Chemical Control/New Products

Codling moth control in apple - 2002

Diane G. Alston and Thor Lindstrom
Utah State University, Department of Biology, Logan, UT

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Abstract: The efficacy of two new, unregistered insecticides (Calypso and Novaluron) was evaluated for codling moth control in apple as compared to a conventional grower standard (Guthion) and untreated check. Numbers of male codling moths caught in pheromone traps were moderate (0.5-4 moths per trap per day), and there were two complete generations and a partial third. Calypso 4SC (thiacloprid) was applied at two rates (4 and 6 fl oz/acre) and three times per complete codling moth generation. Novaluron 7.5WG (chitin synthesis inhibitor IGR) was applied three times and Guthion 50WP (azinphosmethyl) twice per complete generation. Percentage of fruit injury was higher than expected following the first generation of codling moth in all insecticide treatments (6.3-9.5% stings and 0.3-0.8% larval entries). Following second generation, both Calypso and Novaluron were just as effective (0.8-1.8% fruit injury) as Guthion (0.9%) and significantly better than the untreated (7.3%). Spider mite and predaceous mite densities were generally not affected by any treatment. Calypso at 6 oz and Guthion showed some aphicidal activity to green apple aphid. Novaluron treated trees had excessively high aphid infestation levels in late June. Aphid predator densities were low in all treatments.

Introduction

Objective. To evaluate the efficacy of two new, unregistered insecticides for codling moth control (Calypso [thiacloprid; Bayer] and Novaluron [Uniroyal]) were compared to a conventional grower standard (Guthion [azinphosmethyl; Bayer]) and an untreated check. The influence of trial materials on densities of non-target pests (aphids and spider mites) and their natural enemies (predatory insects and mites) will also be evaluated.

Brief Background on the New Insecticides Tested. Calypso is an insecticide in the chloronicotinyl family, related to the registered insecticide Provado (imidacloprid). Calypso acts on the insect nervous system as an agonist of the nicotinic acetylcholine receptor (*n*AChR). There is no known cross-resistance to conventional insecticide classes, such as organophosphates, carbamates and pyrethroids. Calypso acts as an acute contact and stomach poison, combining systemic properties with relatively low application rates. Novaluron is an insect growth regulator (IGR) that inhibits normal synthesis of chitin in the insect cuticle (exterior skeleton). IGRs slowly kill insects over several days by disrupting the development and growth of immature insects. Novaluron acts as an insecticide mainly by ingestion but has some contact activity.

Materials and Methods

The trial was conducted in a 2.1-acre apple orchard of mixed cultivars ('Gala', 'Mutzu', 'Prime Gold', 'Idared', 'Jonathan', and three strains of 'Red Delicious': 'Dixiered', 'Supreme', and 'Ultrastripe') at the Utah State University research farm in Kaysville, UT. The experimental design was a randomized complete block with seven treatments and four replications (28 plots). Each plot was 3 rows wide (60 ft) and 4 trees long (48 ft) (12 ft x 20 ft tree spacing) (see attached plot map).

A delayed dormant (applied at one-quarter to half-inch-green) treatment of Superior oil + Lorsban 4E at 4 pt/acre was applied to the entire orchard on 9 April 2002. Other pesticide treatments included streptomycin for fire blight and fungicides (Rally, Flint and Bayleton) for powdery mildew control. The only insecticides applied to the orchard were those evaluated in the trial. A concurrent trial to evaluate materials for control of green apple and woolly apple aphids occurred in the same experimental plots. Actara and USU02 were the two materials targeting aphid control, and their application timing targeted increasing aphid densities rather than codling moth.

Adult male codling moth density was monitored with one pheromone-baited trap to determine biofix (first consistent moth catch) and to follow seasonal flight patterns. Timing of codling moth treatments was based on biofix and a degree-day (DD) model. The typical DD model advises the first insecticide application timed for 3% egg hatch of the first summer generation, or 250 DD after biofix. The IGR, Novaluron, was targeted earlier, for 50 DD after biofix, as the material is most effective when applied before egg laying begins. Reapplication intervals were either approximately 14 days (Novaluron and Calypso) or 21 days (Guthion). The DD model targets the first application for the second summer generation at 6% egg hatch, or 1260 DD after the first generation biofix. Again, Novaluron was targeted earlier, on 1060 DD. Reapplication for the second generation followed at either 14- or 21-day intervals as before. Treatments were applied with an airblast sprayer at a rate of 70-80 gal of dilute spray per acre.

