Project Title: Evaluation of Insecticide Effects on Biology of Cherry Fruit Fly

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Cooperators: Various homeowners in Tri-Cities and Yakima, WA

Budget History:

Item	**Year 1:** 2004	**Year 2:** 2005	**Year 3:** 2006
Salaries	22,050	22,050	22,050
Benefits	2,450	2,450	2,450
Wages	0	0	0
Benefits	0	0	0
Equipment	1,000	1,000	1,000
Supplies	1,000	1,000	1,000
Travel	0	0	0
Miscellaneous	500	500	500
Total	27,000	27,000	27,000

Objectives 2004-2006:
1) Determine effects of insecticides on adult fly mortality, oviposition, and preference for cherries.
2) Determine relative importance of contact or ingestion mechanisms of kill of adult flies.
3) Determine residual activity of insecticide formulations in the field.
4) Determine effects of insecticide on larval infestations in the field.
5) Determine feeding times on insecticide droplets.
6) Determine effects on egg production of flies treated with sublethal amounts of insecticides.
7) Determine translaminar effects on cherries with various stages of fly eggs and larvae during early, mid, and late season.

Significant findings in 2004-2006:

● Entrust and GF-120 (spinosad insecticides) were the most effective insecticides against adult cherry fruit flies and caused 100% mortality within 1-4 days, followed by Provado (imidacloprid) and Calypso (thiacloprid). Results show there are fairly toxic non-organophosphate materials for use against the fly.

● GF-120, Entrust, Provado, Actara, Avaunt, and Guthion reduced oviposition into cherries by flies; Guthion was most effective, followed by Entrust, Provado, and Actara, which were similar. Mortality caused by all insecticides except Avaunt was >90% after 2 days, but Guthion caused 100% mortality after this time. This suggests the toxicity of materials need to be increased to improve their ability to reduce oviposition or that other, more toxic materials need to be identified.

● Flies laid equally in insecticide-treated versus untreated cherries, suggesting the insecticides are not a deterrent and that the flies cannot tell the two types of cherries apart.

● Spinosad in GF-120 and Entrust had equally high contact and oral activity; Provado and Calypso had higher oral than contact activity. This suggests flies may not need to feed on spinosad or Provado to be killed.

● GF-120 had residual activity of 14 days; Entrust, Provado, and Calypso had no activity after 14 days of aging. This suggests that under ideal conditions of no rain and moderate weather, the bait in GF-120 is able to protect the spinosad from degradation from environmental factors or prevent or reduce it from being absorbed rapidly into leaves.

● A field trial indicated Entrust, GF-120, Provado, and Calypso can reduce larval infestations of cherries significantly, at least when fly densities are low; however, except for GF-120 (in this one trial), no materials eliminated infestations.

● Flies fed more on all insecticides when they were mixed with sugar than without. This suggests sugar mixed in insecticide solutions can speed up kill.

● Calypso had the highest ovicial (egg-killing) and young larval-killing activity, suggesting it can be used in a post-harvest sprays.

● Provado when sprayed on cherries reduced larval emergence the most, suggesting it also could be used as an effective post-harvest spray.

● Further study showed that all insecticides tested except Avaunt reduced larval emergence from cherries, with Guthion, GF-120, and Provado most effective; however, Guthion was the only one that prevented emergence. Despite reducing emergence, the other materials should be improved for their ability to be absorbed into fruit tissue (at post-harvest) or that their toxicities need to be increased against the eggs or larvae, to be as effective as Guthion.

1) Determine Effects of Insecticides on Adult Fly Mortality, Oviposition, and Preference for Cherries

Experiments using the label rates of the following were conducted: (1) Entrust (spinosad, no bait), (2) GF-120 (spinosad mixed with bait of sugar, protein, attractants), (3) Provado (imidacloprid), and (4) Calypso (thiacloprid). An untreated control (water) was included. Insecticides were tested without sugar (except GF-120). Ten male and 10 female flies 2-7 days old were placed inside a pint-size paper container with food and water with no insecticides (control) or with 100 μl (test 1) or 500 μl (test 2) of each of the 4 treatments. Treatments were presented as 5 (test 1) or 25 (test 2) 20 μl drops spread uniformly on a shallow plastic dish on the bottom of a container over 4 d. Fly mortality was determined at 1, 2, 3, and 4 days after exposure. Flies were classified as dead if they could not walk. There were 3 or 4 replicates of the control and treatments in test 1 and 5 of each in test 2.

