ARTHROPOD MANAGEMENT STUDIES ON FRUIT AND VEGETABLE CROPS IN WESTERN NORTH CAROLINA

2014

ANNUAL REPORT

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Acknowledgments

This report is a summary of pest management-related studies conducted on fruit and vegetable crops in 2014 under the supervision of James F. Walgenbach, Extension Entomologist, North Carolina State University. Additional information (i.e., surveys, pest population trends, etc.) that may be of interest to extension agents, growers, industry representatives and consultants in western North Carolina is also presented.

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2014 Weather Data - Mountain Horticultural Crops Research Station, Mills River, NC

March

Date	Temp (°F) Max	Temp (°F) Min	Rainfall (inches)
1	58.5	27.1	
2	70.3	27.9	
3	56.3	30.4	0.22
4	43.3	26.2	
5	61.2	27.3	
6	40.8	27.3	0.31
7	54.3	32.7	0.47
8	65.8	29.5	
9	62.1	39.7	
10	68.9	27.9	
11	77.0	32.0	
12	70.5	31.8	
13	40.6	22.8	
14	58.8	19.6	
15	65.8	33.3	
16	46.8	39.6	0.61
17	39.6	31.8	0.36
18	48.7	31.8	0.01
19	55.2	36.1	0.02
20	58.6	33.8	
21	64.4	27.0	
22	68.2	38.8	
23	47.8	36.5	0.31
24	54.0	27.9	
25	43.0	27.1	0.02
26	43.5	23.4	0.01
27	59.0	22.1	
28	57.4	44.6	
29	63.5	39.6	0.48
30	52.2	35.6	
31	73.9	32.4	
			2.82

April

Date	Temp (°F) Max	Temp (°F) Min	Rainfall (inches)
1	80.2	38.1	
2	81.9	36.1	
3	79.9	47.3	
4	73.6	49.1	
5	62.1	42.8	
6	57.0	38.5	0.04
7	55.9	43.2	2.08
8	53.8	36.7	0.01
9	61.9	34.3	
10	70.3	30.0	
11	72.9	36.9	
12	77.0	40.6	
13	77.2	45.9	
14	64.6	58.8	0.27
15	59.9	32.7	0.53
16	56.5	30.0	
17	59.5	27.1	
18	53.6	36.1	0.42
19	55.0	45.9	0.93
20	70.5	40.6	
21	75.6	33.8	
22	66.4	46.4	0.12
23	67.5	44.4	
24	72.0	34.7	
25	73.2	46.6	
26	78.8	42.8	
27	81.9	40.8	0.01
28	77.7	56.3	0.32
29	71.4	58.3	0.56
30	71.2	57.6	0.05
			5.34

May

Date	Temp (°F) Max	Temp (°F) Min	Rainfall (inches)
1	66.9	48.2	
2	69.6	43.7	
3	72.7	43.5	
4	82.9	40.8	
5	88.3	46.0	
6	85.1	46.8	
7	83.7	43.9	
8	84.9	45.1	
9	75.7	52.0	0.19
10	71.2	55.9	0.18
11	83.8	52.3	0.01
12	82.6	54.5	
13	84.4	57.2	
14	79.0	55.4	0.34
15	70.7	48.0	2.22
16	64.9	40.6	
17	64.0	35.1	
18	60.3	45.0	0.09
19	68.5	43.9	
20	76.6	44.2	
21	84.9	49.1	
22	82.0	61.9	
23	81.1	61.3	0.01
24	77.9	51.8	
25	76.5	46.6	0.57
26	81.9	58.5	0.71
27	81.3	60.1	0.11
28	83.1	55.4	0.07
29	82.4	56.8	0.04
30	80.2	62.8	0.05
31	73.4	62.4	
			4.59

June

Date	Temp (°F) Max	Temp (°F) Min	Rainfall (inches)
1	73.2	55.8	
2	76.6	54.7	
3	78.3	54.5	
4	84.9	55.9	
5	81.0	64.8	0.04
6	80.1	63.0	0.01
7	81.7	60.8	0.82
8	84.6	60.6	0.11
9	84.2	57.7	
10	85.8	60.1	0.02
11	81.1	62.1	0.25
12	74.7	62.4	0.59
13	78.6	61.0	0.38
14	84.0	56.8	
15	83.5	58.3	
16	84.2	64.6	0.04
17	88.2	64.0	
18	85.6	63.0	
19	87.4	60.3	0.41
20	85.1	60.6	0.22
21	83.5	62.8	0.01
22	86.2	62.8	
23	81.0	64.2	0.04
24	78.3	64.9	0.59
25	81.3	63.0	
26	84.7	64.0	
27	83.7	66.6	0.24
28	79.0	66.4	0.02
29	82.8	65.5	1.24
30	83.3	64.8	0.27
			5.3

2014 Weather Data - Mountain Horticultural Crops Research Station, Mills River, NC

July

Date	Temp (°F)		Rainfall
Date	Max	Min	(inches)
1	88.3	65.5	
2	89.4	64.9	
3	82.8	63.7	0.02
4	77.5	55.6	
5	81.0	50.5	
6	82.0	52.3	
7	84.9	56.1	
8	88.9	56.5	0.16
9	80.4	64.6	0.62
10	79.5	64.4	0.36
11	83.7	64.4	
12	84.9	66.4	
13	85.6	65.1	
14	86.9	64.9	
15	79.3	65.8	0.05
16	76.8	57.4	
17	72.1	57.9	
18	68.0	60.4	1.09
19	65.5	61.3	0.86
20	79.3	61.2	0.01
21	78.1	64.4	0.50
22	82.4	64.9	0.04
23	82.0	66.4	
24	81.3	65.8	0.62
25	81.3	63.0	
26	87.1	64.4	
27	90.1	66.4	0.16
28	80.4	62.6	0.63
29	75.7	55.9	
30	79.0	52.9	
31	70.2	57.2	0.20
			5.32