Treatment List.

1. Untreated.
2. Calypso 4SC at 4 oz/acre applied on 30 May, 13 and 27 June, 15 and 29 July, and 12 August (3 applications per CM gen.=6 total cover sprays).
3. Calypso 4SC at 6 oz/acre applied on the same dates as Treatment 2.
4. Novaluron 7.5WG at 71 oz/acre applied on 9 and 30 May, 13 June, 9 and 20 July, and 7 August (3 applications per CM gen.=6 total cover sprays).
5. Guthion 50WP at 2 lb/acre applied on 30 May, 20 June, 15 July, and 7 August (2 applications per CM gen.=4 total cover sprays).
6. Actara 25WG at 5 oz/acre applied on 30 May to target green apple aphid and on 16 August to target woolly apple aphid (2 applications timed with aphid densities).
7. USU02 240SC at 121 ml/acre + RME adjuvant (0.4%) and acidified spray water to pH 6.9, applied on same dates as Treatment 6.

Table of treatment timing with actual degree-day values

Trt.	May 9 25 DD	May 30 251 DD	Jun 13	Jun 20	Jun 27	Jul 9 1051 DD	Jul 15 1247 DD	Jul 20	Jul 29	Aug 7	Aug 12	Aug 16
1												
2		X	X		X		X		X		X	
3		X	X		X		X		X		X	
4	X	X	X			X		X		X		
5		X		X			X			X		
6		X										X
7		X										X

← 1st CM gen. → ← 2nd CM gen. →

Apple fruits were sampled to determine codling moth injury levels at the conclusion of the first generation on 11 July and following the second generation on 21 August. On 11 July 50 fruits were sampled per tree from the two center trees per plot (100 fruits per plot and 400 fruits per treatment). On 21 August, 100 fruits were sampled per tree from the two center trees per plot (200 fruits per plot and 800s fruit per treatment). The surface of each fruit was inspected for "stings" and then the fruit was cut open to determine larval entry. The percentage of fruit with stings and larval entries was compared among treatments for all cultivars combined (July and August samples) and within cultivars (August samples only).

Effects of the insecticide treatments on secondary pests and non-target natural enemies were evaluated for apple aphids (green apple aphid and woolly apple aphid control are reported in detail in separate reports; a summary of green apple aphid control is reported here) and mites. The number of shoots infested with green apple aphid per tree was determined for the two center trees per plot on 6 and 26 June. These dates correspond with 1 and 4 weeks after application of the two materials targeting aphid control, Actara and USU02. The number of phytophagous and predaceous mites on 10 leaves per tree on the two center trees per plot (20 leaves per plot and 80 leaves per treatment) was sampled on 14 May, 4 June, 2 July, 31 July, and 27 August.

All data were statistically compared among treatments using analysis of variance (GLM; SAS). Percentage data were analyzed as proportions and arcsine-square root transformed before analysis to meet normality assumptions. Aphid and mite density data were square root transformed before analysis. When treatment means were determined to be different among treatments, Waller-Duncan *k*-ratio *t*-test ($P \leq 0.05$) was used to separate treatment means.

Results and Discussion

Fruit Injury. Following the first generation on 11 July, the percentage of fruit with codling moth stings was higher than expected in all treatments (6.3-9.5%) (Table 1). Injury caused by larval entry was low following the first generation, with the greatest level in the untreated control (2.3%) (Table 1). There were no significant differences in fruit injury among treatments following the first generation. The reason for greater sting injury than expected is not clear. Timing of experimental treatments appears to be in line with insect development based on degree-days. An exception is for Novaluron where the first treatment was applied earlier than ideal (25 vs. 50 DD), and the interval between first and second spray was stretched to 21 days rather than the planned 14 days. Despite this less than ideal timing for Novaluron in the first generation, injury was not greater in Novaluron than other treatments and the untreated.

