CONTROL OF WALNUT HUSK FLY USING REDUCED-RISK PRODUCTS

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ABSTRACT

A laboratory trial was conducted to evaluate the effects of walnut husk fly (WHF) density and GF-120 toxicant volume on WHF mortality. There was a significant difference in WHF mortality between the lowest and highest density rates with decreasing mortality as density increased. Field trial evaluations of WHF control strategies were conducted in four walnut growing regions in northern California. High, medium and low population management strategies were investigated using product substitution of organophosphate (OP) insecticides with reduced risk insecticides and combination programs with only reduced risk insecticides. All OP and reduced risk insecticides provided significantly lower WHF infestation than the untreated control except in one trial. Economic evaluations were conducted between the type of application techniques and pesticide. Under moderate to high population, OP insecticides (Lorsban or Malathion) applied with an air-blast sprayer was found to be more cost effective than the reduced risk insecticides (Entrust, Success or GF-120) applied with an air-blast sprayer or an ATV sprayer. However, under low population pressure the application of GF-120 applied with an ATV sprayer was comparable to OP pesticides applied with an air-blast sprayer. In addition, GF-120 applied with an ATV sprayer can be advantageous for growers who want to treat an orchard quickly or shortly after irrigation. Also Entrust and GF-120 are approved for organic walnut production and provided effective control. A trap height comparison study resulted in variable fly captures between high and low traps and was orchard dependent.

OBJECTIVES

The walnut husk fly (WHF), *Rhagoletis completa*, is a serious pest of walnuts. It is speculated that as the use of organophosphate (OP) insecticides is restricted by EPA action, WHF will become a more serious pest. Without OP insecticides for WHF control, growers will rely on pyrethroid insecticides, e.g. Asana, Pounce. However, past research has demonstrated that the pyrethroid insecticides are less effective than the OP insecticides for WHF control. In addition, the pyrethroid insecticides can cause flare-ups of secondary pests, such as spider mites and scales. Spinosad under the trade name Entrust for organic growers or Success for conventional growers and GF-120 fruit fly bait for both conventional and organic growers has recently received registration from EPA and DPR for walnuts. GF-120 provides effective control of a number of tropical fruit flies. Past research has demonstrated that effective control of WHF can be achieved with repeated applications of GF-120. However, there are some indications that GF-120 should be applied earlier in the season than OP insecticides and that control of high populations of WHF with GF-120 may be challenging. GF-120 was used by a number of growers in the past with mixed results. Many growers have been very pleased while others have been extremely disappointed with the efficacy of GF-120. In addition to GF-120, Entrust or Success combined with NuLure bait may be an effective substitution for an OP insecticide and

Table 1. Mean number of WHF per season and infestation at Upper Lake, CA – 2004

Treatment	Rate (/ac)	# of Applications	Mean Total Flies/Trap[a]	Mean % Infested Fruit[a]
Success	0.64 oz	4	147.7 a	0.6 a
Lorsban	0.40 pt	2	133.7 a	0.8 a
+Malathion	0.24 pt	2		
Control	—		120.0 a	5.9 b

[a]Means followed by the same letter within a column are not significantly different (Fisher's protected LSD, P = 0.05).

Table 2. Mean number of WHF per season in high versus low traps – 2004

	Mean Total Flies/Trap[a]	
Orchard	High Trap	Low Trap
Hollister 1**	63.9 a	109.0 b
Hollister 2**	152.0 a	140.0 a
Escalon**	41.0 a	43.3 a
Farmington*	101.3 a	11.3 b
Upper Lake**	108.3 a	36.7 a
Kelseyville**	697.0 a	412.3 a
Marysville**	47.0 a	5.7 a

[a]Means followed by the same letter within a row are not significantly different (Student's T-test, *P = 0.05, **P = 0.10).

Table 3. Cost range for pesticides used in WHF trials – 2004

	Pesticide Cost Range	
Pesticide	Cost/gal	Cost/ac
GF-120	$ 72.00 – 106.00	$ 11.72 – 16.54
Success	$ 643.00 – 800.00	$ 16.00 – 20.00
Entrust	$ 335.00 – 377.00	$ 20.94 – 23.53
Lorsban	$ 29.00 – 48.00	$ 7.25 – 11.92
Malathion	$ 36.00 – 50.00	$ 26.63
NuLure	$ 18.00 – 27.00	$ 4.70 – 6.74
MoBait	$ 24.00	$ 15.00

Table 4. Application cost of air-blast sprayer for WHF control – 2004

Orchard	Cost/hr	mph	# of ac/hr	Cost/ac[b]
Hollister 1	$ 100.00	4.2	14.93	$ 7.79
Hollister 2	$ 100.00	4.2	16.29	$ 7.42
Escalon	$ 77.00	2.5	8.08	$ 8.91
Farmington	$ 77.00	2.5	14.54	$ 6.09
Upper Lake	$ 60.00	—	5.00	$ 12.00[a]
Kelseyville	$ 50.00	4.0	9.70	$ 5.05[c]
Marysville	$ 76.00	3.0	13.33	$ 6.02-10.77[d]

[a]Upper Lake used a spot spray applicator
[b]Cost includes 20 min/10 ac refill
[c]Cost includes 20 min/5 ac refill
[d]Cost includes 10 min/10 ac refill

Table 5. Total cost per acre for the season in Upper Lake, CA – 2004

Treatment	Rate (/ac)	# of Applications	Total Cost/ac/Season
Success	0.64 oz	4	$ 66.48
Lorsban[a]	0.40 pt	2	$ 60.22
+Malathion	0.24 pt	2	

[a]Cost/ac includes NuLure (0.2 pt/ac)

Table 6. Mean number of WHF per season and infestation at Marysville, CA – 2004

Treatment	Rate (/ac)	# of Applications	Mean Total Flies/Trap[a]*	Mean % Infested Fruit[a]**
GF-120	20.0 oz	6	36.0 a	1.9 a
GF-120	20.0 oz	3	26.7 a	1.8 a
Control	—		47.0 a	5.6 b

[a]Means followed by the same letter within a column are not significantly different (Fisher's protected LSD, *P = 0.05, **P = 0.10).

Table 7. Application cost for ATV sprayer going 10 mph for WHF control – 2004

Orchard	Cost/hr	# of ac/hr[a]	Cost/ac[c]
Hollister 1	$ 17.18	43.64	$ 0.39
Hollister 2	$ 17.18	40.00	$ 0.43
Escalon	$ 44.00	40.40	$ 1.09
Farmington	$ 44.00	58.18	$ 0.76
Kelseyville	$ 30.00	30.30[b]	$ 0.99
Marysville	$ 20.00	24.44[b]	$ 0.82

[a]GF-120 applied as a skip row treatment
[b]GF-120 applied as an every row treatment
[c]Cost includes 5 min/25 ac refill

Table 8. Total costs per acre for the season in Marysville, CA – 2004

Treatment	Rate (/ac)	# of Applications	Total Cost/ac/Season
GF-120[a]	20.0 oz	3	$ 58.14
GF-120[a]	20.0 oz	6	$ 102.93

[a]Cost includes initial Success application (3.2 oz/ac with 2.0 pt NuLure/ac as bait)

