FINAL PROJECT REPORT
WTFRC Project Number: AE-04-427

Project Title: Control of Apple Maggot Using Bait Spray Insecticides and Traps

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Cooperators: WSU personnel, growers, and homeowners in Vancouver and Puyallup

Budget History:

Item	**Year 1:** 2004	**Year 2:** 2005	**Year 3:** 2006
Salaries	22,000[1]	22,000[1]	22,000[1]
Benefits	2,200	2,200	2,200
Wages	0	0	0
Benefits	0	0	0
Equipment	0	0	0
Supplies	2,000[2]	2,000[2]	2,000[2]
Travel	1,500[3]	1,500[3]	1,500[3]
Miscellaneous	0	0	0
Total	27,700	27,700	27,700

[1]Two GS-5, for 6 months, One to two GS-3, 3 months.
[2]Traps and spray equipment and insecticides; [3]Gasoline for travel to and from field sites.

Objectives (2004-2006):
1) Determine release of ammonia and other volatiles from bait sprays.
2) Determine attraction to bait sprays and feeding behaviors on baits.
3) Determine effects of bait sprays under different habitat types.
4) Determine effects of bait sprays and trapping methods on apple maggot control.

Significant Findings:
● GF-120 bait mixed with ammonium carbonate was more attractive than GF-120 mixed with ammonium acetate when placed with traps, suggesting attraction to the bait can be increased, and that ammonia form is important.
● In the laboratory, the percentages of flies feeding on GF-120 with or without ammonium carbonate or ammonium acetate were low, suggesting low attractiveness of even enhanced bait
● In the field, more flies were attracted to and fed on GF-120 mixed with ammonium carbonate and ammonium acetate than on GF-120 alone, indicating GF-120 attractiveness can be increased, even though overall responses over 30-min periods were low.
.● Inconsistent with attraction and feeding tests, in two tests, no reduction in larval infestations in apples were seen when GF-120 alone or with ammonium carbonate and ammonium acetate was sprayed on apple trees; possibly due to habitat effects and to dispersing flies.
.● In three other tests, GF-120 alone was very effective (>90% control) against apple maggot infestation of apples; however, in these tests, GF-120 with additional ammonia did not increase control, and Entrust (spinosad alone) was equally effective.
● In tests of different baits, larval infestations of apples were reduced equally by spinosad alone, GF-120, and Mazoferm + spinosad, but were not reduced by Nulure + spinosad, suggesting spinosad alone and the less expensive Mazoferm can both be substituted for GF-120.
● Use of GF-120 sprays and use of ammonium carbonate-baited red spheres were equally and very effective in reducing larval infestations in apple at two sites; however, in no case were infestations eliminated.
● When GF-120 and red spheres were used together, there was no further decrease in larval infestations, perhaps because flies were more attracted to the red spheres than the bait.

Results and Discussion:

1) Determine release of ammonia and other volatiles from bait sprays. Only low amounts of ammonia could be detected from 40% GF-120, and only from fresh drops, not those aged for three or seven days in a fume hood. The calculated release of ammonia from fresh 40% GF-120 was 2.84 nanograms per 6-mm drop per hour, which is much lower than the optimal 2 mg/h release from a single ammonium lure. Other volatiles were released, but could not definitively be identified, although they presumably included acetic acid, a component of the ammonium acetate in the bait. Although other volatiles were not identified, these results alone suggest attraction to GF-120 is low in part because of the low ammonia release from them.

2) Determine attraction to bait sprays and feeding behaviors on baits. In a test to determine the effects of GF-120 with ammonia compounds (ammonium carbonate = AC; ammonium acetate = AA) on attraction to traps at Vancouver, WA the 10 g AC lure attracted more flies than the 40% GF-120 + 10% AC lure, which attracted more than the control and the 17% and 40% GF-120 lures, although not more than the 40% GF-120 + 10% AA lure (Table 1). At Saint Cloud Ranch, the 40% GF-120 + 10% AC lure attracted more flies than the control and other GF-120 lures, including the 40% GF-120 + 10% AA lure (Table 1). Numerically, slightly more flies were caught in the 40% GF-120 alone treatment than in the control. Results show that GF-120 can be modified to increase fly responses from moderate distances. This assumes that flies trapped were not initially in the immediate vicinity of traps, but flew to them either from other parts of the tree or from the closest neighboring trees.