To determine effects of insecticides on fly oviposition, flies were exposed to cherries sprayed with insecticides. Flies were aged from emergence inside half gallon white paper containers containing food and water. Flies were tested at 14-16 days old. Treatments were (1) Entrust, (2) GF-120, (3) Provado, (4) Calypso, (4) Avaunt (indoxacab, an oxadiazine), (5) Actara (thiamethoxam, a neonicotinoid), and Guthion (azinphos-methyl). A control was included. Insecticides were applied on cherries the day before testing. Thirty cherries were spread as one layer on a piece of aluminum foil on a plastic tray in a fume hood. Using a spray bottle, 4.8 ml of solution was evenly applied onto the cherries. Cherries were left on trays for 24 h at 20-21 ºC. On the test day, the 30 cherries were gently poured onto the bottom of a half gallon paper container. The container had 2 water wicks and a strip of food. Six males and 6 females were then introduced into each container. Males were placed in with females to allow for mating. Female fly mortality was checked at 1, 2, and 3 days after exposure to treatments. At 3 days, all 30 cherries were removed and stored in alcohol to check for eggs later. There were 5 replicates of the control and all treatments.

The same treatments were compared in an experiment to determine if there is an oviposition preference by flies for insecticide-treated versus untreated cherries. Procedures were essentially the same as in the previous experiment, except that 15 cherries were treated and 15 were left untreated in each container. A strip of paper acted as a barrier and separated the 2 types of cherries on the bottom of the cage. There were 5 replicates of the control and treatments.

2) Determine Importance of Ingestion or Topical Application Mechanisms of Kill of Adult Flies

Entrust, Provado, and Calypso were mixed with 20% sucrose (wt:wt) to stimulate feeding and tested against 3-11 day old flies. The control was 20% sucrose only. Newly-emerged flies were held inside pint-size containers with food and water. Food was removed 16-20 hours before tests. Individual flies were immobilized at 1.7-3.3 ºC for 5-6 min. For testing effects of topical application, a 2 μl drop of solution was placed on top of the thorax of a single fly under a microscope. For ingestion effects, a 2 μl drop of solution was placed in a glass vial 15 min after a fly was introduced into the vial. The fly was closely observed and given a maximum of 15 min to drink the solution. All flies drank the insecticide solutions within this time, some consuming the entire 2 μl drop. After topical application and ingestion treatments, each fly was placed inside a pint-size paper container with food and water. Mortality was checked daily up to 30 days. There were 15-25 flies of each sex for the control and treatments.

3) Determine Residual Activity of Insecticide Formulations in the Field

Entrust, GF-120, Provado, and Calypso aged for 0, 3, 7, and 14 days on sweet cherry leaves at the USDA experimental orchard in Moxee, WA were exposed to field-collected flies in 2005. A hand-held sprayer was used to deliver about 10 ml of spinosad bait and 20 ml of the other materials to tops and bottoms of approximately 30 leaves on the south sides of trees on 6, 13, 17, and 20 June. Bait sprays are not intended to provide 100% coverage and thus a lower spray volume of GF-120 was used. Unsprayed leaves served as controls. There was 1.3 mm precipitation on 7 June and a trace amount on 18 June. Most days were sunny. For the "0" day treatment, leaves were sprayed and then air dried for one hour before being exposed to flies. Flies were collected from Kennewick and Zillah, WA over a 2.5-week period before the experiment, and maintained at 20-21 ºC with food and water inside pint-size paper containers. Each replicate container held 8 male and 4 female flies. Flies that died before the start of the experiment were replaced as needed. For each replicate, one randomly chosen control or treated leaf was placed inside a container. The leaf was laid on its edge to maximize exposure of flies to insecticide residues on both sides of the leaf. Flies were provided with food and water. Mortality was checked at 1, 3, and 7 days after fly exposure to the leaves. There were 5 replicates of the control and each treatment. The experiment was conducted at 24-29 ºC.