Table 9. Mean number of WHF per season and infestation at Hollister 1, CA – 2004

Treatment	Rate (/ac)	# of Applications	Mean Total Flies/Trap[a]	Mean % Infested Fruit[a]
GF-120	20.0 oz	9	14.3 a	0.2 a
GF-120	20.0 oz	5	13.0 ab	0.4 a
Entrust[b]	1.0 oz	2	29.0 ab	0.3 a
Control	—		69.3 b	5.6 b

[a]Means followed by the same letter within a column are not significantly different (Fisher's protected LSD, P = 0.05).
[b]Treatment includes NuLure (2.0 pt/ac)

Table 10. Total costs per acre for the season in Hollister 1, CA – 2004

Treatment	Rate (/ac)	# of Applications	Total Cost/ac/Season
GF-120	20.0 oz	5	$ 84.67
GF-120	20.0 oz	9	$ 152.40
Entrust[a]	1.0 oz	2	71.86

[a]Cost/ac includes NuLure (2.0 pt/ac)

Table 11. Mean number of WHF per season and infestation at Kelseyville, CA – 2004

Treatment	Rate (/ac)	# of Applications	Mean Total Flies/Trap[a]*	Mean % Infested Fruit[a]**
GF-120 (1:4)	20.0 oz	6	483.3 a	6.9 a
GF-120 (1:1.5)	20.0 oz	6	716.0 b	5.3 a
Control	—		727.0 b	9.5 a

[a]Means followed by the same letter within a column are not significantly different (Fisher's protected LSD, *P = 0.10, **P = 0.05).

Table 12. Total costs per acre for the season in Kelseyville, CA – 2004

Treatment	Rate (/ac)	# of Applications	Total Cost/ac/Season
GF-120[a]	20.0 oz	6	$119.48

[a]Cost includes additional application of Entrust (1.0 oz/ac with 2.0 pt NuLure as bait)

Table 13. Mean number of WHF per season and infestation at Escalon, CA – 2004

Treatment	Rate (/ac)	# of Applications	Mean Total Flies/Trap[a]	Mean % Infested Fruit[a]
GF-120	20.0 oz	5	21.0 ab	0.03 a
GF-120	20.0 oz	3	16.7 ab	0.13 a
Entrust[b]	1.0 oz	2	13.0 a	0.10 a
Control	—		41.0 b	0.10 a

[a]Means followed by the same letter within a column are not significantly different (Fisher's protected LSD, P = 0.05).
[b]Treatment includes NuLure (2.0 pt/ac)

Table 14. Application costs per acre for the season in Escalon, CA – 2004

Treatment	Rate (/ac)	# of Applications	Total Cost/ac/Season
GF-120	20.0 oz	3	$ 38.43
GF-120	20.0 oz	5	$ 64.05
Entrust[a]	1.0 oz	2	$ 69.10

[a]Cost/ac includes NuLure (2.0 pt/ac)

Table 15. Mean number of WHF per season and infestation at Farmington, CA – 2004

Treatment	Rate (/ac)	# of Applications	Mean Total Flies/Trap[a]	Mean % Infested Fruit[a]
GF-120	20.0 oz	12	136.7 a	0.1 a
Success[b]	3.2 oz	4	101.0 a	0.3 ab
Lorsban[b]	2.0 pt	4	163.0 a	0.0 a
Control	—		101.3 a	0.5 b

[a]Means followed by the same letter within a column are not significantly different (Fisher's protected LSD, P = 0.05).
[b]Treatment includes NuLure (2.0 pt/ac)

Table 16. Application costs per acre for the season in Farmington, CA – 2004

Treatment	Rate (/ac)	# of Applications	Total Cost/ac/Season
GF-120	20.0 oz	12	$ 149.72
Success[a]	3.2 oz	4	$ 107.16
Lorsban[a]	2.0 pt	4	$ 90.84

[a]Cost/ac includes NuLure (2 pt/ac)

Table 17. Mean number of WHF per season and infestation at Hollister 2, CA – 2004

Treatment	Rate (/ac)	# of Applications	Mean Total Flies/Trap[a]	Mean % Infested Fruit[a]
GF-120	20.0 oz	3	57.0 a	2.4 a
GF-120	20.0 oz	6	7.0 a	0.6 a
Control	—		152.0 b	7.5 b

[a]Means followed by the same letter within a column are not significantly different (Fisher's protected LSD, P = 0.05).

Table 18. Application costs per acre for the season in Hollister 2, CA – 2004

Treatment	Rate (/ac)	# of Applications	Total Cost/ac/Season
GF-120	20.0 oz	3	$ 50.91
GF-120	20.0 oz	6	$ 101.82

Fig. 1. Mean percent corrected mortality of WHF density and GF-120 toxicant volume.

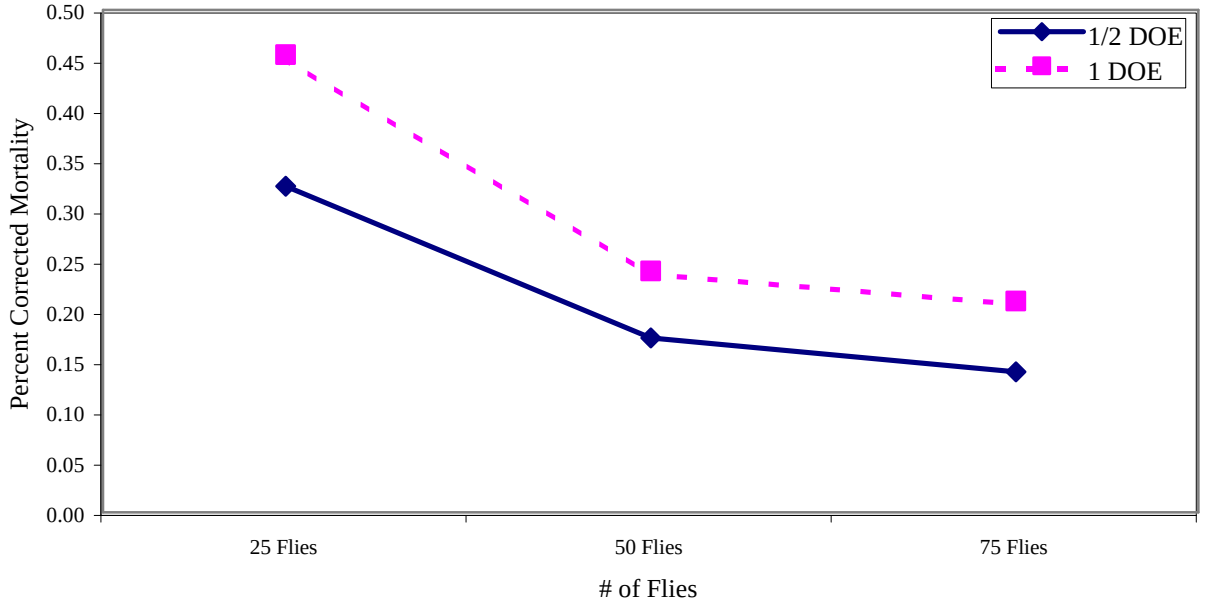


Fig. 2. Mean number of flies/trap/day in Upper Lake, CA-2004. 🡻 indicates application with air-blast sprayer, while ☆ indicates control being sprayed out.