GF-120 + 10% AC was more attractive than GF-120 + 10% AA, suggesting AA is repellent to a degree, perhaps due to release of acetic acid. Also, when amounts of the compounds are the same, AC may have released more ammonia than the AA.

In a test to determine the effects of GF-120 with ammonia compounds on feeding responses in the laboratory, there were low responses to the baits, but female flies responded less to water than to 13% sucrose and 17% and 20% GF-120. Responses to 40% GF-120 and 40% GF-120 + AA were lower, and the response to 40% GF-120 + AC was intermediate (Table 2). Unlike females, however, males did not respond less to water than any of the baits. Results show that the presence of bait can bring flies onto apples more than the absence of baits. Female flies are more likely to feed on baits, which is consistent with the attraction results in the trapping test. The lack of differences between AC and AA was surprising given the results using the lures with traps in experiment 1. Possibly tests in the laboratory lacked the cues flies need to home in on odors.

Several tests were conducted to determine the effects of GF-120 with ammonia compounds on attraction and feeding in the field by watching flies as they approached or fed on drops sprayed on leaves, At Saint Cloud Ranch in 2005, fly visits were infrequent given the 3.7 total h of continuous observations per treatment, but there were greater percentages of sightings of flies near or feeding on 40% GF-120 + 10% AC or 10% AA than sucrose, 17% GF-120, and 40% GF-120 (Table 3). No differences were detected using AC and AA treatments with GF-120 sprayed on leaves. At Saint Cloud Ranch in 2006, fly responses were also low given the 5.7 total h of observation/treatment and similar results were obtained, with percentages of sightings of flies near or feeding on GF-120 + 10% AC or 10% AA higher than water, sucrose, 40% GF-120, and spinosad only (Table 3). In Puyallup in 2005, percentages of sightings of flies feeding on or near GF-120 + 2.5% AC or 2.5% AA were higher than near or feeding on water, sucrose, 17% and 40% GF-120, and spinosad only (Table 4). Also, no differences were seen between AC and AA treatments. This was also true in Puyallup in 2006, although the percentage of sightings of flies near or feeding on GF-120 + 2.5% AC was slightly higher than on or near GF-120 + 2.5% AA (Table 4). Overall results show that additional ammonia clearly increased the attractiveness of GF-120 when it was sprayed on apple leaves, although it was equally clear that no differences existed between adding AC or AA in the bait. There was also evidence that GF-120 with or without AC or AA was more attractive than water and spinosad only. However, because numbers of flies responding were low (especially at Saint Cloud Ranch), ammonia release from the enhanced GF-120 drops seemed insufficient to elicit strong or immediate responses from a large percentage of a fly population. Point sources of ammonia that emanate from lures such as those in the trapping test certainly are difficult to duplicate from spray drops on leaves and it may take most flies longer than the 30-min observation periods to find the bait. The slightly greater response to GF-120 alone on leaves (compared with sucrose) suggests the bait is somewhat attractive, whether because of olfactory cues, visual cues, or both. Numbers of feeds were lower than numbers of non-feeding visits near GF-120 in Puyallup, possibly due to arrestment of flies, although more evidence is needed to confirm this.