August

Date	Temp (°F)		Rainfall
Date	Max	Min	(inches)
1	74.5	61.2	0.13
2	76.3	63.0	0.03
3	82.6	63.1	
4	84.7	62.4	
5	85.6	56.3	
6	84.2	60.8	
7	84.2	60.8	
8	76.1	62.6	0.76
9	83.3	66.9	1.04
10	71.6	64.4	0.02
11	83.1	65.8	0.25
12	82.8	66.4	0.23
13	74.7	59.2	
14	82.8	55.4	
15	81.7	55.9	
16	82.9	56.3	
17	86.7	59.9	
18	86.7	66.7	0.07
19	83.3	63.7	0.03
20	91.0	61.9	
21	87.1	62.4	0.01
22	90.7	64.6	
23	87.8	64.2	
24	77.9	66.7	
25	79.5	57.4	
26	83.3	52.9	
27	88.0	53.2	
28	90.7	55.9	
29	86.9	60.6	
30	84.2	64.0	
31	84.9	67.3	0.90
			3.47

September

Date	Temp (°F)		Rainfall
Date	Max	Min	(inches)
1	89.6	65.8	0.04
2	85.1	63.7	0.95
3	86.5	64.4	0.09
4	84.9	66.4	0.61
5	85.8	66.4	
6	86.0	66.6	0.14
7	84.0	65.8	1.81
8	74.7	65.5	0.59
9	80.8	64.4	0.09
10	79.0	66.0	
11	83.8	63.0	0.04
12	85.3	66.7	0.14
13	77.7	63.7	0.01
14	67.5	60.8	0.01
15	79.2	60.8	0.69
16	81.3	63.0	
17	72.5	59.4	
18	77.5	59.9	
19	75.7	58.8	
20	78.1	55.0	
21	83.8	53.4	0.01
22	71.1	51.1	0.01
23	66.6	48.9	
24	72.9	45.5	0.02
25	74.1	59.9	
26	71.1	62.1	
27	76.1	58.5	
28	75.7	53.2	
29	67.5	59.7	0.07
30	78.4	54.5	0.01
			5.33

October

Date	Temp (°F)		Rainfall
Date	Max	Min	(inches)
1	79.9	48.4	
2	82.4	55.4	0.01
3	72.9	56.7	0.49
4	59.2	36.5	
5	66.2	31.8	
6	68.4	37.4	0.26
7	68.2	52.7	0.23
8	79.7	51.6	0.01
9	79.5	47.8	
10	79.7	55.2	
11	76.1	57.9	
12	62.2	55.2	0.39
13	68.0	55.2	0.29
14	67.8	55.6	2.54
15	67.5	48.2	0.03
16	61.3	45.0	0.10
17	76.3	40.3	0.01
18	64.8	48.2	
19	66.9	41.9	
20	68.7	37.0	0.01
21	65.7	40.3	
22	56.1	45.3	
23	64.0	43.0	
24	65.7	37.8	
25	70.3	35.1	
26	75.2	40.8	
27	78.3	37.8	
28	77.9	41.0	
29	63.9	42.4	
30			
31			
			4.37

Cucumber Insecticide Trial

Cucumber, *Cucumis sativus* 'Dasher II'

Cucumber beetle (CB): *Diabrotica undecimpunctata howardi* (Barber) and *Acalymma vittatum* (Fabricius)
Melon aphid (MA): *Aphis gossypii* Glover
Thrips (FT): *Frankliniella fusca* (Hinds), *F. tritici* (Fitch) and *F. occidentalis* (Pergande)
Pickleworm (PW): *Diaphania nitidalis* (Stoll)

This study was conducted at the Mountain Horticultural Crops Research Station in Mills River, NC. 'Dasher II' cucumber seeds were field planted on 4 Jul on black plastic mulch with drip irrigation. Plots consisted of single 25-ft long beds on 10-foot centers planted with a single row of cucumbers spaced 12" apart within rows. Plants were grown using a staked trellis system. Treatments were replicated four times and arranged in a RCB design. All insecticide treatments were made with a CO_2-powered backpack sprayer delivering 71 GPA. Materials, rates, and application dates are listed in the tables. All plots were sprayed with a standard fungicide program.

Cucumber beetles were monitored by shaking 10 plants and recording the number of adult insects observed flying away. Aphids were monitored by recording the number of apterous aphids on 10 leaves per plot. Flower thrips and insidious flower bugs were monitored by removing 5 flowers per plot, placing them in a vial of 50% ETOH, and counting dislodged insects under a stereomicroscope. Mature fruit were harvested from the same 18 consecutive plants from each plot on 6 and 26 Aug and 2 Sep. Fruit were graded for insect damage, which consisted of surface scarring caused by adult cucumber beetle feeding, and fruit with infested with pickleworm. All data were subjected to two-way ANOVA and means were separated by LSD (P = 0.05).