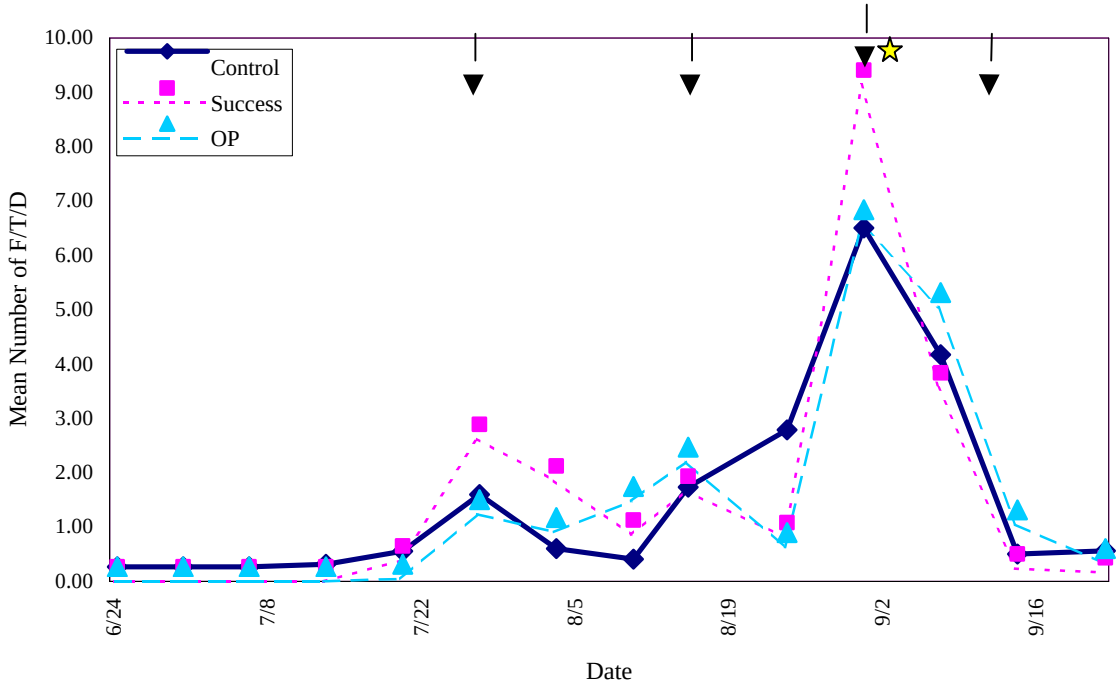


Fig. 3. Mean number of flies/trap/day in Marysville, CA – 2004. ⬇ indicates application with air-blast sprayer, while ☆ indicates control being sprayed out.

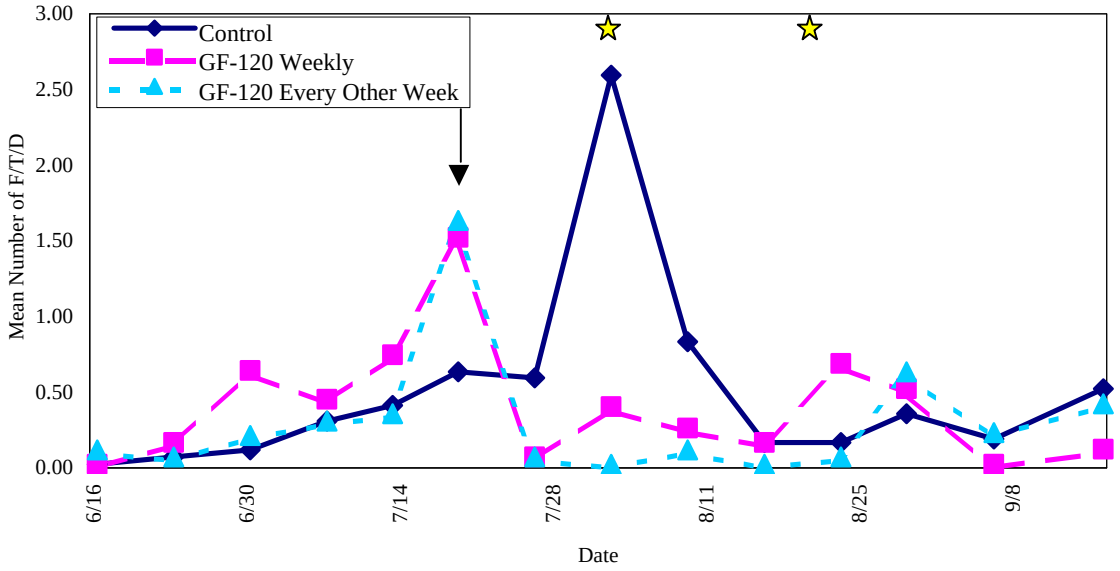


Fig. 4. Mean number of flies/trap/day in Hollister 1, CA – 2004. ⬇ indicates application with air-blast sprayer, while ☆ indicates control being sprayed out.

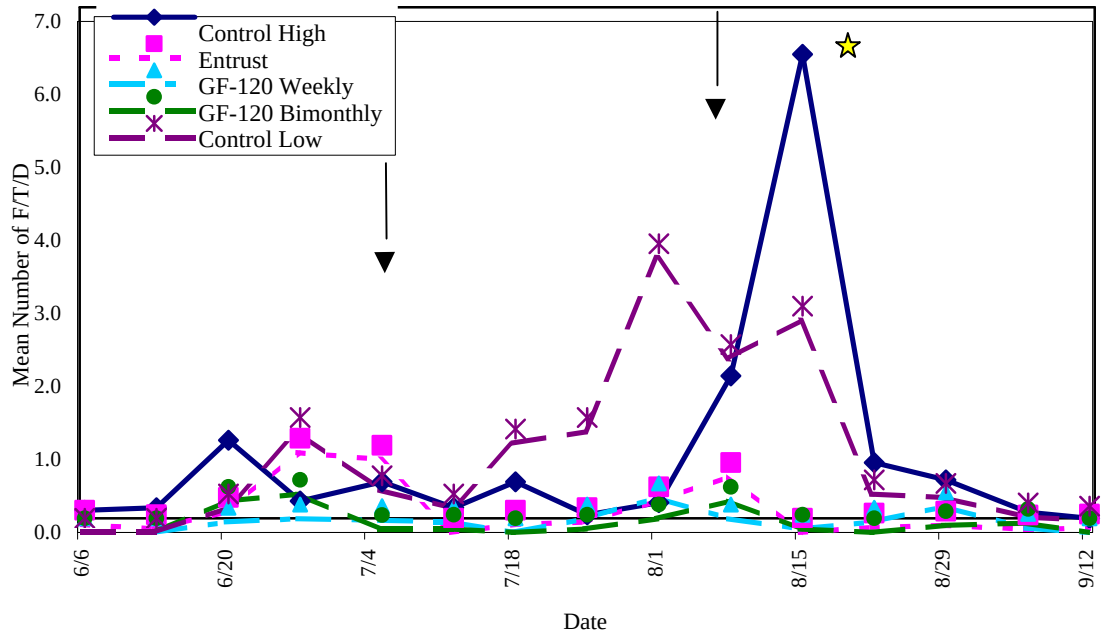


Fig. 5. Mean number of flies/trap/day in Kelseyville, CA – 2004. ⬇ indicates application with air-blast sprayer, while ☆ indicates control being sprayed out.