3) Determine effects of bait sprays under different habitat types. Five tests determined the effects of GF-120 with added ammonia compounds on infestations in apples. In Woodland in 2005 using orchard trees (100 ml spray/tree), there were no effects of any treatment on adult fly numbers, which were low in the orchard (Table 5). Numbers of larvae/fruit did not differ statistically among the control and treatments, although statistically there were fewer larvae/fruit in 40% GF-120 and 40% GF-120 + 10% AA than in other treatments (Table 5). Results from Woodland/Vancouver in 2005 using isolated trees (100 ml spray/tree) were similar in that no statistical differences were detected, but numerically there were fewer larvae/fruit in all treatments than in the control (Table 5). In Vancouver in 2006 using orchard trees (200 ml spray/tree), numbers of flies were low, and although there were significantly more adults in the 40% GF-120 + 10% AC treatment than in the control, there were significantly fewer larvae/fruit in all treatments than in the control (Table 6). However, the GF-120 + 10% AC or 10% AA treatments did not perform better than GF-120 alone, and statistically no better than spinosad only. In Puyallup in 2005 using orchard trees (100 ml spray/tree), statistically fewer adults were caught on traps in all treatments than in control trees. There were high levels of control using all the treatments, and similar to Vancouver in 2006, GF-120 + 2.5% AC or 2.5% AA treatments did not perform better than GF-120 alone, and statistically no better than spinosad only (Table 7). In Puyallup in 2006 using orchard trees (also 100 ml spray/tree), all treatments reduced the numbers of adults caught compared with the control, but spinosad only decreased it the most, whereas 40% GF-120 + 2.5% AC reduced it the least (Table 7). Despite different effects on adult captures, all treatments again resulted in high levels of control of larvae/fruit. Also, again no differences among GF-120 with and without AA or AC and spinosad only were detected (Table 7).

In tests comparing various baits, it was found that in the laboratory, flies fed on the various baits at similar frequencies (Table 8), numbers of times, and durations (Table 9). When baits were sprayed on apple leaves in the field, flies responded most to Mazoferm (Table 10). When baits were sprayed on infested apple trees, GF-120, Mazoferm (with spinosad), and spinosad alone were equally effective and all reduced infestations >80% (Tables 11 and 12). Nulure was least effective. These tests were conducted using 100 ml of spray per tree in an orchard.

Results show that GF-120 treatments resulted in high levels of larval control in three of five tests, but adding AC or AA to GF-120 did not enhance its effectiveness in reducing adult fly numbers and larval infestations compared with using GF-120 alone, which was surprising given the consistently greater attraction to enhanced fresh GF-120 in the behavioral observations. It was unclear why results differed among tests, but differences in habitat type probably was one reason, as this affected numbers of dispersing flies around test trees. Fruiting phenology, susceptibility of apple cultivars, numbers of spray applications, spray coverage, and the way fruit were collected (from ground versus tree) among tests also could have affected results. No significant rainfall occurred that could explain them.

With respect to adult flies, in Vancouver in 2006 and in Puyallup in 2005, more flies were caught on traps hung in trees sprayed with GF-120 + AC than in trees sprayed with GF-120 alone, suggesting the enhanced bait brought more flies in from surrounding trees. This apparent influx of adults to the trees did not increase larval infestations, however, suggesting flies were caught before they oviposited. With respect to larval infestations, one possible explanation for the lack of differences between GF-120 and GF-120 + AC or AA treatments is that ammonia release rates from enhanced drops decreased quickly after sprays, so after a few days the enhanced GF-120 was the same as GF-120 alone in attractiveness. If so, ingredients that prolong the release of ammonia may be beneficial. It is possible that at the spray volumes tested, flies were able to find drops even after they lost their attractiveness through normal foraging movements. Coverage of all single trees in an area or of entire orchards with GF-120 may lead to greater suppression than obtained by spraying randomly selected single trees in this study or may even eliminate fly populations over time.

Despite the high levels of control obtained using GF-120 in three of five tests, the similarly high levels of control using 100 ml of spinosad only/tree suggests bait may not be needed with spinosad for it to be effective. Spinosad seems unattractive compared with 40% GF-120 alone, so its effectiveness even at a low volume probably is unrelated to attraction. This suggests the flies found drops of spinosad and fed on them during the course of normal foraging. Also, it is possible there was some contact activity, as spinosad drops are smaller than bait drops and result in greater coverage. More work is needed to determine if baits are needed with spinosad for controlling flies, especially at volumes < 100 ml/tree. The hypothesis is that GF-120 or other baits have more beneficial effects at these volumes, which result in very low coverage of leaves.

The effectiveness of GF-120 and Mazoferm with spinosad suggests that any number of baits will work. However, Nulure with spinosad was not as effective, suggesting not all baits are equally effective and that the flies can detect differences among them in the field, although apparently not in the confined conditions laboratory, and although the taste of Nulure apparently is not repellent.