Thrips and cucumber beetles were relatively low in this trial, and on 6 August the 16.4 oz rate of IKI-3106 was the only treatment to significantly reduced numbers below the control (Table 1). Cucumber beetle populations were extremely low, with ≤0.5 beetles recorded in any plot and no significant differences. On 6 Aug there were significantly more aphids in the control (approximately 2 per leaf) than in the treated plots (<0.6 per leaf), and by 26 Aug populations had reached 18.9/leaf in the control and over 30/leaf in the standard treatment. The pyrethroid applications in August clearly flared aphid populations in the standard treatment, while both IKI-3106 treatments maintained densities below an average of 2 per leaf. Despite the low cucumber beetles recorded in plant beatings, fruit scarring caused by adult beetles reached almost 10% in the control. Scaring was generally lower in the insecticide treatments compared with the control, but these data were highly variable and there were no significant differences among treatments after the first harvest date. Pickleworm damage was relatively low until the last harvest date when almost 11% of fruit were damaged. All treatments provided high levels of pickleworm control.

Table 1. Thrips, cucumber beetles, and aphids on 'Dasher II' cucumber plants sprayed with various insecticides. Mills River, NC. 2014.

Treatment	Rate/A	Application dates	Thrips / 5 flowers (6 Aug)		Cucumber beetles / 10 plants	Aphids / 10 leaves	
			Adults	Immatures	6 Aug	6 Aug	26 Aug
IKI-3106 SL	11.0 fl oz	7/29, 8/4, 8/11, 8/18, 8/25	1.3ab	0.0a	0.5a	6.0a	5.5a
IKI-3106 SL	16.4 fl oz	7/29, 8/4, 8/11, 8/18, 8/25	0.3a	0.0a	0.3a	2.5a	18.0a
Asana XL Assail 70WDG Perm-Up 3.2EC	6.0 fl oz 4.0 fl oz 6.0 fl oz	7/29, 8/18, 8/25 8/4 8/11	2.0ab	0.0a	0.0a	3.3a	301.3b
Untreated Control	-	-	3.0b	0.0a	0.3a	19.8b	188.5b

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Table 2. Insect damage to fruit of 'Dasher II' cucumber plants treat with various insecticides. Mills River, NC. 2014.

Treatment	Rate/A	Application dates	Total fruit				% Fruit Scarred				% PW damage			
			6 Aug	26 Aug	2 Sep	Total	6 Aug	26 Aug	2 Sep	Total	6 Aug	26 Aug	2 Sep	Total
IKI-3106 SL	11.0 fl oz	7/29, 8/4, 8/11, 8/18, 8/25	77.8a	45.5b	54.0a	177.3a	0.0a	12.6a	11.6a	6.5a	0.0a	0.0a	0.4a	0.1a
IKI-3106 SL	16.4 fl oz	7/29, 8/4, 8/11, 8/18, 8/25	89.8a	34.8a	58.0a	182.5a	0.3a	11.0a	9.7a	5.8a	0.0a	0.0a	0.0a	0.0a
Asana XL Assail 70WDG Perm-Up 3.2EC	6.0 fl oz 4.0 fl oz 6.0 fl oz	7/29, 8/18, 8/25 8/4 8/11	65.8a	47.5b	38.0a	151.3a	0.3a	10.8a	11.5a	6.2a	0.6a	0.4a	0.0a	0.3a
Untreated Control	-	-	74.0a	33.0a	36.0a	143.0a	2.9b	17.8a	15.3a	9.6a	1.1a	2.4a	10.7b	3.8b

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Cucumber Chemigation Trial

Cucumber, *Cucumis sativus* 'Dasher II'

Cucumber beetle (CB): *Diabrotica undecimpunctata howardi* (Barber) and *Acalymma vittatum* (Fabricius)
Potato aphid (PA): *Macrosiphum euphorbiae* (Thomas)
Thrips (FT): *Frankliniella fusca* (Hinds), *F. tritici* (Fitch) and *F. occidentalis* (Pergande)
Insidious flower bug (IFB): *Orius insidiosus* (Say)
Miscellaneous lepidopterans (LEP)

This study was conducted at the Mountain Horticultural Crops Research Station in Mills River, NC. 'Dasher II' cucumber seeds were field planted on 10 Jun on black plastic mulch with drip irrigation. Plots consisted of two 25-ft long beds on 5-foot centers planted with a single row of cucumbers spaced 12" apart within rows. Cucumbers were staked and strung as needed and sprayed with a standard fungicide program. Treatments were separated by 10 ft of bare ground and were replicated four times and arranged in a RCB design. Insecticide chemigation treatments were applied via a CO_2 injector into a 1" poly tube that delivered materials to treatment drip lines. Foliar applications were made with a CO_2-powered backpack sprayer. Materials, rates, and application dates are listed in the tables.

Cucumber beetles were monitored by shaking 10 plants and recording the number of adult insects observed flying away. Aphids were monitored by recording the number of apterous aphids on 10 leaves per plot. Flower thrips and insidious flower bugs were monitored by removing 5 flowers per plot, placing them in a vial of 50% ETOH, and counting dislodged insects under a stereomicroscope. Mature fruit were harvested from the same 18 consecutive plants from each plot on 1, 6, 8, 12, 15, 19, and 22 Aug. For the purpose of analysis, harvests were combined into Week 1 (1 Aug), Week 2 (6 and 8 Aug), Week 3 (12 and 15 Aug), and Week 4 (19 and 22 Aug). Fruit were graded for size, marketability, weight, and insect damage, which included categories for clean fruit, slight surface scarring (≤10%), heavy surface scarring (>10%), and fruit with lepidopteran entries. All surface scarring damage was assumed to be the result of adult cucumber beetle feeding. All data were subjected to two-way ANOVA and means were separated by LSD ($P = 0.05$).