After the second generation, percentage of fruit with larval entry and combination of stings and entries was significantly greater in untreated, Actara and USU02 treatments than in Calypso, Novaluron and Guthion treatments (Table 1). Sting injury was lower than after the first generation and not different among treatments. It is not surprising that fruit injury was higher in Actara and USU02 plots, as these two treatments were applied only twice to target aphid populations. Injury of untreated fruit was lower than in a comparable 2000 study (22%) and likely so because of small plot size (48 ft x 60 ft) in this trial and thus relatively small area of untreated trees in the orchard.

There were no significant differences among cultivars in their sensitivity to codling moth injury following the second generation (Table 2); however, a low number of fruits were sampled for some cultivars, and so the comparison is not robust. In past years' trials in this orchard, the cultivars 'Gala', 'Jonathan' and 'Mutzu' have been more sensitive to injury (31-36% in untreated plots) than the three 'Red Delicious' strains and 'Idared' (8-20% in untreated plots).

Codling Moth Pressure. Male codling moth density as measured by pheromone trap catch was moderate (Fig. 1) and similar to past years. The beginning of a third generation was observed in late August, but had no impact on fruit injury sampling in August.

Effects on Secondary and Non-Target Arthropods.

Mites. There were no differences in densities of phytophagous mites among insecticide treatments on any of the five sampling dates from mid-May through late August (Table 3). The predominant spider mite species present was *Tetranychus urticae*, twospotted spider mite. *Panonychus ulmi* (European red mite) and *Bryobia rubrioculus* (brown mite) were present in low numbers. Densities of spider mites on leaves were very low in May and June, exceeded an economic threshold of 10 mites per leaf in some treatments on 2 and 31 July, and then dramatically declined again by late August (Table 3). "Mite burn" was observed on many trees in July and August, indicating heavy mite feeding and probable tree injury. Despite the lack of statistical significance, numerical values of spider mites were different among some treatments in July. On 31 July, Calypso and Guthion treatments had 50-63 spider mites per leaf while untreated and Actara had <1, and Novaluron and USU02 had 27-28 spider mites per leaf.

Two predaceous mite species were found on tree leaves: the Phytoseiid, *Galendromus occidentalis* (western predatory mite) and the Stigmaeid, *Zetzellia mali*. Predaceous mite densities did respond to increasing prey (spider mite) densities in July and reached high densities by late August (8-94 per leaf), but their increase and suppression of spider mites was not rapid enough to prevent mite burn on many trees. More than 5-10 predaceous mites per leaf is a very substantial population density and not commonly encountered in commercial apple orchards. There were no differences in predaceous mite numbers in May to July but, in late August when densities were high, densities in Calypso treatments were significantly greater ($p<0.0001$) than those in USU02, Novaluron, Guthion and untreated plots (Table 3). Higher densities of predators in Calypso plots are likely explained by higher densities of spider mites in these plots in July, but there were no significant differences in spider mite densities on any date.

Ratios of densities of phytophagous mites to predaceous mites were calculated for the five dates but were not different among treatments (Table 3). Despite lack of statistical differences, numeric values of ratios did vary widely on 2 and 31 July (Fig. 2). On 2 July, untreated trees had substantially greater prey to predator ratios than all other treatments. The two Calypso treatments had moderate ratios on 2 July. By 31 July ratio values had dramatically dropped and all treatments had low values, especially the untreated. The tremendous change in ratio values from early to late July was primarily caused by increasing densities of predaceous mites in all treatments from very low to low to moderate densities.

In a 2000 study in this same research orchard, Calypso (4 oz/acre) was observed to significantly elevate twospotted spider mite densities in July and August as compared to Guthion, Intrepid (an IGR), and untreated trees. Hormoligosis, or stimulatory effects, of Calypso and other chloronicotinyls on spider mite populations has been suggested and documented in a number of studies. The results presented here do not statistically support a hormoligosis effect from Calypso on spider mites. Spider mite counts were high in Calypso plots as compared to most others in late July, but high variability in mite densities across trees reduced our ability to discern such an effect. A companion toxic effect of chloronicotinyls on predaceous mites has also been suggested. A negative effect of Calypso on predaceous mites was not found in the 2000 or this study, and so toxic effects of Calypso on *G. occidentalis* and *Z. mali* have not been found in Utah studies.