4) Determine effects of bait sprays and trapping methods on apple maggot control. In 2004 in Puyallup, there was a significant reduction in numbers of larvae in apples when trees were trapped used 6 baited red spheres alone, sprayed with GF-120 alone (540 ml/tree), or when spheres and GF-120 were combined, as compared with the control (Table 13). Presumably, the baited red spheres alone removed enough gravid flies to reduce larval infestations, while GF-120 sprays killed enough flies to reduce infestations. The combination of the two surprisingly did not further reduce infestations, perhaps because flies were more attracted to the red spheres than to the bait spray, and were caught before they fed on the bait. When ammonia-baited spheres were absent, the flies apparently fed on the bait and suffered high mortality, resulting in reduced infestations. Red spheres did not eliminate infestations in one season, but they may increase the effectiveness of sprays by reducing populations, making it easier to eliminate populations the following. Trees were relatively small at 5-13.5 ft tall and 4.5-11.5 ft wide, and the 540 ml sprays resulted in very thorough coverage of the trees.

In 2004 in Woodland, there were significant reductions in larval infestations in apple when 6 red spheres were used, when 6 red spheres were combined with weekly GF-120 sprays (540 ml spray/tree), and when 1 yellow panel was combined with weekly GF-120 sprays, as compared with when single yellow traps alone were used (Table 13). Possibly results may have even been more dramatic had no yellow panels been placed in the control, for some female flies that would have oviposited were removed from the population in these trees. Because the test was conducted in isolated trees, larval infestations in the single yellow trap treatment may have reduced due to lack of many immigrating flies. Trees were relatively large at 12.5-20 ft tall and 12-20 ft wide, so coverage was not as high as in Puyallup. However, as in Puyallup, the results indicate that either baited red sphere traps or GF-120 can reduce larval infestations.

Significance to the Industry and Potential Economic Benefits: The results are significant to the apple industry in that they show GF-120, spinosad alone, and other protein baits (in particular Mazoferm) appear to be highly capable of managing apple maggot flies in feral or backyard apple trees, and likely in hawthorn trees as well, although this has yet to be tested. Use of sprays represent a second line of defense against flies moving into commercial apples orchards, after flies are detected using traps. By suppressing fly populations using spinosad-based bait sprays or even spinosad alone, the risks of flies spreading into previously un-infested commercial apple-growing areas and of these areas being placed under quarantine are greatly reduced. GF-120 and other baits with spinosad are safer alternatives to the main organophosphate currently used (Imidan) to control the flies and thus are more desirable to use near residential areas and near creeks and rivers. Results also show the potential of mass trapping to reduce larval infestations, suggesting baited red spheres may be useful in feral and backyard trees. Results of this study show that GF-120 and other baits can be improved with respect to attractiveness, but that this increased attractiveness does not necessarily result in increased control. It is possible that GF-120 is so effective that it did not need added ammonia at the spray volumes used, and that addition of ammonia in GF-120 for control or the use of baits in general may be more critical at spray volumes much lower than those used in this study. Even though spinosad baits are highly effective, infestations were not eliminated using them, so there should be further benefits of optimizing the bait, e.g., by making it effective at very low amounts or making it attractive over longer periods of time. The best possible bait spray should eliminate fly infestations after one season and virtually ensure that there is no chance flies will invade orchards.

Table 1. Mean total numbers of apple maggot flies ± SE caught over the season per sticky yellow panel trap with different GF-120 bait lures at two sites, WA, 2005

	Vancouver	Saint Cloud Ranch
Treatment	19 July-22 August	28 July-22 September
Control	1.2 ± 0.9c	9.0 ± 2.0b
10 g AC	15.5 ± 2.7a	----
17% GF-120	1.8 ± 1.1c	17.3 ± 1.8b
40% GF-120	1.8 ± 1.0c	66.0 ± 47.9b
40% GF-120 + 10% AC	7.0 ± 2.3b	220.3 ± 39.1a
40% GF-120 + 10% AA	2.8 ± 1.8bc	41.8 ± 4.7b
Randomized Block	$F = 8.4$; df = 5, 15	$F = 13.0$; df = 4, 12
ANOVA	$P = 0.0006$	$P = 0.0003$

Blank GF-120 used; AC, ammonium carbonate; AA, ammonium acetate.
Four replicates of the control and each treatment in both tests.
10 ml of each GF-120 or GF-120 + ammonia compound mixture in 15 ml polypropylene bottles. Means within columns followed by the same letter are not significantly different (Fisher's LSD test, $P > 0.05$).