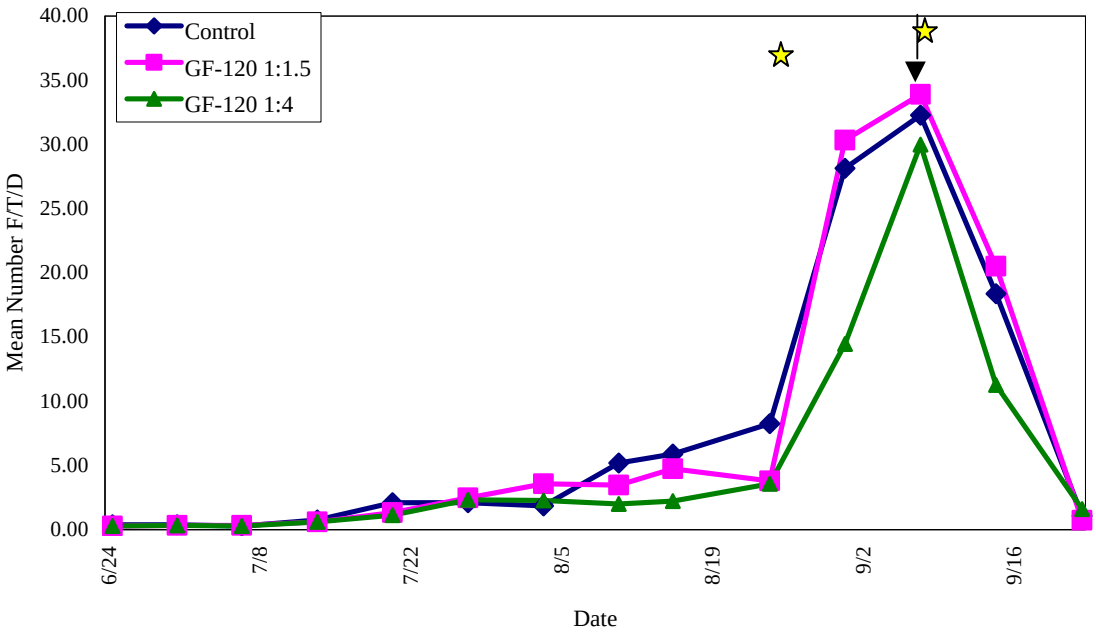


Fig. 6. Mean number of flies/trap/day in Escalon, CA-2004. ⬇ indicates application with air-blast sprayer, while ☆ indicates control being sprayed out.

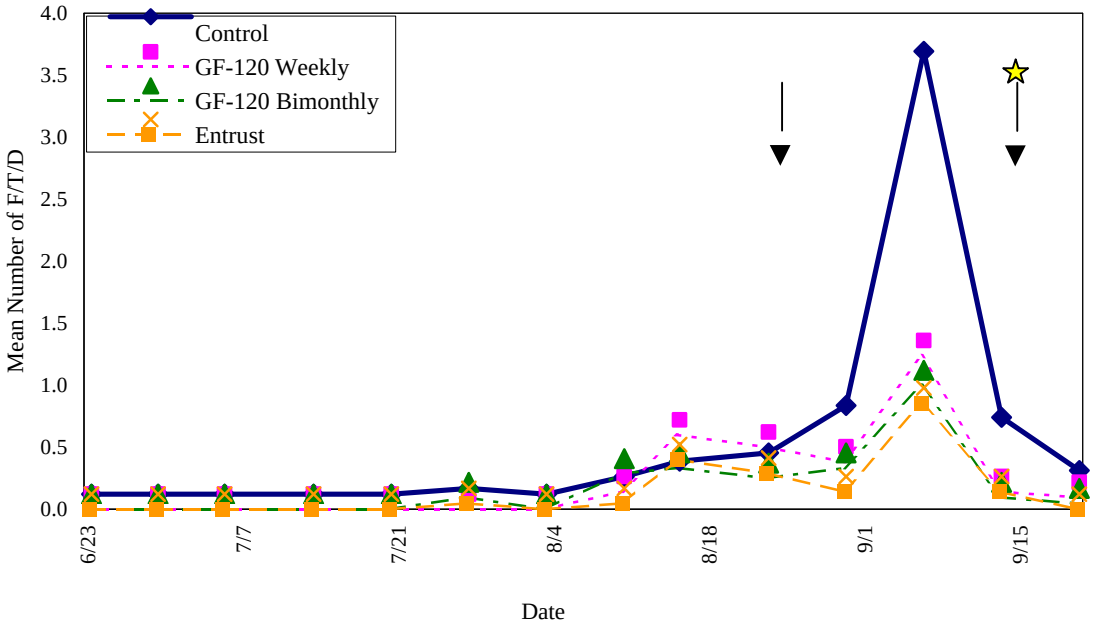


Fig. 7. Mean number of flies/trap/day in Farmington, CA-2004. ⬇ indicates application with air-blast sprayer, while ☆ indicates control being sprayed out.