These results do suggest that USU02, under development as an aphicide, has potential toxic effects on predaceous mites based on the statistically lower densities on 27 August as compared to other treatments, except Novaluron. Again, mite count variability was high and this potential effect needs further investigation.

Aphids. There were differences among treatments in the number of shoots infested with green apple aphid (*Aphis pomi*) per tree on 6 and 26 June (Fig. 3). Actara and USU02 were the materials evaluated for aphicidal activity, but we were interested in evaluating effects of all materials in the codling moth trial on secondary pests. Actara and USU02 were applied only once at the beginning of assessment of green apple aphid densities (30 May), while all other treatments were applied twice (Calypso: 30 May and 13 June; Guthion: 30 May and 20 June) or thrice (Novaluron: 9 and 30 May and 13 June). One day before treatments were applied, green apple aphid infestation was low (mean of 5-7 infested shoots per tree) and there was no difference between treatments. Of the materials evaluated, USU02 was the most effective aphicide and kept infestations low on 6 and 26 June (1 and 4 weeks after treatment, respectively). Poorest aphid control occurred in the Novaluron, untreated and 4-oz/acre rate of Calypso treatments. Performances of Actara, Guthion and 6-oz/acre rate of Calypso were better than the former three. USU02 had significantly lower aphid infestation (Fig. 3). Aphid infestation in Novaluron plots was very high, a mean of over 80 shoots per tree, by 26 June. Numbers of predatory insects (ladybeetles, campylomma and syrphids) were sampled (data not shown). Predatory insect densities were low during late May to late June (0-0.9 per shoot). Numbers of predatory insects in Novaluron plots were the highest of the entire trial on 26 June (mean of 5.3 per shoot) and significantly greater than all other treatments. Despite the response of predatory insects to abundant aphid prey in the Novaluron plots, the elevation of aphid densities in

Novaluron over untreated levels suggests that Novaluron had a stimulatory effect on green apple aphid.

Conclusions

Both new insecticides evaluated in this trial for efficacy of codling moth control, Calypso and Novaluron, were just as effective as a standard Guthion program. Fruit injury (stings and larval entries) following second generation of codling moth was 0.8 to 1.8% in these efficacious treatments, while injury was 6.2 to 7.3% in the two aphid targeted treatments (Actara and USU02) and the untreated control. Calypso was equally effective at both the 4 and 6 oz/acre rates. There was no difference in the sensitivity of the eight apple cultivars to codling moth injury and no difference in the performance of the insecticides across cultivars. The number of fruit sampled for some cultivars was very low, and this could prevent our ability to discern any differences in cultivar response.

Six applications each of Calypso and Novaluron were used in the trial as compared to four applications of Guthion. Targeting the timing for Novaluron is different than the others, as the IGR needs to be in place at initiation of codling moth egg laying. IGRs tend to have slower action and must be ingested by first-instar larvae for efficacy. These two new products offer benefits over Guthion in worker and environmental safety. U.S. EPA commonly approves shorter worker reentry intervals and preharvest intervals for softer insecticides.

Evaluation of secondary pest densities generally did not find that spider mite or green apple aphid densities were lower with Calypso or Novaluron due to lower toxicity to natural enemies. In contrast to some other studies, Calypso did not significantly elevate spider mite densities due to hormoligosis (stimulation of reproduction) or reduce predaceous mite densities. As an aphicide, Calypso applied at 6 oz per acre showed some efficacy on infestation of green apple aphid as compared to untreated trees. In contrast, Novaluron treated trees had excessively high aphid infestation levels in late June. This effect was not due to elimination of predatory insects, but predator densities were low throughout the trial in all treatments including the untreated. Such high infestation levels suggest a stimulation of aphid densities by Novaluron, but a biological explanation is not obvious at this time.

Table 1. Percentage fruit injury (stings and entries caused by codling moth larvae) as influenced by insecticide treatments following first and second generations of codling moth (July 11 and August 21, 2002) for all cultivars combined. The number of fruit sampled was 400 and 800 per treatment for first and second generation, respectively.