4) Determine Effects of Insecticides on Larval Infestations in the Field

In Washington, one spray trial was conducted in 2004 at the USDA experimental cherry orchard in Moxee using single trees, which simulated unmanaged homeowners' trees. Yellow sticky traps baited with ammonium carbonate were placed in selected trees in May to detect first fly emergence. A control and Entrust, GF-120, Provado, and Calypso treatments were compared. The test was set up as a randomized complete block design. Each tree was separated from others by one untreated tree. There were 7 replicate blocks. Applications were made within 5 days after the first fly capture. Because of the low fly density, traps were removed afterwards to reduce the possibility they would capture too many flies. GF-120 was applied using a hand-held sprayer at 532 ml of spray/tree (per label for single trees). The other treatments were applied using a Nifty Pul-Tank and a handgun at 100 psi in a volume of 7.56 liters per tree. Applications were made every 8 or 10 days. Two hundred cherries were removed from each tree on 1 July. Mature cherries were laid on emergence trays over one month to collect pupae.

5) Determine Feeding Times on Insecticide Drops
Observations were made of flies exposed to 2.5 μl drops of insecticide solutions with and without 20% sucrose inside clear glass vials. One fly was tested at a time and exposed to one drop. Insecticides tested were GF-120, Entrust, Provado, and Avaunt, and Actara. Water with or without sucrose was the control. Numbers of feeds and durations of feeds over a 5-minute period were recorded.
6) Effects of Sublethal Insecticide Amounts
For Entrust and Provado treatments, egg production of flies exposed to 2.5 μl drops of insecticide placed on the dorsa or that ingested the drops were determined by allowing flies to lay eggs into untreated cherries at days 10-14 inside pint-size containers.
7) Determine Translaminar Effects on Cherries with Eggs and Larvae
In 2005, sweet cherries with stems attached were picked from 5 infested trees on 7 and 8 June in Kennewick, WA and treated with water, Entrust, GF-120, Provado, and Calypso on 8 June. The cherries were ripe. There were 110 cherries for the control and each treatment from each tree. The 110 cherries were placed on hardware cloth and then sprayed with 10 ml of each material using a squirt bottle. They were then suspended above a tub containing dry soil and held outdoors in the shade for 30 days (8 June to 8 July). At 8 days, 10 cherries were randomly selected from each sample and opened to determine numbers of dead and live larvae. Each larva was measured to determine if growth was affected. The other 100 cherries were held on the hardware cloth for an additional 22 days. At 15 and 30 days after treatment, numbers of pupae in the soil at the bottom of each tub were counted. Pupae were stored in sealed cups at 21 ºC in moist soil. All pupae were dissected at 30-37 days post treatment to determine mortality. There were 5 replicates of the control and treatments.

In 2006, cherries from 7 infested cherry trees in Kennewick were collected and treated with Entrust, GF-120, Provado, Calypso, Avaunt, Actara, and Guthion. A water control was included. Samples from the 7 trees were considered replicates. Cherries were collected on 3 dates that represented early, mid, and late season: 31 May, 7 June, and 14 June. Stems were retained on the cherries. Cherries were brought back to the laboratory, and spread among hardware cloths, with 30 cherries each. The cherries were sprayed with 2.8-3.2 ml insecticide solutions using a squirt bottle on the day of collections and again one week later. Cherries were kept outdoors in the shade for 30 days for larvae to emerge. All pupae in tubs were counted. Pupae were then chilled at 3 ºC and removed after 4 months to determine survival of flies.

2004-2006 Results and Discussion:

1) Determine effects of insecticides on adult fly mortality, oviposition, and preference for cherries.
In test 1 using 100 μl solutions, mortality among all treatments was higher than in the control and rankings of effectiveness were similar among days (Table 1). Entrust caused the highest mortality, although statistically it was not different from GF-120. Provado did not differ from GF-120 and Calypso, but it was less effective than Entrust at 1, 3, and 4 days and Calypso was less effective than Entrust at 1, 2, 3, and 4 days (Table 1). Exposure to 5 times greater volume in test 2 resulted in higher mortality in the Provado than Calypso treatment at 3 and 4 d. Mortality caused by Entrust or GF-120 and Provado was not different except at 2 days after exposure (Table 1). These results indicate there are fairly toxic non-organophosphate materials against adult cherry fruit flies.