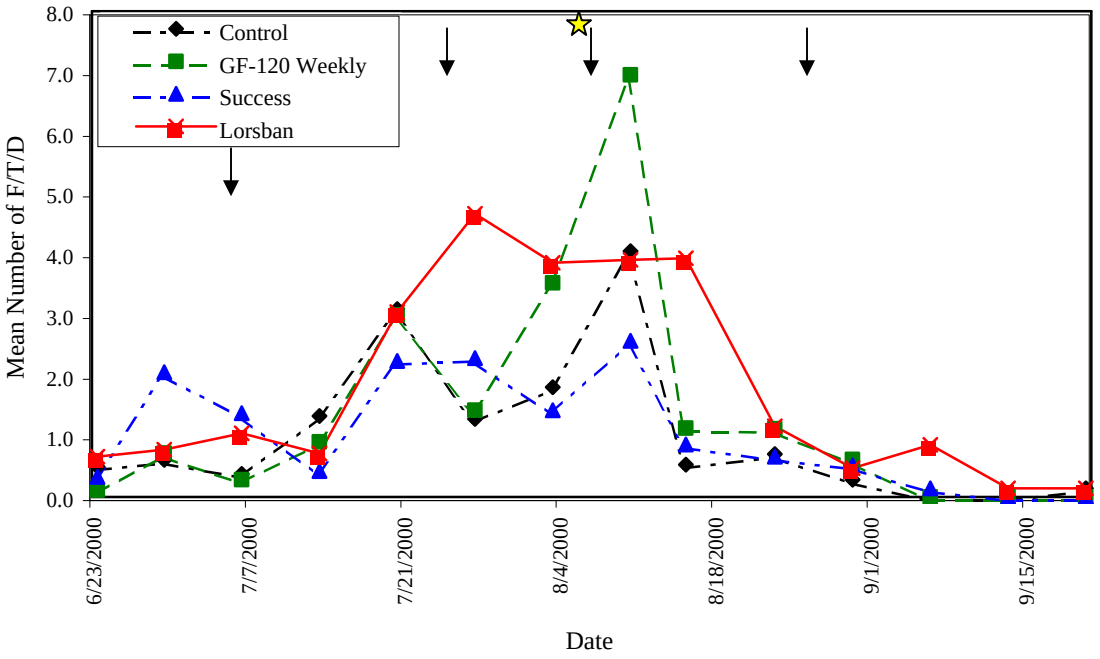
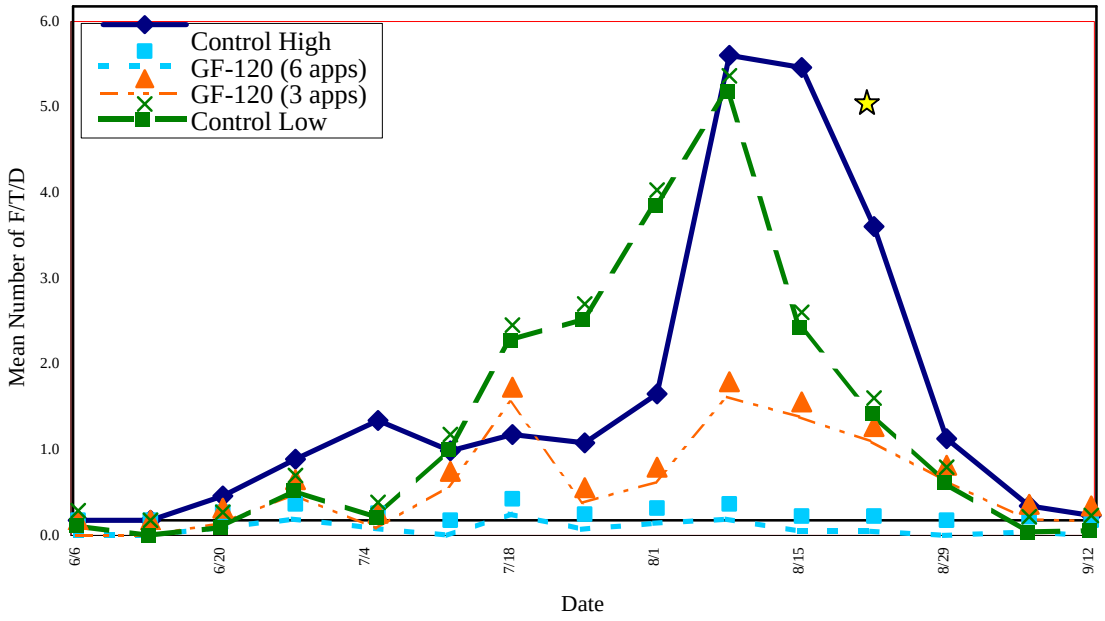


Fig. 8. Mean number of flies/trap/day in Hollister 2, CA-2004. ☆ indicates control being sprayed out.



NuLure. Entrust is a 80 WP (wettable powder) formulation of spinosad and organically approved while Success is a 2 SC (soluble concentrate) formulation of spinosad and is not organically approved. It is important to determine how to make these products work since they are important non-OP alternatives for the future. Currently, OP insecticides such as Malathion, Lorsban or Imidan plus NuLure bait provide effective control of WHF at a reasonable cost. However, as the continued registration of these products is uncertain in the long-term, GF-120 will likely provide very cost effective WHF control without resulting in the secondary pest flare-ups of pyrethroid insecticides. The studies conducted this year were seeking to improve the efficacy and reliability of Entrust or Success plus NuLure and GF-120 for WHF control.

PROCEDURES

Laboratory Efficacy

Effects of WHF Density/GF-120 Toxicant Volume on WHF Mortality

A trial was conducted to evaluate the effects of adult WHF density and GF-120 toxicant volume on WHF mortality. Three WHF densities were replicated four times. Each fly density was exposed to one walnut leaf treated with one 20 µL droplet of GF-120 (1:4 dilution). There was a blank bait control evaluated simultaneously with each treatment density. After the GF-120 was applied on the leaves, the droplets were allowed to dry (1 hr) and the leaves were placed into a 4 L cage with 25, 50 and 75 adult WHF. The flies were reared from field collected larvae. The WHF were pre-fed a 3:1 sugar/yeast diet. Mortality was determined at 1/2 and 1 day of exposure (DOE).

Field Efficacy

A. High Population Management Strategy – Spot Sprayer Application Methodology with Product Substitution

The first trial was conducted in a commercial 'Hartley' orchard in Upper Lake. Three treatments were replicated three times in a randomized complete block (RCB) design. Each replicate was 2 to 5 acres in size. The treatments were: reduced-risk insecticide (0.64 oz/ac Success with 0.4 pt/ac NuLure), OP insecticide (two applications of 0.4 pt/ac Lorsban and two applications of 0.24 pt/ac Malathion applied with 0.4 pt/ac NuLure), and a blank bait control (0.4 pt/ac NuLure). Treatments were spot sprayed and applied with a handgun sprayer delivering 10 gal/ac of final spray solution. The Success and Lorsban treatments were applied on an as needed basis. Treatments were initiated on 30 July and terminated on 13 September with a total of four applications during the season. The blank bait control was sprayed at the same time as the insecticides. On 3 September the blank bait control was sprayed with Malathion (0.24 pt/ac Malathion with 0.4 pt/ac NuLure). The Malathion and NuLure was applied to the blank bait control in order to maintain infestation levels within acceptable levels, i.e. around 5% infested nuts. The efficacy of the treatments was evaluated by placing one super charged yellow AM trap high in the tree canopy in the center of each plot. In addition to the high trap, the control

treatment was also monitored with a low super charged yellow AM trap. The traps were monitored weekly from mid-June through to husk split. At husk split on 22 September, 1000 nuts per plot (3000 nuts per treatment) were inspected for WHF infestation, and 100 infested and uninfested nuts were collected for quality evaluation by Diamond Walnut, Stockton, CA. Application and material costs were obtained from the grower to evaluate economic costs.

B. Moderate Population Management Strategy A – Combination Program with only Reduced-Risk Products

A trial was conducted in a commercial 'Hartley' orchard in Marysville. Three treatments were replicated three times in a RCB design. Each replicate was about 3 acres in size. There were two GF-120 treatments, which were treated with Success (3.2 oz/ac with 2 pt/ac NuLure) at sustained fly capture on 20 July to suppress the early WHF population, while the blank control was treated with NuLure (2 pt/ac) at the same time. After this initial application, the three treatments were: GF-120 (20 oz/ac diluted to 1:4) applied weekly, GF-120 (20 oz/ac diluted to 1:4) applied every other week and a blank bait control (20 oz/ac blank GF-120 diluted to 1:4). GF-120 and blank GF-120 treatments were applied using a modified weed sprayer mounted on an ATV and were every row. The Success/NuLure treatment was applied with an air-blast sprayer with a final spray volume of 50 gal/ac applied to every other row. The GF-120 and blank GF-120 treatments were initiated on 4 August and continued to 8 September. One control block was sprayed out on 4 August (2 pt Malathion with 1 pt MoBait/ac) while one of the other two control blocks were sprayed out on 25 August (6 pt Malathion with 5 pt MoBait/ac) with an air-blast sprayer with a final spray volume of 100 gal/ac. The efficacy of the treatments was evaluated by placing one super charged yellow AM trap high in the tree canopy in the center of each plot. In addition to the high trap, the control treatment also was monitored with a low super charged yellow AM trap. The traps were monitored weekly from mid-June through to husk split. At husk split on 16 September, 1000 nuts per plot (3000 nuts per treatment) were inspected for WHF infestation, and 100 infested and uninfested nuts were collected for quality evaluation by Diamond Walnut, Stockton, CA. Application and material costs were obtained from the grower to evaluate economic costs.