There were very few cucumber beetles observed during beat samples and populations never exceeded 1 per plant; nonetheless, the foliar-only treatment consistently demonstrated the greatest control (Table 1). Thrips populations were also low, with a peak of fewer than 1.5 total (adults + immatures) thrips per flower in the drip-only treatment on 7 Aug (Table 1). This was significantly higher than either the drip-foliar or foliar-only treatment, but not significantly different from the control. Aphid populations were very low until 7 Aug, when the control had significantly more than the treated plots (Table 2). By 26 Aug, populations in the foliar-only treatment built to high densities, with >180 aphids/leaf compared to <10/leaf in the other plots. There were no significant differences in season total fruit production, which averaged 121.8

lbs/18 plants, or 29.5 tons/acre (Table 3). There were some significant differences in the number of culls among treatments on isolated harvest dates, but when season totals were calculated, there were no significant differences in percent scar damage, lep damage, or fruit size, which averaged 3.8, 0.3, and 10.2%, respectively. Season total marketable fruit was very similar among treatments, ranging from 80.7% in the foliar-only treatment to 85.4% in the drip-foliar treatment (Table 4).

Table 1. Cucumber beetles and thrips on 'Dasher II' cucumber plants treated with insecticides through drip irrigation and foliar sprays. Mills River, NC. 2014.

			Cucumber beetles per 10 plants					Motile thrips per 5 flowers				
Treatment	Rate/A	Application dates	9-Jul	16-Jul	23-Jul	7-Aug	Season Total	9-Jul	16-Jul	23-Jul	7-Aug	Cumulative thrips days
Admire (drip) Coragen (drip)	10.5 fl oz 5.0 fl oz	6/23 6/23	0.5a	3.0b	2.8a	0.3a	6.5b	0.0a	0.5a	1.5a	6.3b	66.9c
Admire (drip) Coragen (drip) Assail 70WDG (foliar) Asana XL (foliar)	10.5 fl oz 5.0 fl oz 4.0 oz 5.0 fl oz	6/23 6/23 8/4 8/11	0.3a	1.5ab	1.8a	0.0a	3.5ab	0.0a	0.3a	2.0a	1.3a	33.1ab
Sevin XLR (foliar) Perm-Up 3.2EC (foliar) Asana XL (foliar) Assail 70 WDG (foliar)	1 qt 6.0 fl oz 5.0 fl oz 4.0 fl oz	7/14 8/11 6/23, 6/30, 7/7, 7/21, 7/28, 8/11 8/4	0.0a	0.0a	0.5a	0.3a	0.8a	0.0a	0.0a	0.0a	2.0a	15.0a
Untreated Control	-		0.5a	0.8a	3.8a	1.5b	6.5b	0.0a	1.0a	2.0a	4.0a	59.0bc

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Table 2. Aphids on 'Dasher II' cucumber plants treated with insecticides through drip irrigation and foliar sprays. Mills River, NC. 2014.

Treatment	Rate/A	Application dates	Aphids per 10 leaves 9-Jul	16-Jul	23-Jul	7-Aug	26-Aug	Cumulative Aphid Days
Admire (drip) Coragen (drip)	10.5 fl oz 5.0 fl oz	6/23 6/23	0.0a	0.3a	0.0a	2.8a	17.0a	210.0a
Admire (drip) Coragen (drip) Assail 70WDG (foliar) Asana XL (foliar)	10.5 fl oz 5.0 fl oz 4.0 oz 5.0 fl oz	6/23 6/23 8/4 8/11	0.0a	0.3a	0.0a	0.8a	75.3a	729.4a
Sevin XLR (foliar) Perm-Up 3.2EC (foliar) Asana XL (foliar) Assail 70 WDG (foliar)	1 qt 6.0 fl oz 5.0 fl oz 4.0 fl oz	7/14 8/11 6/23, 6/30, 7/7, 7/21, 7/28, 8/11 8/4	0.0a	0.3a	0.0a	1.5a	1861.3b	17709.1b
Untreated Control	-		0.0a	0.3a	0.0a	10.0b	10.0a	266.8a

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Table 3. Season total fruit (by weight) harvested from 'Dasher II' cucumber plants treated with insecticides through drip irrigation and foliar sprays. Mills River, NC. 2014.

				% Marketable		% Unmarketable			
Treatment	Rate/A	Application dates	Total yield (lbs/plot)	% Clean fruit	% Slight scarring	% Heavy scarring	% Lep entries	Size	% Other
Admire (drip) Coragen (drip)	10.5 fl oz 5.0 fl oz	6/23 6/23	125.8a	52.4a	29.9a	4.6a	0.2a	10.1a	2.8a
Admire (drip) Coragen (drip) Assail 70WDG (foliar) Asana XL (foliar)	10.5 fl oz 5.0 fl oz 4.0 oz 5.0 fl oz	6/23 6/23 8/4 8/11	114.7a	50.7a	34.7a	3.2a	0.1a	8.3a	3.0a
Sevin XLR (foliar) Perm-Up 3.2EC (foliar) Asana XL (foliar) Assail 70 WDG (foliar)	1 qt 6.0 fl oz 5.0 fl oz 4.0 fl oz	7/14 8/11 6/23, 6/30, 7/7, 7/21, 7/28, 8/11 8/4	123.6a	23.1a	27.5a	2.6a	0.6a	13.4a	2.7a
Untreated Control	-		123.1a	48.8a	32.9a	4.7a	0.5a	8.9a	4.3a

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Table 4. Fruit (by weight) harvested from 'Dasher II' cucumber plants treated with insecticides through drip irrigation and foliar sprays. Mills River, NC. 2014.