Table 2. Percent of single apple maggot flies that drank or fed on water or GF-120 baits on apples and that were on apples over 1-h observations in the laboratory

	Females			Males		
Treatment	*N*	% Drank or Fed	% all Flies on Apple[a]	*N*	% Drank or Fed	% all Flies on Apple[a]
Water	22	0.0	9.1	18	0.0	16.7
13% Sucrose	27	33.3	81.4	20	15.0	40.0
17% GF-120	25	20.0	64.0	21	0.0	28.6
20% GF-120	22	27.3	86.4	18	11.1	33.3
40% GF-120	27	7.4	25.9	24	16.7	37.5
40% GF-120 + 10% AC	21	9.5	52.4	20	5.0	35.0
40% GF-120 + 10% AA	12	0.0	25.0	10	10.0	70.0
Fisher's Exact Test[b]	$P = 0.0054^b$ $P < 0.0001^c$			$P = 0.2826^b$ $P = 0.2072^c$		

Blank GF-120 used; AC, ammonium carbonate; AA, ammonium acetate.
[a]Feeders and non-feeders combined; [b]Comparing % that fed and not fed; [c]Comparing total fly numbers on apple and not on apple.

Table 3. Total numbers of apple maggot fly sightings every 2 min feeding on or near GF-120 baits sprayed on apple leaves at Saint Cloud Ranch, WA, 2005-2006

2005[a] Treatment	No. <15 cm From Bait[b]	No. Feeding[c]	Total Fly Sightings	% of Total
13% Sucrose	0	1	1	2.9
17% GF-120	1	1	2	5.7
40% GF-120	1	1	2	5.7
40% GF-120 + 10% AC	6	8	14	40.0
40% GF-120 + 10% AA	12	4	16	45.7
Total fly sightings: Chi square = 30.9; df = 4; $P < 0.0001$.				
2006[d] Treatment	No. <15 cm From Bait[b]	No. Feeding[c]	Total Fly Sightings	% of Total
13% Sucrose	0	4	4	15.4
40% GF-120	0	2	2	7.7
40% GF-120 + 10% AC	1	9	10	38.5
40% GF-120 + 10% AA	2	7	9	34.6
Spinosad Only	1	0	1	3.8
Total fly sightings: Chi square = 12.8; df = 4; $P = 0.0121$.				

Blank GF-120 used in 2005; GF-120 and spinosad only in 2006 had 0.0096% spinosad (wt/vol).
AC, ammonium carbonate; AA, ammonium acetate.
[a]Total sightings from three to six replicate trees from each of eight d.
[b]Not drinking or feeding.
[c]Expected cells <5, data not analyzed.
[d]Total sightings from four or five replicate from each 11 d.

Table 4. Total numbers of apple maggot fly sightings every 2 min feeding on or near GF-120 baits sprayed on apple leaves in Puyallup, WA, 2005-2006

2005[a] Treatment	No. <15 cm From Bait[b]	No. Drinking or Feeding[c]	Total Fly Sightings	% of Total
Water	1	0	1	0.4
13% Sucrose	1	0	1	0.4
17% GF-120	13	0	13	5.5
40% GF-120	38	3	41	17.4
40% GF-120 + 2.5% AC	82	6	88	37.4
40% GF-120 + 2.5% AA	83	6	89	37.9
Spinosad Only	2	0	2	0.8
Total fly sightings: Chi square = 286.7; df = 6; $P < 0.0001$.				
2006[d] Treatment	No. <15 cm From Bait[b]	No. Drinking or Feeding[c]	Total Fly Sightings	% of Total
Water	1	0	1	1.2
13% Sucrose	3	2	5	6.1
40% GF-120	13	1	14	17.1
40% GF-120 + 2.5% AC	30	6	36	43.9
40% GF-120 + 2.5% AA	23	3	26	31.7
Spinosad Only	0	0	0	0.0
Total fly sightings: Chi square = 51.8; df = 4; $P < 0.0001$; spinosad only not included.				