C. Moderate Population Management Strategy B – Application Methodology with only Reduced-Risk Products

A trial was conducted in a commercial 'Payne' orchard (Hollister 1) in Hollister. Four treatments were replicated three times in a RCB design. Each replicate was 2 to 5 acres in size. All treatments were applied to every other row (skip row). The four treatments were: GF-120 (20 oz/ac diluted to 1:4) applied weekly, GF-120 (20 oz/ac diluted to 1:4) applied every other week, Entrust (1 oz/ac with 2 pt NuLure per ac as bait) and a blank bait control (20 oz/ac blank GF-120 diluted to 1:4). The GF-120 and blank GF-120 treatments were applied using a modified weed sprayer mounted on an ATV while the Entrust was applied with an air-blast sprayer with a final spray volume of 40 gal/ac. The

GF-120 treatment was initiated on 1 July and terminated on 7 September. The Entrust treatment was initiated on 6 July and received a second application on 9 August. The blank bait control treatment was initiated on 1 July and was sprayed out on 25 August with Entrust (1 oz/ac with 2 pt NuLure /ac as bait). The efficacy of the treatments was evaluated by placing one super charged yellow AM trap high in the tree canopy in the center of each plot. In addition to the high trap, the control treatment was also monitored with a low super charged yellow AM trap. The traps were monitored weekly from early June through to husk split. At husk split on 13 September, 1000 nuts per plot (3000 nuts per treatment) were inspected for WHF infestation, and 100 infested and uninfested nuts were collected for quality evaluation by Diamond Walnut, Stockton, CA. Application and material costs were obtained from the grower to evaluate economic costs.

Another trial was conducted in a commercial 'Hartley' orchard in Kelseyville. Three treatments were replicated three times in a RCB design. Each replicate was over 2.5 acres in size. The three treatments were: GF-120 (20 oz/ac diluted to 1:4) applied weekly, GF-120 (20 oz/ac diluted to 1:1.5) applied weekly and a blank bait control (20 oz/ac blank GF-120 diluted to 1:4). The GF-120 and blank GF-120 treatments were applied using a modified spot sprayer mounted on an ATV. The GF-120 treatment was initiated on 28 July and terminated on 16 September. The blank bait control treatment began on 28 July. On 26 August, two control blocks were spot sprayed with Entrust (2 oz/ac and a 1:4 dilution of blank GF-120 as bait). All treatments were sprayed with Entrust (1 oz/ac and 2 pt NuLure/ac as bait) on 10 September using an air-blast sprayer with a final spray volume of 100 gal/ac applied to every other row, due to the high number of flies. The efficacy of the treatments was evaluated by placing one super charged yellow AM trap high in the tree canopy in the center of each plot. In addition to the high trap, the control treatment was also monitored a low super charged yellow AM trap. The traps were monitored weekly from mid-June through to husk split. At husk split on 22 September, 1000 nuts per plot (3000 nuts per treatment) were inspected for WHF infestation, and 100 infested and uninfested nuts were collected for quality evaluation by Diamond Walnut, Stockton, CA. Application and material costs were obtained from the grower to evaluate economic costs.

A trial was also conducted in a commercial 'Chandler' orchard in Escalon. Four treatments were replicated three times in a RCB design. Each replicate was about 3 acres in size. The four treatments were: GF-120 (20 oz/ac diluted to 1:4) applied as a skip row weekly, GF-120 (20 oz/ac diluted to 1:4) applied every row every other week, Entrust (1 oz/ac and 2 pt NuLure/ac as bait) applied on an as needed basis, and a blank bait control (20 oz/ac blank GF-120 diluted to 1:4). The GF-120 and blank GF-120 treatments were applied using a modified weed sprayer mounted on an ATV. The Entrust treatment was applied to every other row (skip row) using an air-blast sprayer with a final spray volume of 45 gal/ac. The GF-120 treatment was initiated on 18 August and terminated on 15 September. The Entrust was applied on 25 August and 15 September. The blank bait control treatment was initiated on 18 August and the control was then sprayed out with Entrust (1 oz/ac and 2 pt NuLure/ac as bait) on 15 September. The efficacy of the treatments was evaluated by placing one super charged yellow AM trap high in the

canopy of a tree in the center of each plot. In addition to the high trap, the control treatment also included a low super charged yellow AM trap. The traps were monitored weekly from mid-June through to husk split. At husk split on 19 September, 1000 nuts per plot (3000 nuts per treatment) were inspected for WHF infestation, and 100 infested and uninfested nuts were collected for quality evaluation by Diamond Walnut, Stockton, CA. Application and material costs were obtained from the grower to evaluate economic costs.

D. Moderate Population Management Strategy C – Comparison Program

A product substitution and comparison trial was conducted in a commercial 'Chandler'/ 'Eureka' orchard in Farmington. Each replicate was about 6 acres in size. All treatments were applied to every other row (skip row). The treatments were: GF-120 (20 oz/ac diluted to 1:4) applied weekly, Success (3.2 oz/ac and 2 pt NuLure/ac as bait) applied as needed, OP insecticide (2 pt/ac Lorsban and 2 pt NuLure/ac as bait) applied as needed, and blank GF-120 (20 oz/ac diluted to 1:4) applied weekly. The GF-120 and blank GF-120 treatments were applied using a modified weed sprayer mounted on an ATV. The Success and Lorsban treatments were applied with an air-blast sprayer with a final spray volume of 45 gal/ac. The GF-120 treatment was initiated on 30 June and terminated on 15 September. Success and Lorsban treatments were initiated on 7 July with a two-week alternate row split application and was terminated on 1 September. The blank GF-120 control treatment was initiated on 30 June and the control was sprayed out with Lorsban on 12 August. The efficacy of the treatments was evaluated by placing one super charged yellow AM trap high in the tree canopy in the center of each plot. In addition to the high trap, the control treatment was also monitored with a low super charged yellow AM trap. The traps were monitored weekly from mid-June through to husk split. At husk split on 19 September, 1000 nuts per plot (3000 nuts per treatment) were inspected for WHF infestation, and 100 infested and uninfested nuts were collected for quality evaluation by Diamond Walnut, Stockton, CA. Application and material costs were obtained from the grower to evaluate economic costs.