Treatment	Rate/A	Application dates	Total yield (tons/A)	% Marketable Week 1	Week 2	Week 3	Week 4	Season Total
Admire (drip) Coragen (drip)	10.5 fl oz 5.0 fl oz	6/23 6/23	30.4a	86.7a	88.6a	70.1a	77.6a	82.3a
Admire (drip) Coragen (drip) Assail 70WDG (foliar) Asana XL (foliar)	10.5 fl oz 5.0 fl oz 4.0 oz 5.0 fl oz	6/23 6/23 8/4 8/11	27.8a	95.5a	92.7a	66.0a	79.1a	85.4a
Sevin XLR (foliar) Perm-Up 3.2EC (foliar) Asana XL (foliar) Assail 70 WDG (foliar)	1 qt 6.0 fl oz 5.0 fl oz 4.0 fl oz	7/14 8/11 6/23, 6/30, 7/7, 7/21, 7/28, 8/11 8/4	29.9a	90.7a	88.9a	63.2a	76.1a	80.7a
Untreated Control	-		29.8a	87.0a	90.7a	63.7a	78.9a	81.7a

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Tomato Foliar Insecticide Trial

Tomato, *Solanum lycopersicon* L. 'Florida 47'

Thrips (FT): *Frankliniella tritici* (Fitch) and *Frankliniella occidentalis* (Pergande)
Potato aphid (PA): *Macrosiphum euphorbiae* (Thomas)
Lepidopterans (LEP)
Tomato fruitworm: *Helicoverpa zea* (Boddie)
Armyworm: *Spodoptera* spp.
Cabbage looper: Trichoplusia ni (Hubner)
Stink bugs (SB): *Euschistus servus* (Say) and *Acrosternum hilare* (Say)

This study was conducted at the Mountain Research Station in Waynesville, NC. Six-wk-old 'Florida 47' tomato transplants were set on 27 May on black plastic mulch with drip irrigation. Plots consisted of single 20-ft long rows on 5-ft centers with a non-treated row separating treatment plots. Plants were spaced 1.5 ft within rows, and treatments were replicated four times and arranged in a RCBD. Tomatoes were staked and strung as needed and sprayed with a standard fungicide program. All treatment applications were made with a CO_2 backpack sprayer delivering 50 to 90 GPA (volume increased as plants grew). Treatments, rates, and application dates are listed in the tables. Flower thrips were monitored by removing 10 flowers per plot, placing them in a vial of 50% ETOH, and counting dislodged adults and immatures under a stereomicroscope. Potato aphids were monitored by recording the number of apterous aphids on 10 leaves per plot. Season cumulative thrips and aphid days were calculated by multiplying average insect density by sample interval (days) and summing values for each date. On 13, 20, and 27 Aug, mature fruit were harvested and assessed for damage. All data were subjected to two-way ANOVA and means were separated by LSD ($P = 0.05$).

Thrips populations were low and consisted primarily of *Frankliniella tritici*. Populations reached their peak densities in flowers on 28 Jul, averaging just 7.5 thrips per 10 flowers in the control (Table 1). Based on season total thrips days, only the Brigade, Mustang Max, and Radiant/Coragen/Actara treatments significantly reduced numbers below those of the control. Aphid populations were very low, with less than 2 per leaf observed in the control on 25 Aug, and there were no differences among treatments (Table 2). Total yield from the 3 harvest dates averaged about 160 fruit across all treatments (Table 3). Season total damage from lepidopteran pests was relatively low at 3.9% in the control. While all treatments significantly reduced damage below the control, the Brigrade and Cmpd X treatments had the lowest levels of damage. Stink bug damage increased with each successive harvest data, with Brigade and Mustang Max the only treatments with ≤ 1% damage. Thrips damage to fruit did not differ among treatments.

Table 1. Mean thrips populations in tomato (cv. FL-47) flowers treated with various insecticides. Mountain Research Station, Waynesville, NC. 2014.

Treatment	Rate/A	Application dates	Motile (adult+immature) thrips per 10 flowers							Cumulative Thrips Days
			6/24	7/2	7/7	7/15	7/24	7/28	8/4	
Brigade 2EC	6.4 oz	6/23, 7/1, 7/8, 7/14, 7/21, 7/29, 8/12	0.3a	1.3a	2.3a	0.0a	0.5a	1.5ab	2.0a	42.3a
Athena EW	10 oz	8/5								
Mustang Max 0.8EC	4 oz	6/23, 7/1, 7/8, 7/14, 7/29, 8/12	0.8a	0.5a	1.8a	0.5ab	2.0ab	1.3a	2.5a	50.5a
Gladiator EW	19 oz	7/21, 8/5								
Compound X	—	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	1.5a	4.0a	1.5a	9.3d	4.3abc	5.3bcd	5.0a	194.4c
Admire Pro	2.0 oz	8/12								
Actara 25WDG	3.5 oz	6/23								
Compound X	—	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	0.5a	2.3a	0.0a	5.3cd	5.5bc	8.0d	4.0a	155.0bc
Admire Pro	2.0 oz	8/12								
Actara 25WDG	3.5 oz	6/23								
Compound X	—	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	1.0a	9.5b	0.8a	5.3cd	2.0ab	2.8abc	3.3a	154.8bc
Admire Pro	2.0 oz	8/12								
Actara 25WDG	3.5 oz	6/23								
Compound X	—	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	0.0a	1.3a	0.5a	5.0cd	2.0ab	2.5abc	2.8a	90.3ab
Admire Pro	2.0 oz	8/12								
Actara 25WDG	3.5 oz	6/23								
Coragen	5.0 oz	6/23, 7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	1.5a	3.8a	0.8a	4.5bc	6.0bc	5.3bcd	4.0a	155.4bc
Admire Pro	2.0 oz	8/5, 8/12								
Avaunt	3.5 oz	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	1.0a	3.5a	1.8a	1.3abc	3.3abc	5.8cd	1.5a	106.8ab
Admire Pro	2.0 oz	6/23, 8/12								
Radiant	5 oz	7/1, 7/8, 7/29, 8/12	0.0a	2.0a	1.5a	2.0abc	2.0ab	3.3abc	0.3a	71.5a
Coragen	4 oz	7/14								
Actara 25WD	3.5 oz	7/21, 8/5								
Dimethoate	1.0 pt	6/23								
Untreated Control	-	-	0.5a	4.8a	1.3a	3.3abc	7.3c	7.5d	4.0a	171.0bc