CM Generation	Treatment	Percentage of fruit*		
		Stings	Entries	Stings+Entries
1st	Untreated	6.9	2.3	9.2
	Calypso 4 oz.	6.3	0.8	7.1
	Calypso 6 oz.	9.5	0.3	9.8
	Novaluron	6.5	0.3	6.8
	Guthion	8.0	0.3	8.3
	Actara	9.3	0.5	9.8
	USU02	9.5	0.8	10.3
	P>F	0.7629	0.4152	0.7491
2nd	Untreated	1.4	5.9 a	7.3 a
	Calypso 4 oz.	1.0	0.1 b	1.1 b
	Calypso 6 oz.	1.8	0 b	1.8 b
	Novaluron	0.8	0 b	0.8 b
	Guthion	0.6	0.3 b	0.9 b
	Actara	1.6	4.6 a	6.2 a
	USU02	3.1	3.1 a	6.2 a
	P>F	0.5984	<0.0001	0.0020

*Means followed by the same letter within a column are not significantly different ($P \leq 0.05$) using Waller-Duncan *k*-ratio *t*-test. Data were square root transformed before analysis.

Table 2. Percentage fruit injury as influenced by cultivar following second generation of codling moth (August 21, 2002) for all treatments combined

Cultivar	Percentage of fruit			# Fruit sampled
	Stings	Entries	Stings+Entries	
'Gala'	0	2.3	2.3	300
'Idared'	6.0	0	6.0	100
'Jonathan'	1.5	0.9	2.4	1100
'Mutzu'	1.3	1.2	2.5	600
'Prime Gold'	1.3	2.2	3.5	900
'Red Del.' – 'Dixiered'	1.9	0.9	2.8	800
'Red Del.' –'Supreme'	1.6	4.0	5.6	1100
'Red Del. '-'Ultrastripe'	0.9	2.4	3.3	700
P>F	0.2884	0.2144	0.2348	

Data were square root transformed before analysis.

Table 3. Mean number of phytophagous (twospotted spider mite + European red mite + brown mite) and predaceous (*Galendromus occidentalis* + *Zetzellia mali*) mites per leaf and ratio of phytophagous to predaceous mites on five dates in codling moth control trial plots at Kaysville, 2002.

Treatment	Mean number of mites per leaf*														
	May 14			June 4			July 2			July 31			August 27		
	Phyto[+]	Pred	Ph/Pr	Phyto	Pred	Ph/Pr	Phyto	Pred	Ph/Pr	Phyto	Pred	Ph/Pr	Phyto	Pred	Ph/Pr
Untreated	0	0.1	0.7	0.17	0	2.7	18.8	0.4	172.0	0.15	1.7	0.2	0.3	35.5 cd	0.05
Calypso 4 oz.	0	0	1.0	1.50	0	16.0	13.0	0.08	74.1	62.5	4.4	7.0	3.0	94.0 a	0.05
Calypso 6 oz.	0	0	1.0	0.08	0	1.8	6.6	0	67.3	55.1	3.6	12.2	3.8	65.8 ab	0.08
Novaluron	0	0.08	0.8	0.08	0	1.8	3.6	0	37.3	27.8	4.2	12.5	0.3	17.0 de	0.13
Guthion	0.03	0	1.3	0	0	1.0	4.4	0.03	25.3	50.8	2.7	12.0	1.8	28.0 cd	0.09
Actara	0	0.01	0.8	0.60	0	7.0	10.8	0.2	28.0	0.8	1.7	0.4	0	37.5 bc	0.03
USU02	0.08	0.01	1.6	0.03	0	1.3	1.6	0.03	15.5	26.7	1.4	9.3	0	8.0 e	0.41
$P>F$	0.4552	0.4779	0.5216	0.7945	--	0.7771	0.6931	0.0977	0.7265	0.4893	0.3454	0.5512	0.1515	<0.0001	0.0990

*Means followed by the same letter within a column are not significantly different ($P \leq 0.05$) using Waller-Duncan *k*-ratio *t*-test. Data were square root transformed before analysis.

[+]Phyto=twospotted spider mites + European red mites + brown mites (all life stages combined: eggs, immatures and adults); Pred=*G. occidentalis* + *Z. mali* (all life stages combined: eggs, immatures and adults); Ph/Pr=(number of phytophagous mites + 1)/(number of predaceous mites + 1).