E. Low Population Management Strategy – Reduced Cost with Reduced-Risk Products

A trial was conducted in a commercial 'Payne' orchard (Hollister 2) in Hollister. Three treatments were replicated three times in a RCB design. Each replicate was 2 to 4 acres in size. The three treatments were: GF-120 (20 oz/ac diluted to 1:4) applied six times a season on an as needed basis, GF-120 (20 oz/ac diluted to 1:4) applied three times a season on an as needed basis and a blank bait control (20 oz blank GF-120 diluted 1:4/ac). The GF-120 and blank GF-120 treatments were applied using a modified weed sprayer mounted on an ATV. All treatments were skip row treatments. The treatments were initiated on 1 July and terminated on 7 September. The control treatment was sprayed out on 25 August with Entrust (1 oz/ac with 2 pt NuLure/ac as bait). Entrust was applied as a skip row with an air-blast sprayer with a final spray volume of 40 gal/ac. The efficacy of the treatments was evaluated by placing one super charged yellow AM trap high in the canopy of a tree in the center of each plot. In addition to the high trap, the

control treatment also included a low super charged yellow AM trap. The traps were monitored weekly from early June through to husk split. At husk split on 13 September, 1000 nuts per plot (3000 nuts per treatment) were inspected for WHF infestation, and 100 infested and uninfested nuts were collected for quality evaluation by Diamond Walnut, Stockton, CA. Application and material costs were obtained from the grower to evaluate economic costs.

RESULTS AND DISCUSSION

Laboratory Efficacy

Effects of WHF Density/GF-120 Toxicant Volume on WHF Mortality

There was a significant difference ($P \leq 0.05$) in WHF mortality between the lowest density rate of 25 flies per cage and the two higher fly density rates of 50 and 75 flies per cage at both the 1/2 and 1 DOE (Fig. 1). It was observed that the flies consumed the GF-120 droplet within the first hour of the experiment. Those flies that ate the GF-120 died within 24 hours. Due to the absence of any toxicant at the higher fly densities, flies that were unable to consume a toxic dose of GF-120 did not die. This resulted in a decreasing percent mortality with increasing fly density. This would indicate that in field situations with large WHF populations, GF-120 must be applied more frequently than when the WHF population is low, since the maximum field rate of GF-120 is 20 oz/ac. There is no limit on the number of applications or length of time between applications. This would help explain the lack of field control of high populations of WHF with weekly or every other week applications of GF-120.

Field Efficacy

A. High Population Management Strategy – Air-blast Application Methodology with Product Substitution

The WHF population in Upper Lake was a moderate to high fly population (Table 1). There was significantly ($P \leq 0.05$) more WHF infestation at harvest in the control treatment compared to the other treatments. However, there was no corresponding difference in the mean total flies captured during the season among the treatments. There was no significant difference between the reduced-risk insecticide, Success and the OP insecticides, Lorsban or Malathion in either the mean total flies captured in a season or in the final walnut infestation evaluation. The control treatment was treated out with Malathion on 3 August that suppressed the late season flight and held infestation within an acceptable level (Fig. 2). There was no significant ($P \leq 0.10$) difference in the mean number of flies caught in the AM traps placed high in the tree canopy versus AM traps placed low in the tree (Table 2). The trees in this orchard were very tall and the branches were overlapping, thus most of the nuts were in the upper canopy, which may explain the large numerical difference in fly catch between the trap heights. Diamond Walnut has not finished the quality assessment, so there is no nut quality data available at this time.

Pesticide costs were extremely low in this orchard due to the method of application (spot spray technique) and low amount (10 gal/ac) of final spray solution applied/ac. Due to the spot spray application technique utilized in this orchard, pesticide costs were extremely low, $3.00 to 5.00/ac including NuLure as bait. This cost was much lower than the other orchards and was not reported in Table 3. However, the cost of application per acre for the orchard was the highest among orchards (Table 4). Due to the low material costs, Upper Lake was able to spray both treatments at a very low cost per acre for the season (Table 5). The overall cost per acre for the season for the reduced-risk insecticides was slightly more expensive than the OP insecticides.

B. Moderate Population Management Strategy A – Combination Program with only Reduced-Risk Products

The WHF population in Marysville was low this past season with a mean total of 47 flies caught per trap in the high AM trap in the control blocks (Table 6). This low number can be attributed to one of the control blocks (replicate). Another control block was treated out with Malathion on 4 August when the first GF-120 application was made because of high infestation levels that were detected in the weekly samples. After the initial application of Success, the number of flies immediately declined, so the first application of GF-120 did not go on until 4 August (Fig. 3). During the season, there was no significant difference in the mean total flies caught per trap, but there was a significant difference between the treatments in mean percent infested nuts. Even though one of the control blocks had to be treated out in early August, both weekly and every other week GF-120 treatment regimes had significantly ($P \leq 0.10$) less WHF infestation. Due to the low early season fly captures in the control, but a high level of infestation, it seems that an earlier treatment was necessary in order to control WHF. Trap height comparison in Marysville also resulted in no significant ($P \leq 0.10$) difference between the two trap heights (Table 2). However there were numerically a greater number of flies in the high placement of the traps. The large number of flies would be beneficial in detecting earlier season WHF populations. The trees in the orchard were very tall, and had few low hanging limbs with nuts, which may be a reason why there were few WHF caught in the low traps. However, due to the patchy nature of the WHF in the orchard, there was no significant difference in the WHF captures due to the height of the trap. Diamond Walnut has not finished the quality assessment, so there is no nut quality data available at this time. Pesticide costs were slightly higher in this orchard. Application costs for the air-blast sprayer had a range in price due to the initial application that was applied to every other row whereas subsequent application was applied to every row. Application costs for the ATV sprayer were kept low due to the low cost per hour at this location (Table 7). Total costs per acre for the season with six applications of GF-120 were comparable to other orchards with six applications even with a Success spray (Table 8). More importantly, Success followed by the three applications of GF-120 had similar infestation to six applications of GF-120. Thus the concept of initial application with Success to reduce the population, then followed by a low number of GF-120 applications appears to be a viable economic control strategy.

C. Moderate Population Management Strategy B – Application Methodology with only Reduced-Risk Products

The WHF population in Hollister 1 was low throughout the season (Table 9). There were significantly ($P \leq 0.05$) more flies caught in the control blocks than in the GF-120 weekly treatment, and numerically more flies caught throughout the season in the control blocks compared to the other treatments. There was significantly ($P \leq 0.05$) more infestation in the control treatment than the other treatments, which closely correlated with total fly captures throughout the season. The flight data for the season shows when the two Entrust applications were applied the number of flies dropped immediately after the treatments (Fig. 4). Unlike the previous orchards, Hollister 1 had significantly ($P \leq 0.10$) more flies in the low AM trap location (Table 2). However, the flight data indicates that especially late in the season, the trend shifted from a higher number of flies in the low trap to a higher number of flies in the high trap prior to spraying out of the control. The higher number of flies in the low traps could be could be due to the low hanging limbs with nuts and lower stature trees, i.e. trees were about 35 ft tall. Diamond Walnut has not finished the quality assessment, so there is no nut quality data available at this time. Pesticide costs were slightly higher in this orchard. Overall application costs in this orchard were about average, even though the estimated cost per hour was $100.00/hr, (Table 4). However, the overall costs per acre to run the air-blast sprayer were kept low because of the 4.2 mph and skip row application. Application costs per acre for the GF-120 ATV sprayer were the lowest of any growing region. This was due the lowest machinery costs per hour. The initial GF-120 spray was a spot spray with a modified tractor traveling at 2 mph. Not only was the spot spray application time consuming, it also cost $4.97/ac, which was over 13 times the cost per acre of the ATV applicator. The cost of nine applications of GF-120 was over $150/ac and five applications was about $85/ac while two applications of Entrust was only about $70/ac and all three treatments had similar levels of infestation (Table 10).

