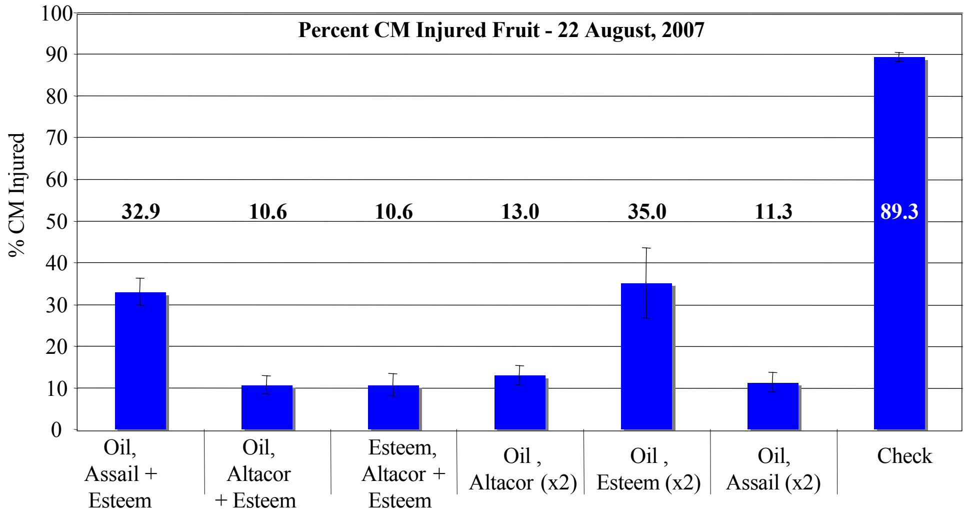


Figure 2. Efficacy of insecticides applied at delayed first hatch timings, either in tank mixes or alone on 17-day re-treatment intervals.

In the second test an experimental insecticide was tested at different rates in comparison to three new insecticides. There was not a significant difference in CM control between the three rates of the Experimental product tested in this trial. Belt provided good CM control after the first CM generation but also had a high number of stings at the time of the final evaluation. Calypso provided CM control that was statistically equivalent to Altacor, which had the smallest percentage of CM injured fruit after each generation.

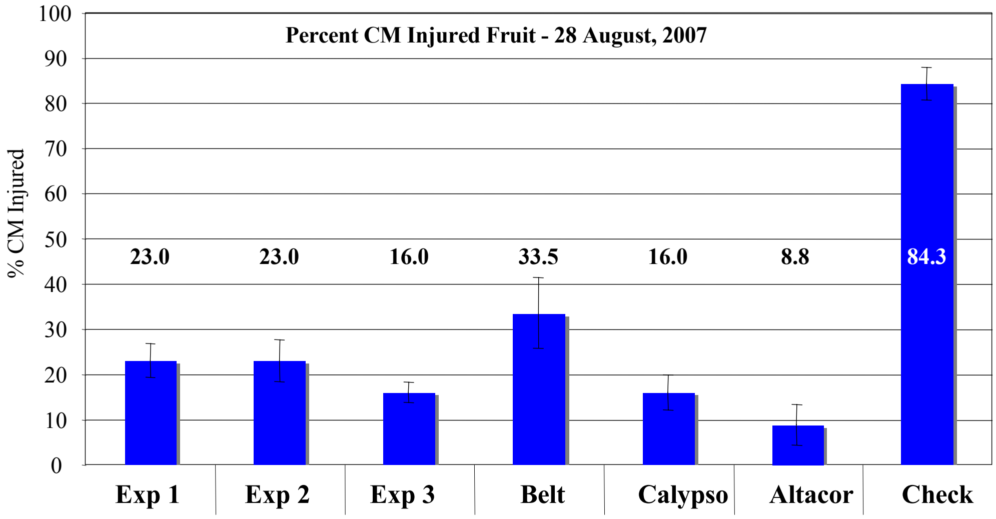


Figure 3. Efficacy of insecticides applied against codling moth at traditional egg hatch timings.