In the oviposition deterrence test (Table 2), all materials suppressed infestations and numbers of eggs laid by 14-16 day old flies, but none of the materials prevented oviposition. The ranking of effectiveness in percentages infestation that were reduced and numbers of eggs laid in cherries was: Guthion > Provado >GF-120 >Actara > Entrust > Avaunt > control, although statistically Guthion = Provado = GF-120, with Entrust and Actara and Avaunt similar and all more effective than the control. The data on mortality (Table 2) indicate that even though mortality was highest at day 1 for Actara and Guthion, flies were not killed quickly enough in these 2 treatments to prevent oviposition.

At days 1 and 2, mortality among all treatments increased and was more similar, with Avaunt causing the lowest mortality. Results suggest that despite relatively high toxicity to adults, more toxic materials are still needed, to be comparable to Guthion.

In the oviposition choice test (Table 3), contrary to expectations, there were no differences between infestations in cherries that were treated or untreated with insecticides, except for GF-120 (Table 3). Even though half of the cherries in a container were untreated, mortality of females was high, especially at days 2 and 3. The results suggest the insecticides are not a deterrent and that the flies cannot tell the two types of cherries apart. There is thus no reason to believe flies will leave insecticide-treated trees because of a repellent effect.

2) Determine Importance of Ingestion or Topical Application Mechanisms of Kill of Adult Flies

Contrary to expectations, spinosad in GF-120 and Entrust had equally high contact and oral activity; Provado and Calypso had higher oral than contact activity (Table 4). Although it is possible the materials may have spread down the thorax of flies and caused the flies to feed on the materials, the fact is that flies did not need to directly ingest the materials to suffer high mortality. Thus sprays of GF-120 and the other insecticides may affect control through both contact and ingestion of materials. However, which mechanism accounts for the control in the field is not known, although the less toxic materials may be more effective if ingested.

3) Determine Residual Activity of Insecticide Formulations in the Field

There were clear effects of aging insecticides and baits and of different insecticides on fly mortality (Table 5). Entrust lost effectiveness when aged over the 14 days, whereas GF-120 did not lose any effectiveness over 14 days. Provado lost effectiveness after only 3 days of aging. Calypso did not lose any effectiveness over 14 days of aging, but it also was ineffective, causing lower mortality than any of the other materials (Table 5). At 1 DAE, mortality within 0-day old residues ranked as follows: GF-120=Entrust> Provado> Calypso. With 3-day old residues, the ranking was GF-120>Entrust= Provado=Calypso. With 7- and 14-day old residues, GF-120 caused greater mortality than all other materials, with Calypso least effective. These same rankings were generally seen at 3 and 7 DAE, even though there was increased overall mortality, including in the controls. Significantly, GF-120 was the only material that caused 100% mortality by 7 days after exposure when aged 0, 3, and 14 days (Table 5). The results clearly suggest that GF-120 has the longest residual activity when there is little precipitation. It is possible that the bait component of GF-120 (sugars, ammonium acetate, oil, etc.) protected the spinosad from degradation or that it concentrated the spinosad on the leaves. It is also possible that the bait reduced the absorption of spinosad into the leaves. Entrust possibly was more easily washed off or subjected to degradation by the sun's rays. Under idea conditions, it appears that GF-120 can be applied every 14 days and remain effective. The others need to be applied every 7 days. Increasing the longevity of insecticides may make them more useful for fly management.

4) Determine Effects of Insecticides on Larval Infestations in the Field

Numbers of flies in the test trees at Moxee were low and significant reductions in larval infestations were obtained using Entrust, GF-120, Provado, and Calypso (Table 6). No larvae emerged from the GF-120 treatment.

5) Determine Feeding Times on Insecticide Drops

Whether flies fed on insecticide drops depended on the feeding history of the fly and also on whether sugar was mixed with the insecticide solution (Table 7). When flies were not starved and no sugar was in the insecticide solutions, flies rarely fed on any treatment. When flies were starved and no sugar was in the insecticide solutions, flies still fed. There was no evidence of any deterrence, but flies fed longest on GF-120 because sugar and protein were present in this bait. When flies were starved and there was sugar in the insecticide solutions, flies fed the most and longest. Feeding again was longest on GF-120, but flies fed for relatively long periods on the other materials as well. The exception was Actara, which may have had some deterrent effect (Table 7). The results suggest that insecticides mixed with sugar alone may increase the speed of fly kill, especially if the flies are in a food-deprived state. Sugar mixed in insecticide solutions perhaps can result in better control than using insecticides only if the less toxic materials are used.