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Table 2. Mean aphid populations on tomato (cv. FL-47) plants treated with various insecticides. Mountain Research Station, Waynesville, NC. 2014.

Treatment	Rate/A	Application dates	Aphids per 10 leaves					Cumulative Aphid Days
			7/24	7/28	8/4	8/11	8/25	
Brigade 2EC	6.4 oz	6/23, 7/1, 7/8, 7/14, 7/21, 7/29, 8/12	0	0	0	0	0a	0
Athena EW	10 oz	8/5						
Mustang Max 0.8EC	4 oz	6/23, 7/1, 7/8, 7/14, 7/29, 8/12	0	0	1.5	0	0a	10.5
Gladiator EW	19 oz	7/21, 8/5						
Compound X	—	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	0.5	0	3.5	7.3	0.8a	109.1
Admire Pro	2.0 oz	8/12						
Actara 25WDG	3.5 oz	6/23						
Compound X	—	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	1.5	0	0	9.8	2.3a	127.9
Admire Pro	2.0 oz	8/12						
Actara 25WDG	3.5 oz	6/23						
Compound X	—	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	3	0	1.3	4.8	0a	78.1
Admire Pro	2.0 oz	8/12						
Actara 25WDG	3.5 oz	6/23						
Compound X	—	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	0	0	0	0	1.3a	8.8
Admire Pro	2.0 oz	8/12						
Actara 25WDG	3.5 oz	6/23						
Coragen	5.0 oz	6/23, 7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	3	0	0.5	9.3	0a	120.1
Admire Pro	2.0 oz	8/5, 8/12						
Avaunt	3.5 oz	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	1.8	0	0	2.0	2.0a	46.4
Admire Pro	2.0 oz	6/23, 8/12						
Radiant	5 oz	7/1, 7/8, 7/29, 8/12	0.25	0	2.3	0	0a	17.4
Coragen	4 oz	7/14						
Actara 25WD	3.5 oz	7/21, 8/5						
Dimethoate	1.0 pt	6/23						
Untreated Control	-	-	3.3	0	0	2.78	17.5a	172.5

Data presented are means; there were no significant ANOVAs for aphid counts.

Table 3. Percent insect damage on tomatoes (cv. FL-47) treated with various insecticides. Mountain Research Station, Waynesville, NC. 2014.

			Total	% lep damage				% stink bug damage				% thrips damage			
Treatment	Rate/A	Application dates	Fruit	8/13	8/20	8/27	Total	8/13	8/20	8/27	Total	8/13	8/20	8/27	Total
Brigade 2EC	6.4 oz	6/23, 7/1, 7/8, 7/14, 7/21, 7/29, 8/12	187.5a	0.7a	0.0a	0.6ab	0.4ab	0.6	1.1	0.3a	0.8a	4.1a	2.2a	2.3a	2.5a
Athena EW	10 oz	8/5													
Mustang Max 0.8EC	4 oz	6/23, 7/1, 7/8, 7/14, 7/29, 8/12	142.5a	2.6a	0.3ab	0.8abc	1.4bc	0.0a	0.9a	1.5ab	1.0a	2.5a	1.8a	1.3a	1.7a
Gladiator EW	19 oz	7/21, 8/5													
Compound X	—	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	159.5a	1.5a	0.3ab	1.0abc	0.9abc	1.5a	3.0a	4.4ab	3.3abc	3.3a	4.5a	2.8a	3.6a
Admire Pro	2.0 oz	8/12													
Actara 25WDG	3.5 oz	6/23													
Compound X	—	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	163.8a	1.0a	0.0a	0.9abc	0.5abc	1.2a	5.1a	6.4bc	4.9bcd	2.4a	3.7a	3.6a	3.6a
Admire Pro	2.0 oz	8/12													
Actara 25WDG	3.5 oz	6/23													
Compound X	—	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	158.0a	0.0a	0.0a	0.0a	0.0a	0.6a	1.7a	4.4ab	2.4ab	6.5a	4.0a	3.6a	4.0a
Admire Pro	2.0 oz	8/12													
Actara 25WDG	3.5 oz	6/23													
Compound X	—	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	160.3a	0.0a	0.0a	2.3bc	0.8abc	0a	4.7a	2.1ab	2.9ab	4.7a	2.2a	3.0a	2.8a
Admire Pro	2.0 oz	8/12													
Actara 25WDG	3.5 oz	6/23													
Coragen	5.0 oz	6/23, 7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	153.0a	0.7a	0.9abc	1.1abc	1.0abc	2.7a	7.4a	7.0bc	6.5cd	11.3a	3.2a	3.8a	5.2a
Admire Pro	2.0 oz	8/5, 8/12													
Avaunt	3.5 oz	7/1, 7/8, 7/14, 7/21, 7/29, 8/5, 8/12	151.0a	1.5a	1.1bc	2.5c	1.6c	1.8a	2.9a	6.3bc	3.4abc	3.8a	4.5a	7.7a	5.3a
Admire Pro	2.0 oz	6/23, 8/12													
Radiant	5 oz	7/1, 7/8, 7/29, 8/12	160.8a	1.1a	0.0a	0.4a	0.5abc	1.7a	2.4a	4.7ab	3.2abc	2.4a	2.4a	2.3a	2.3a
Coragen	4 oz	7/14													
Actara 25WD	3.5 oz	7/21, 8/5													
Dimethoate		6/23													
Untreated Control	-	-	154.0a	6.0b	1.8c	5.5d	3.9d	2.1a	6.0a	11.8c	7.0d	8.7a	3.9a	5.7a	4.7a