GF-120 and spinosad only in 2005 and 2006 had 0.0096% spinosad (wt/vol); AC, ammonium carbonate; AA, ammonium acetate. [a]Total sightings from four replicate trees from four d.
[b]Not feeding; [c]Expected cells <5, data not analyzed; [d]Total sightings from 10 replicate trees from five d.

Table 5. Mean numbers of adult apple maggot flies and larvae per apple fruit $\pm$ SE in GF-120 bait spray tests in Woodland and Woodland/Vancouver, WA, 2005

Woodland				
Treatment	No. Flies/Trap	% Lower	No. Larvae/Fruit	% Lower
Control	0.2 $\pm$ 0.2	----	0.22 $\pm$ 0.08	----
17% GF-120	0.8 $\pm$ 0.8	----	0.21 $\pm$ 0.12	4.5
40% GF-120	0.5 $\pm$ 0.3	----	0.09 $\pm$ 0.05	59.1
40% GF-120 + 10% AC	0.2 $\pm$ 0.2	----	0.31 $\pm$ 0.22	----
40% GF-120 + 10% AA	0.2 $\pm$ 0.2	----	0.08 $\pm$ 0.05	63.6
Randomized Block	$F = 0.2$		$F = 0.7$	
ANOVA, df = 4, 12	$P = 0.9175$		$P = 0.5916$	
Woodland/Vancouver				
Treatment	No. Flies/Trap	% Lower	No. Larvae/Fruit	% Lower
Control	2.0 $\pm$ 0.7	---	1.71 $\pm$ 0.89	---
17% GF-120	4.0 $\pm$ 2.2	---	0.42 $\pm$ 0.25	75.4
40% GF-120	3.3 $\pm$ 2.6	---	0.30 $\pm$ 0.07	82.5
40% GF-120 + 10% AC	3.8 $\pm$ 2.4	---	0.30 $\pm$ 0.05	82.5
40% GF-120 + 10% AA	2.8 $\pm$ 1.6	---	0.84 $\pm$ 0.46	50.8
Randomized Block	$F = 0.1$		$F = 1.4$	
ANOVA, df = 4, 12	$P = 0.9705$		$P = 0.3092$	

GF-120 and spinosad only had 0.0096% spinosad (wt/vol).
AC, ammonium carbonate; AA, ammonium acetate; 100 ml spray/tree.
Four replicates of the control and treatments.
Means within columns followed by the same letter are not significantly different (Fisher's LSD test, $P > 0.05$).

Table 6. Mean numbers of adult apple maggot flies and larvae per apple fruit $\pm$ SE in GF-120 bait spray test in Vancouver, WA, 2006

Treatment	No. Flies/Trap	% Lower	No. Larvae/Fruit	% Lower
Control	0.0 $\pm$ 0.0b	----	0.030 $\pm$ 0.009a	---
40% GF-120	0.17 $\pm$ 0.17b	----	0.000 $\pm$ 0.000b	100.0
40% GF-120 + 10% AC	1.00 $\pm$ 0.36a	----	0.000 $\pm$ 0.000b	100.0
40% GF-120 + 10% AA	0.17 $\pm$ 0.17b	----	0.007 $\pm$ 0.004b	76.7
Spinosad Only	0.0 $\pm$ 0.0b	----	0.013 $\pm$ 0.013b	56.7
Randomized Block	$F = 4.2$		$F = 2.9$	
ANOVA, df = 4, 20	$P = 0.0129$		$P= 0.0480$	

GF-120 and spinosad only had 0.0096% spinosad (wt/vol).
AC, ammonium carbonate; AA, ammonium acetate; 200 ml spray/tree.
Six replicates of the control and treatments.
Means within columns followed by the same letter are not significantly different (Fisher's LSD test, $P > 0.05$).