6) Effects of Sublethal Insecticide Amounts

Results using sublethal amounts of insecticides were inconclusive, although there was some evidence that sublethal doses of Entrust reduced oviposition by flies (control, mean of 31.8 eggs; lethal Entrust, 0.2 eggs; sublethal Entrust, 5.0 eggs). More tests are needed to determine if insecticides can reduce oviposition of flies that are exposed to but not killed by insecticides.

7) Determine Translaminar Effects on Cherries with Eggs and Larvae

When eggs were exposed to insecticides for 15 seconds, hatch in the Calypso treatment was significantly lower hatch in the control and Entrust and Provado treatments (Table 8). Greater than 90% of eggs in all treatments hatched between 3-7 days old, and thus it appeared the insecticides did not delay hatching. Up to 12, 48, and 24% of unhatched eggs exposed to Entrust, Provado, and Calypso, respectively, contained fully developed but dead larvae. In contrast to a 15-second exposure, eggs exposed continuously to all insecticides never hatched. Up to 60, 68, and 62% of eggs exposed to Entrust, Provado, and Calypso, respectively, contained fully developed but dead larvae. This shows that despite its relatively low toxicity to adults, Calypso is highly toxic to eggs. Calypso could be used during early season when cherries have only eggs as the life stage. An obstacle to overcome is how to make Calypso penetrate the fruit quickly.

When small larvae were exposed to insecticides, Calypso caused the highest mortality (Table 9). Large larvae were affected differently, because there was either no effect or a negative effect on larval survival when they were exposed to insecticides (Table 9). When infested cherries were sprayed, there was no evidence the large larvae were killed by any of the insecticides, based on dissections of fruit. However, larval emergence rates were reduced, indicating movement of all materials into the cherries. The materials either prevented egg hatch or killed a small percentage of the small larvae. The results strongly suggest that sprays applied on unpicked fruit after harvest can reduce larval populations.

In 2005, larval emergence from treated fruit was lower than in the control at days 1-15 (Table 10). At days 16-30, emergence was lowest from the Provado and Calypso treatments, although Calypso was not different from GF-120. Entrust was not different from the control. Over the 30 days, all treatments had significantly lower emergence than the control, with Provado having the lowest numerically, even though it was not different from GF-120 (Table 10). There was no effect of any material on mortality of pupae at 30-37 days post-treatment (Table 10). Results here also suggest Provado could be used as an effective post-harvest spray.

In 2006, all materials reduced larval emergence from cherries, except for Avaunt (Table 11). Of those that did reduce emergence, Guthion was the most effective, and Entrust was the least effective numerically (Table 11). The numbers of larvae that emerged increased as the season progressed, but the relative effects among materials were fairly constant. This suggests that, despite reducing emergence, the other materials should be improved for their ability to be absorbed into fruit tissue or that their toxicities against eggs or larvae need to be synergized and increased.

Significance to the Industry and Potential Economic Benefits

The significance of the results from this project to the cherry industry is that it identifies potential alternatives to the use of one type of chemistry for fly control and identifies the mechanisms of kill of some of the insecticides and materials. Specifically, GF-120, Entrust, and Provado appear to be the most effective products tested against all life stages of the fly, with Calypso having effects mostly against eggs. The use of the most effective insecticide reduces the risk of infestations in orchards and of bins being rejected at the packinghouse. The continued use of one material, including spinosad, may potentially result in resistance, if not in fruit flies, then perhaps in other, non-target pests on cherries such as leafrollers, thrips, or even beetles. The use of insecticides with different chemistries may reduce the chances that control will be needed for these pests. Insecticidal control of other insect pests on cherries would clearly incur more spray costs.