In Kelseyville, there was an extremely high WHF population (Table 11). There were significantly ($P \leq 0.10$) more flies caught in the control and GF-120 (1:1.5) blocks than in the GF-120 (1:4) treatment blocks. The GF-120 (1:1.5) had half the amount of finished spray volume than GF-120 (1:4). It is speculated that the flies consumed all of the bait in both the GF-120 (1:1.5) and GF-120 (1:4) resulting in reduced fly mortality. However, the GF-120 (1:1.5) was consumed sooner than the GF-120 (1:4) resulting in a higher population in the GF-120 (1:1.5) than the GF-120 (1:4) treatment. From laboratory studies, it has been shown that GF-120 is very effective when consumed. Thus, the large population in the GF-120 (1:1.5) treatment could be the result of consumption of all GF-120 bait. Due to the large WHF population, communication problems with the grower and the grower's inability to treat the orchard in a timely manner with Entrust, the WHF population was not controlled. This resulted in similar infestation level among the treatment. From this experiment, it appears that large WHF populations cannot be controlled with GF-120 at either 1:1.5 or 1:4 dilution or Entrust plus NuLure spot sprays. However, it appears that Entrust plus NuLure applied over the entire orchard with an air-blast sprayer will reduce the WHF population (Fig. 5). Trap height comparison in

Kelseyville also resulted in significantly ($P \leq 0.10$) more flies being caught in the high trap compared to the low trap. The trees in the orchard were tall, spaced far apart and were not overlapping. Due to the tree structure, there were more nuts in the upper portion of the canopy, resulting in a higher trap count in the high traps. Diamond Walnut has not finished the quality assessment, so there is no nut quality data available at this time. Application cost per acre for the air-blast sprayer was the lowest of any orchard (Table 4). Application costs for the ATV sprayer was expensive compared to the other orchards because tree height and row spacing required that the GF-120 applications needed to be applied every row. The total cost per acre for the season was also quite high due to an application of Entrust that was applied to the entire orchard to suppress the population that could not be suppressed by GF-120 (Table 12).

In Escalon, the fly population was low throughout the season (Table 13). The fly population began to increase in mid-August (Fig. 6). Although, few flies were captured, two applications of Entrust resulted in significantly ($P \leq 0.05$) fewer flies captured compared to the control blocks. There were also numerically fewer flies in the GF-120 block compared to the control blocks. However, due to the low and late flight of the WHF, the infestation failed to materialize. In the trap height comparison, there was no significant difference in the number of flies captured between high and low AM traps. The trees were uniform in height with overlapping branches. This resulted in low hanging branches with a heavy and low crop load. Diamond Walnut has not finished the quality assessment, so there is no nut quality data available at this time. The application cost for the air-blast sprayer was moderate in cost (Table 4). However, the ATV sprayer was the most expensive of the test plots due to the high cost per hour of the ATV sprayer (Table 7). Due to the late emergence of WHF, the total cost per acre for the season was still low compared to other orchards (Table 14).

D. Moderate Population Management Strategy C – Comparison Program

In Farmington, the orchard had a moderate WHF population (Table 15). There was no significant difference in mean total flies caught per trap among the treatments. Even with very low infestation throughout the orchard, Lorsban plus NuLure and the GF-120 weekly applications had significantly ($P \leq 0.05$) lower infestation than the control. However, there was no significant difference between the control and the Success treatments. Due to communication problems, the control blocks were treated earlier than desired, i.e. 5% infestation. It was treated at 0.5% infested nuts. Unfortunately, this resulted in a very low level of infestation in the control treatment. Although the GF-120 treatment blocks had a high population of flies throughout the season, weekly applications of 20 oz/ac provided effective control (Fig. 7). It appears that fly population can be sustained in the GF-120 without causing economic infestation. GF-120 will ultimately kill the flies before they are sexually mature and capable of causing economic damage. The trap height comparison in Farmington resulted in significantly ($P \leq 0.05$) more flies being caught in the high trap compared to the low trap. The trees in the orchard were tall (45+ ft.), spaced far apart and were not overlapping. Due to the tree structure, there were more

nuts in the upper portion of the canopy, resulting in a higher trap count in the high traps. Diamond Walnut has not finished the quality assessment, so there is no nut quality data available at this time. Application costs per acre to operate the air-blast sprayer were one of the lowest due to the large tree spacing and skip row applications (Table 4). The application cost of ATV sprayer per acre was also moderate due to the large amount of acreage the ATV was able to cover in a short time. However, the total cost per acre for the season was quite high due to the frequency of applications and the WHF population pressure on the orchard (Table 16). The frequent GF-120 applications resulted in the total cost per acre for the season using GF-120 to be the highest of any experimental orchards. Similar to Upper Lake, the OP insecticide plus NuLure were slightly cheaper than the reduced risk pesticide Success plus NuLure.

E. Low Population Management Strategy – Reduced Cost with Reduced-Risk Products

In Hollister 2, there was a low to moderate WHF population (Table 17). There were significantly ($P \leq 0.05$) more flies caught in the control treatment than in the GF-120 treatments. As expected, there were numerically more flies caught in the low frequency application of GF-120 compared to the higher frequency GF-120 applications. However, due to the clumped behavior of WHF and the low number of replicates, the large numerical difference between the two GF-120 treatments failed to cause significant differences in total fly capture. Even with a very low number of applications, both the three and six applications of GF-120 for the season had significantly ($P \leq 0.05$) less infestation than the control. The infestation levels mirrored the fly counts. The application strategy was based on an as need basis and the six applications of GF-120 were initiated whenever there was a rise in WHF populations (Fig. 8). Trap counts were shown for both low and high traps to indicate the different times of year when the traps appeared to be most effective. There was no significant difference in the mean total number of flies captured for the season in the high versus low AM traps. The trees in the orchard were not tall (35 ft) and had a uniform nut distribution, which may explain the similar fly captures in high and low traps. In this orchard, six applications of GF-120 for the season provided excellent control of WHF. Diamond Walnut has not finished the quality assessment, so there is no nut quality data available at this time. Application costs for applying GF-120 using the ATV sprayer was the second lowest of any orchard examined due to the low cost per hour for operating the sprayer, as well as the high number of acres that the sprayer was able to travel in an hour. For cost per acre for the season was similar to other orchards with similar frequency of applications (Table 18).

CONCLUSIONS

There was a WHF density and GF-120 toxicant effect as increasing density resulted in decreasing fly mortality. All treatment strategies had significantly less WHF infestation than in the control. Reduced-risk insecticides (GF-120, Success/Entrust) were as successful as OP insecticides in providing economic control of WHF. The cost of using an air-blast sprayer with OP insecticides or Success/Entrust plus NuLure appeared to be slightly more cost effective than the ATV sprayer with GF-120. The cost of OP pesticides was slightly less than the reduced-risk

insecticides. The ATV sprayer with GF-120 is a convenient method for many growers due to the ease of use and the ability to apply WHF control when orchards are wet because of irrigation or after rainfall. Furthermore, a whole orchard can be sprayed in much less time and less training is needed to use the ATV sprayer with GF-120. There were differences in the number of flies caught in high and low traps among the different orchards. However, trap placement will need to be determined on an individual orchard basis.

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