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Evaluation of Drip Irrigation Applied Neonicotinoids for Aphid and Stink Bug Control on Tomato

Tomato, *Solanum lycopersicon* L. 'Florida 47'

Thrips (FT): *Frankliniella tritici* (Fitch) and *Frankliniella occidentalis* (Pergande)
Potato aphid (PA): *Macrosiphum euphorbiae* (Thomas)
Stink bugs (SB): *Euschistus servus* (Say) and *Halyomorpha halys* Stål

The trial was conducted at the Mountain Horticultural Crops Research Station in Mills River, NC. Six-wk-old tomato transplants (cv. Florida 47) were set on 15 May in black plastic mulch with drip irrigation. Plots consisted of two 25-ft long rows on 5-ft centers, with a non-treated row separating treatment rows. Plants were spaced 1.5 ft within rows, and treatments were replicated four times and arranged in a RCBD. The objective of the experiment was to compare the level of insect control with various neonicotinoids applied via drip irrigation. Treatments were applied on 8 July, approximately 21 days before anticipated harvest, and consisted of Admire 4.6SC at 10.5 fl oz/A, Platinum 75SG at 3.67 oz/A, Belay 2.13SC at 12 fl oz/A, and Venom 70SG at 6 oz/A. All insecticides were applied with a CO_2 injector into one-inch ploy tube connected to treatment drip lines. All treatments (including the control) also received Coragen 1.67SC at 4 oz/A on 2 June and 4 August for control lepidopteran pests. Plants were staked and strung as needed, and sprayed with a standard fungicide program.

Flower thrips were monitored by removing 10 flowers per plot, placing them in a vial of 50% ETOH, and counting dislodged adults and immatures under a stereomicroscope. Potato aphids were monitored by recording the number of apterous aphids on 10 leaves per plot. Season cumulative thrips and aphid days were calculated by multiplying average insect density by sample interval (days) and summing values for each date. On 31 Jul, 14, 21 and 28 August, mature fruit were harvested from the middle 8 plants in each plot and were assessed for insect damage. All data were subjected to two-way ANOVA and means were separated by LSD (P = 0.05).

Results

No treatment effects were detected against flower thirps populations, although numbers were very low (Table 1). Potato aphid populations began in increase in mid July shortly after application of the neonicotinoid treatments, and gradually grew to their highest densities on the last sample date on 25 August, peaking at a density of about 175 aphids/10 leaves. With the exception of Venom, all neonicotinoids applied on 8 July provided excellent control of aphids for the following seven weeks (Table 2). The Venom treatment delayed aphid buildup for two to three weeks after application, but by one month populations did not differ from the control. Venom was the most effective material against stink bugs, of which brown marmorated stink bug was the predominate species. Although all treatments except Belay had lower stink bug damage than the control at 5 wks post application (14 August), Venom was the only material that significantly reduced damage below the control. However, by seven weeks post application (21 August) damage had increased to relatively high levels in all treatments.

Table 1. Flower thrips in tomatoes treated with different neonicotinoid insecticides applied through the drip irrigation system on 8 July, 2014. Mills River, NC.

		Thrips/10 flowers					
Insecticide	Rate/A	7/2	7/9	7/16	7/23	7/7	CTD
Admire Pro 4.6SC	10.5 fl oz	2.0a	2.2a	1.0a	0.2a	0.1a	59.6a
Platinum 75SG	3.67 oz	1.9a	2.2a	1.0a	0.6a	0.1a	54.9a
Belay 2.13SC	12.0 fl oz	2.1a	2.1a	1.3a	0.2a	0.1a	53.4a
Venom 70SG	6.0 oz	1.5a	1.6a	1.2a	0.3a	0.1a	41.6a
Control	—	1.7a	1.7a	0.9a	0.1a	0.0a	45.0a

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Table 2. Potato aphid populations on tomatoes treated with different neonicotinoid insecticides applied through the drip irrigation system on 8 July, 2014. Mills River, NC.