Table 1. Effects of insecticides and bait on mean cumulative percent mortality of adult cherry fruit flies at 1-4 days after exposure in the laboratory

Test 1: 100 μl solution				
Treatment	1 day	2 days	3 days	4 days
Control	2.5	3.8	8.8	16.3
Entrust	77.0	94.8	100.0	100.0
GF-120	57.3	79.3	89.7	96.3
Provado	40.5	58.5	63.3	68.5
Calypso	45.0	50.0	60.0	63.3
1-way ANOVA				
df = 4, 13 *F*	16.17	9.66	8.89	7.76
P	< 0.0001	0.0007	0.0011	0.0020
Test 2: 500 μl solution				
Treatment	1 day	2 days	3 days	4 days
Control	0.0	0.0	2.0	5.0
Entrust	75.0	88.0	99.0	100.0
GF-120	70.2	86.6	93.8	97.0
Provado	50.0	65.0	87.0	89.0
Calypso	38.0	43.0	60.0	65.0
1-way ANOVA				
df = 4, 13 *F*	16.30	21.25	23.56	26.20
P	<0.0001	<0.0001	<0.0001	<0.0001

Test 1: 3 or 4 replicates; Test 2: 5 replicates; 20 flies/replicate
Means followed by the same letter within columns are not significantly different (LSD test, $P > 0.05$).

Table 2. Effects of insecticides on mean oviposition by cherry fruit fly and mortality of flies in the laboratory

Insecticide	% Cherries Infested[a]	No. Eggs[a]	Cumulative % Female Mortality[b] Day 1	Day 2	Day 3
Control	88.7a	141.2a	0.0e	3.3d	3.3c
GF-120	9.3cd	4.6cd	76.7b	96.7a	100.0a
Entrust	22.7bc	16.6bc	66.7bc	90.0ab	96.7a
Provado	7.3cd	3.0cd	42.5cd	81.7b	94.2a
Actara	14.7bc	7.0cd	80.0ab	86.7ab	93.3a
Avaunt	34.0b	27.8b	23.3d	56.7c	73.3b
Guthion	1.3d	0.4d	100.0a	100.0a	100.0a
1-way ANOVA					
F (df = 6, 28)	19.08	26.69	17.18	23.53	49.45
P	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

5 replicates of 6 females and 6 males; [a]Per 30 cherries; [b]Days after exposure to insecticides.
Means within columns followed by the same letter are not significantly different (LSD test, $P > 0.05$).

Table 3. Effects of insecticides on mean oviposition on treated and untreated cherries by cherry fruit flies and mortality of flies in the laboratory

	% Cherries Infested[a]		No. Eggs[a]	
Insecticide	Treated	Untreated	Treated	Untreated
Control	96.0	98.7	105.6	153.8
GF-120	12.0	24.0	2.4	10.0
Entrust	18.7	17.3	3.0	3.2
Provado	30.7	20.0	5.0	4.6
Actara	25.4	33.4	5.0	9.6
Avaunt	60.0	62.7	25.0	41.2
Guthion	4.0	6.7	0.6	1.4

5 replicates of 6 females and 6 males; [a]Per 15 cherries.

Table 4. Effects of contact with and ingestion of insecticides on mean days survived post treatment[a] by single adult cherry fruit flies

	Contact with Water or Insecticide[b]				Ingestion of Water or Insecticide[c]			
Treatment	N	Males	N	Females	N	Males	N	Females
Water	17	19.1a(b)	25	1 5.5a(b)	17	16.1a(b)	18	17.3a(b)
Entrust	18	4.9a(a)	20	2.8a(a)	15	1.0a(a)	17	1.2a(a)
Provado	15	7.5a(ac)	18	10.2a(b)	17	4.3a(a)	18	7.0a(a)
Calypso	16	13.3b(bc)	18	12.3b(b)	17	6.1ab(a)	19	4.3a(a)

Water and all treatments contained 20% sucrose.
Means followed by the same letter within rows outside parentheses are not significantly different (LSD test, $P > 0.05$); Means followed by the same letter within columns inside parentheses are not significantly different (LSD test, $P > 0.05$).