Table 7. Mean numbers of adult apple maggot flies and larvae per apple fruit ± SE in GF-120 bait spray tests in Puyallup, WA, 2005-2006

2005				
Treatment	No. Flies/Trap	% Lower	No. Larvae/Fruit	% Lower
Control	35.2 ± 1.9a	---	1.22 ± 0.59a	---
40% GF-120	11.6 ± 3.1b	67.0	0.07 ± 0.02b	94.3
40% GF-120 + 2.5% AC	28.2 ± 2.2b	19.9	0.08 ± 0.04b	93.1
40% GF-120 + 2.5% AA	17.8 ± 2.6b	49.4	0.16 ± 0.03b	86.7
Spinosad Only	14.0 ± 2.8b	60.2	0.05 ± 0.004b	96.0
One-Way ANOVA	$F = 12.5$		$F = 4.4$	
df = 4, 20	$P < 0.0001$		$P = 0.0098$	
2006				
Treatment	No. Flies/Trap	% Lower	No. Larvae/Fruit	% Lower
Control	119.4 ± 10.1a	---	0.99 ± 0.23a	---
40% GF-120	15.0 ± 1.4c	87.4	0.08 ± 0.02b	91.9
40% GF-120 + 2.5% AC	24.4 ± 1.6b	92.0	0.05 ± 0.02b	86.9
40% GF-120 + 2.5% AA	9.6 ± 1.5c	79.6	0.13 ± 0.05b	94.9
Spinosad Only	1.8 ± 0.8d	98.5	0.01 ± 0.01b	99.0
One-Way ANOVA	$F = 158.7$		$F = 19.4$	
df = 4, 20	$P < 0.0001$		$P < 0.0001$	

GF-120 and spinosad only had 0.0096% spinosad (wt/vol).
AC, ammonium carbonate; AA, ammonium acetate; 100 ml spray/tree.
Five replicates of the control and treatments.
Means within columns followed by the same letter are not significantly different (Fisher's LSD test, $P > 0.05$).

Table 8. Percentages of apple maggot flies responding to protein baits inside vials in the laboratory

	Females		Males	
Treatment	*N*	% Response	*N*	% Response
Control	36	8.3	30	3.3
GF-120	38	34.2	34	17.6
Nulure	30	46.7	30	23.3
Mazoferm	36	33.3	38	21.1
Spinosad Only	37	5.4	35	14.3
Fisher's Exact Test		$P = 0.000039$		$P = 0.1785$

All baits and spinosad only had 0.0096% spinosad (wt/vol).
When Fisher's exact test was conducted within treatments and between sexes to determine if responses to a bait were dependent on sex, there were no significant differences ($P = 0.1033$ to 0.6198).

Table 9. Numbers of feeds and feeding duration ± SE of apple maggot flies on protein baits inside vials in the laboratory

	No. Drinks/Feeds		Durations (seconds)	
Treatment	Females	Males	Females	Males
Water	0.08 ± 0.05	0.03 ± 0.03	0.58 ± 0.45	0.13 ± 0.13
GF-120	0.45 ± 0.11	0.21 ± 0.08	8.13 ± 2.84	4.35 ± 2.08
Nulure	0.70 ± 0.16	0.27 ± 0.10	10.30 ± 3.33	3.27 ± 2.26
Mazoferm	0.61 ± 0.17	0.21 ± 0.07	5.89 ± 2.02	1.13 ± 0.53
Spinosad Only	0.05 ± 0.04	0.14 ± 0.06	0.05 ± 0.04	0.20 ± 0.10
Two-way ANOVA	No. Drinks/Feeds		Durations (seconds)	
Treatment	$F = 7.5$, df = 4, 334, $P < 0.0001$		$F = 6.1$, df = 4, 334, $P < 0.0001$[b]	
Sex	$F = 11.4$, df = 1, 334, $P = 0.0008$		$F = 8.0$, df = 1, 334, $P = 0.0051$	
Treatment × Sex	$F = 2.8$, df = 1, 334, $P = 0.0276$[a]		$F = 1.4$, df = 1, 334, $P = 0.2410$	

All baits and spinosad only had 0.0096% spinosad (wt/vol); N, same as in Table 1; [a]Because of the interaction, one-way ANOVA was performed within sexes; for females, $F = 6.9$; df = 4, 172, $P < 0.0001$; water = spinosad <GF-120 = Nulure = Mazoferm (Fisher's LSD test); for males, not significant ($P = 0.2508$).
[b]Water = spinosad >GF-120 = Nulure, Mazoferm not different than any treatment (Fisher's LSD test).