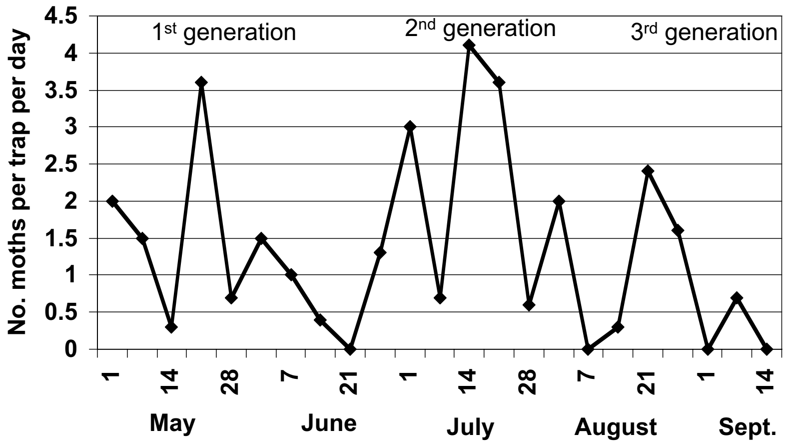


Figure 1. Pheromone trap captures of male codling moth in the codling moth control trial in apple, Kaysville, UT, 2002.

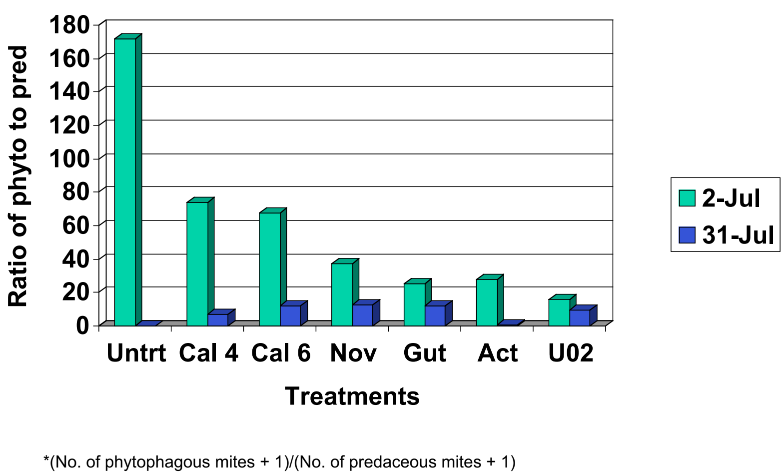
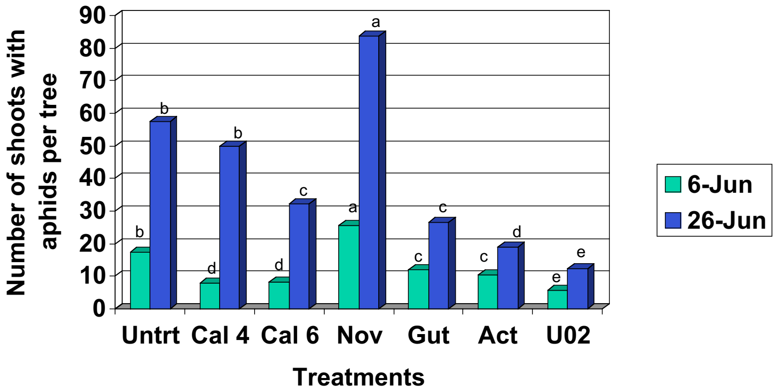


Figure 2. Ratio of number of phytophagous to predaceous mites* on apple leaves in codling moth control trial on July 2 and 31, 2002.



*Novaluron was applied on May 9; all treatments were applied on May 30; Calypso and Novaluron treatments were reapplied on June 13; Guthion was reapplied on June 20.
Bars with the same letter within a date are not significantly different ($P \leq 0.05$) using Waller-Duncan *k*-ratio *t*-test. Data were square root transformed before analysis.

Figure 3. Influence of insecticide treatments on number of shoots infested with green apple aphid per tree on June 6 and 26*, 2002.