Table 5. Effects of field-aged insecticide and bait residues on leaves on mean cumulative percent mortality of adult cherry fruit fly in the laboratory at 1-7 days after exposure (DAE)

Age of Residues on Cherry Leaves at Initial Exposure to Flies				
1 DAE	0 d (fresh)	3 d	7 d	14 d
Control	3.3a(a)	1.7a(a)	3.5a(a)	1.7a(a)
Entrust	70.0c(c)	26.0b(b)	14.6ab(a)	0.0a(a)
GF-120	78.3a(c)	72.4a(c)	70.1a(b)	79.4a(c)
Provado	34.2b(b)	17.0b(b)	23.0b(a)	5.0a(ab)
Calypso	8.3a(a)	3.5a(ab)	8.8a(a)	13.3a(b)
3 DAE	0 d (fresh)	3 d	7 d	14 d
Control	10.1a(a)	3.3a(a)	8.6a(ab)	3.3a(a)
Entrust	95.0b(c)	76.7b(c)	65.0b(c)	8.3a(ab)
GF-120	98.3a(c)	100.0a(c)	91.1a(d)	96.9a(c)
Provado	63.0c(b)	42.3bc(b)	32.3ab(b)	11.7a(ab)
Calypso	16.7a(a)	19.3a(ab)	8.8a(a)	26.7a(b)
7 DAE	0 d (fresh)	3 d	7 d	14 d
Control	23.0a(a)	17.6a(a)	20.4a(a)	15.0a(a)
Entrust	98.3b(bc)	88.3b(c)	98.3b(c)	17.2a(b)
GF-120	100.0a(c)	100.0a(c)	98.2a(c)	100.0a(a)
Provado	91.7c(b)	57.4b(b)	41.0ab(b)	23.3a(a)
Calypso	31.7a(a)	35.1a(ab)	23.8a(ab)	35.0a(a)

5 replicates of 12 flies each (8 males, 4 females).
Means followed by the same letter within rows outside parentheses are not significantly different (LSD test, $P > 0.05$); Means followed by the same letter within columns inside parentheses are not significantly different (LSD test, $P > 0.05$).

Table 6. Effects of insecticide sprays on cherry fruit fly larval infestations of cherry in 2004 at Moxee, WA

Treatment	No. Larvae/100 Cherries	RBD ANOVA
Control	2.45a	$F = 6.35$
Entrust	0.2b	df = 4, 24
GF-120	0b	$P = 0.0012$
Provado	0.1b	
Calypso	0.2b	

7 single tree replicates of each treatment.

Table 7. Effects of different feeding histories on cherry fruit fly feeding responses to insecticide drops under laboratory conditions

Flies not starved before testing; kept on 5% sucrose up to testing; no sucrose in insecticide solutions						
	Males			Females		
Treatment	*N*	No. Feeds	Tot. Dur (min)	*N*	No. Feeds	Tot. Dur (min)
Water	11	0	0	11	0	0
GF-120	11	0.5	7.2	11	0.3	8.1
Entrust	11	0	0	11	0	0
Provado	11	0.1	0.2	11	0.1	0.5
Actara	10	0	0	10	0	0
Avaunt	11	0	0	10	0	0
Guthion	10	0	0	10	0.1	0.4
Flies starved 16-20 hours before testing; kept on 20% yeast and 80% sucrose before starving; no sucrose in insecticide solutions						
	Males			Females		
Treatment	*N*	No. Feeds	Tot. Dur (min)	*N*	No. Feeds	Tot. Dur (min)
Water	18	0.2	1.1	21	0.5	10.3
GF-120	21	0.5	27.7	28	0.8	26.7
Entrust	14	0	0	15	0.2	1.0
Provado	17	0.4	7.8	20	0.2	2.1
Actara	11	0.3	3.5	23	0.2	1.8
Avaunt	12	0.2	3.2	15	0.2	3.1
Guthion	14	0.1	0.5	21	0.3	2.6
Flies starved 16-20 hours before testing; kept on 5% sucrose before starving; 20% sucrose in insecticide solutions						
	Males			Females		
Treatment	*N*	No. Feeds	Tot. Dur (min)	*N*	No. Feeds	Tot. Dur (min).
Water	20	0.4	9.7	20	0.1	1.9
GF-120	21	1.6	74.4	20	1.6	75.1
Entrust	20	1.0	53.1	20	2.0	70.2
Provado	20	0.7	26.8	22	0.6	27.8
Actara	20	0.4	16.4	20	0.8	33.8
Avaunt	20	1.3	56.8	20	1.4	71.2
Guthion	21	0.8	45.6	20	1.4	79.2

Table 8. Effects of insecticides and insecticide exposure time on percent egg hatch of cherry fruit fly

Treatment	15-second Exposure	Continuous Exposure
Control	41.0a	42.4a
Entrust	37.0a	0.0b
Provado	25.0a	0.0b
Calypso	3.3b	0.0b
1-way ANOVA		
F	15.3 (df = 3, 20)	55.7 (df = 3, 16)
P	< 0.0001	< 0.0001

15-second exposure: 6 replicates of 50 eggs; continuous exposure: 5 replicates of 50 eggs each. Means followed by the same letter inside parentheses within days are not significantly different (LSD test, $P > 0.05$).