Table 10. Total numbers of apple maggot flies seen feeding on or near (and not feeding on) protein baits sprayed on apple leaves in Puyallup, WA, 2006

Treatment	No. Feeding	No. Not Feeding[a]	Total Sightings of Flies	% of Total Sightings
Water	0	0	0	0.0
13% Sucrose	2	2	4	6.0
GF-120	7	4	11	16.4
Nulure	10	0	10	14.9
Mazoferm	34	5	39	58.2
Spinosad Only	1	2	3	4.5
Total Sightings: Chi-Square Goodness of Fit Test = 64.9; df = 4; $P < 0.0001$				

All baits and spinosad only had 0.0096% spinosad (wt/vol).
Totals from 10 trees (two trees per day over five days of observations)
[a]≤15 cm from water or baits.

Table 11. Mean numbers of adult apple maggot flies and larvae per apple fruit ± SE in bait spray test in Puyallup, WA, 2005

Treatment	No. Adults/trap	% Reduction	No. Larvae/fruit	% Reduction
Control	43.8 ± 7.7a	---	0.846 ± 0.025a	---
GF-120	12.3 ± 2.8b	71.9	0.095 ± 0.032b	88.8
Nulure	13.5 ± 3.1b	69.2	0.746 ± 0.160a	11.8
Mazoferm	18.0 ± 7.6b	58.9	0.104 ± 0.21b	87.8
Spinosad Only	14.8 ± 5.5b	66.2	0.108 ± 0.026b	87.2
1-way ANOVA	$F = 4.2$		$F = 31.3$	
df = 4, 15	$P = 0.0184$		$P < 0.0001$	

All baits and spinosad only had 0.0096% spinosad (wt/vol).
Four replicates of the control and treatments.
Means within columns followed by the same letter are not significantly different ($P > 0.05$).

Table 12. Mean numbers of adult apple maggot flies and larvae per apple fruit ± SE in bait spray test in Puyallup, WA, 2006

Treatment	No. Adults/trap	% Reduction	No. Larvae/fruit	% Reduction
Control	145.4 ± 18.8a	---	0.92 ± 0.21a	---
GF-120	7.2 ± 2.2bc	95.0	0.19 ± 0.04bc	79.3
Nulure	4.2 ± 0.4cd	97.1	0.38 ± 0.08b	58.7
Mazoferm	14.4 ± 1.8b	90.1	0.18 ± 0.03bc	80.4
Spinosad Only	0.6 ± 0.2d	99.6	0.03 ± 0.01c	96.7
1-way ANOVA	$F = 117.8$		$F = 13.0$	
df = 4, 20	$P < 0.0001$		$P < 0.0001$	

All baits and spinosad only had 0.0096% spinosad (wt/vol).
Five replicates of the control and treatments.
Means within columns followed by the same letter are not significantly different ($P > 0.05$).

Table 13. Effects of GF-120 sprays and red sphere traps on larval infestations, 2004

Test 1: Puyallup			Test 2: Woodland		
Treatment	Adults	Lv/Apple	Treatment	Adults	Lv/Apple
Control	---	0.580b	Control, Panel	41.7	1.795b
GF-120	---	0.011a	GF-120, Panel	12.2	0.027a
6 Red Spheres	220.4	0.059a	6 Red Spheres	113.5	0.167a
GF-120 + 6 Red Spheres	180.2	0.096a	GF-120 + 6 Red Spheres	44.5	0.023a
RBD ANOVA *F*	23.1	---	RBD ANOVA *F*	2.8	6.4
df	3, 12	---	df	3, 8	3, 8
P	< 0.0001	---	*P*	0.1071	0.0163

Means followed by the same letter within columns with the same letter are not significantly different (Fisher's LSD test, $P > 0.05$).