Table 9. Effects of treating small and large larvae with insecticides on percent mortality of larvae and pupae of cherry fruit flies after 2 days

Small Larvae (2-3 mm long)			
Treatment	% Larvae Dead	Larval Lengths (mm)	
Control	6.9a	3.5a	
Entrust	69.7b	3.3a	
Provado	77.3b	3.0a	
Calypso	91.0c	3.1a	
Large Larvae (5.5-7 mm long) Test 1			
Treatment	% Larvae Dead	% Larvae Alive	% Pupae
Control	35.0a	30.0a	35.0ab
Entrust	72.5a	10.0a	20.1a
Provado	37.5a	20.0a	42.5b
Calypso	32.5a	2.5a	65.0c
Large Larvae (5.5-7 mm long) Test 2			
Treatment	% Larvae Dead	% Larvae Alive	% Pupae
Control	38.0a	22.0a	40.0b
Entrust	90.0b	4.0b	6.6a
Provado	72.4b	4.0b	23.6b
Calypso	77.3b	0.0b	22.7b

5 or 4 replicates of 10 larvae each.
Means followed by the same letter inside parentheses within dates are not significantly different (LSD test, $P > 0.05$).

Table 10. Effect of spraying cherries with insecticides and bait on larval mortality and numbers of larvae of cherry fruit flies emerging from cherries collected in Kennewick, WA, 2005

	Dead Larvae/10 Fruit[a]		Live Larvae/10 Fruit[a]	
Treatment	No.	Length (mm)	No.	Length (mm)
Control	0.2a	6.8	12.6b	4.9a
Entrust	1.0a	4.5	12.0b	4.2a
GF-120	0.8a	4.6	11.4b	4.2a
Provado	1.2a	3.5	6.4a	3.8a
Calypso	0.8a	2.1	6.4a	4.9a
		No. Pupae/100 Fruit		
Treatment	Days 1-15	Days 16-30	30-Day Total	% Pupae Dead
Control	130.8b	44.4d	175.2d	36.9a
Entrust	70.4a	33.3cd	103.4b	39.6a
GF-120	66.0a	18.6bc	84.6ab	40.4a
Provado	58.2a	6.0a	64.2a	42.3a
Calypso	89.0a	12.0ab	101.0b	39.4a

5 replicates of the control and each treatment; [a]At 8 days post-treatment; one application only. Means followed by the same letter inside parentheses within dates are not significantly different (LSD test, $P > 0.05$); [b]Too few to analyze statistically.

Table 11. Numbers of mean numbers of cherry fruit fly larvae from detached cherries after 3 weeks of treatment with different insecticides, fruit collected in Kennewick, WA, 2006

	Cherries Collected On (Color):					
	31 May (orange)		7 June (red)		14 June (dark red)	
Insecticide	No. Larvae	% fewer	No. Larvae	% fewer	No. Larvae	% fewer
Control	1.7a	-----	10.9a	-----	32.0a	-----
GF-120	0.3bc	82	1.3cd	88	11.2bc	65
Entrust	1.1abc	35	6.9b	37	20.9ab	35
Provado	0.1bc	94	3.1bc	72	11.7b	63
Actara	0.3bc	82	6.3b	42	17.1ab	47
Avaunt	1.3ab	24	11.1a	----	30.6a	4
Guthion	0.0c	100	0.0d	100	2.3c	93
1-way ANOVA						
F	2.30		14.51		5.93	
P	0.0519		<0.0001		0.0002	

7 replicate (trees) of control and treatments. No. larvae per 27 fruit per replicate. Means within columns followed by the same letter are not significantly different (LSD test, $P > 0.05$).