		Aphids/10 leaves								
Insecticide	Rate/A	7/2	7/9	7/16	7/23	8/7	8/13	8/20	8/25	CAD
Admire Pro 4.6SC	10.5 fl oz	2.8a	0.0a	1.8a	0.0a	0.0a	2.0a	1.0a	1.0a	71.3a
Platinum 75SG	3.67 oz	0.0a	0.5a	0.0a	2.3a	4.0a	3.5a	5.5a	2.0a	144.1a
Belay 2.13SC	12.0 fl oz	0.0a	1.0a	0.5a	0.3a	0.0a	0.3a	1.8a	5.0a	37.9a
Venom 70SG	6.0 oz	0.0a	0.3a	3.8a	1.5a	47.8b	79.0b	58.8b	76.5b	1606.9b
Control	—	0.0a	5.5a	33.0b	60.8a	64.0b	86.5b	119.5b	173.8b	3323.4b

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Table 3. Stink bug damage to tomatoes treated with various neonicotinoid insecticides applied through the drip irrigation system on 8 July, 2014. Mills River, NC.

		% stink bug damage				
Insecticide	Rate/A	Jul 31	Aug 14	Aug 21	Aug 28	Total
Admire Pro 4.6SC	10.5 fl oz	4.6a	13.9b	24.3b	23.7b	15.2ab
Platinum 75SG	3.67 oz	12.8a	15.8b	38.8b	31.1b	23.6b
Belay 2.13SC	12.0 fl oz	7.0a	23.6b	35.4b	32.1b	25.3b
Venom 70SG	6.0 oz	6.2a	6.9a	21.6b	23.6b	12.1a
Control	—	12.4a	20.4b	26.2b	31.9b	23.3b

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Comparison of Drip Chemigation versus Foliar Sprays for Tomato Insect Control

Tomato, *Solanum lycopersicon* L. 'Florida 47'

Potato aphid (PA): *Macrosiphum euphorbiae* (Thomas)
Thrips (FT): *Frankliniella tritici* (Fitch) and *Frankliniella occidentalis* (Pergande)
Twospotted spider mite (TSSM): *Tetranychus urticae* Koch
Stink bugs (SB): *Halyomorpha halys* Stål and *Euschistus servus* (Say)
Tomato fruitworm (TFW): *Helicoverpa zea* (Boddie)

The trial was conducted at the Mountain Horticultural Crops Research Station in Mills River, NC. Six-wk-old tomato transplants (cv. Florida 47) were set on 20 May in black plastic mulch with drip irrigation. Plots consisted of two 25-ft long rows on 5-ft centers, with a non-treated row separating treatment rows. Plants were spaced 1.5 ft within rows, and treatments were replicated four times and arranged in a RCBD. The objective of the experiment was to compare control of the insect complex attacking tomato in western NC using drip irrigation of neonicotinoids and Coragen to foliar sprays of a more diverse group of insecticides. A combination of drip chemigation plus supplemental foliar treatments and a non-treated control were also included. Insecticides, application methods and dates of applications are shown in the tables. Except for the control, transplants used in all treatments were treated with Admire 4.6F (0.44 oz/10,000 plants) as a transplant tray drench four days before planting in the field. Drip applications were made with a CO_2 powered injector into a one-inch ploy tube connected to treatment drip lines, and foliar applications were made with a CO_2 powered backpack sprayer delivering 25 to 90 GPA (volume increased as plants grew) through 3 hollow cone nozzels per side of each row, effectively applying materials through 6 nozzles per row. Plants were staked and strung as needed, and sprayed with a standard season-long fungicide program.

Flower thrips were monitored by removing 10 flowers per plot, placing them in a vial of 50% ETOH, and counting dislodged adults and immatures under a stereomicroscope. Potato aphids were monitored by recording the number of apterous aphids on 10 leaves per plot, and TSSM were monitored by recording the number of motile mites on 10 terminal leaflets per plot. Season cumulative thrips-, aphid- and mite-days were calculated by multiplying the average counts on consecutive sample dates by the sample interval (days) and summing values from all dates. On 31 Jul, 14, 21 and 28 August, mature fruit were harvested from the middle 8 plants in each plot, weighed, graded and assessed for insect damage. All data were subjected to two-way ANOVA and means were separated by LSD ($P = 0.05$).

Results

The drip only treatment received four total insecticide applications, including Admire + Coragen 3-wks after planting, Venom 8-wks after planting, and a second application of Coragen on 23 July. In addition to these same drip applied insecticides, the drip + foliar treatment received three supplemental foliar sprays, including two applications of Danitol targeting stink bugs and an application of Radiant on 18 August. The foliar only treatment received a total of 11 applications of four different insecticides.

Potato aphid populations were of moderate intensity, and the drip chemigation only and drip plus foliar treatments both provided excellent season-long suppression of aphidd, likely due to the Admire applied through the drip system (Table 1). Thrips populations were of low intensity and consisted predominately of *F. tritici*. The foliar only treatment was the only one to significantly reduce thrips populations in flowers below the control (Table 2). Mite populations began to increase in early August and reached a peak density of about 31 mites per leaflet on the last sample date – 20 August ((Table 3). Mite were not differentially affected by the different insecticide programs, as evidenced by the lack of differences among treatments. Total yield was highly variable and there were no differences among treatments, and an overall average of 36.4 tons/acre (Table 4). The foliar only treatment had a significantly higher percent of marketable fruit than all other treatments, and this was due primarily to the high level of stink bug control compared to all other treatments. Lepidopteran damage was relatively low and there were no differences among treatments, although the control had almost twice as much damage as other treatments. The brown marmorated stink bug (BMSB) was the primary cause of stink bug damage, which accounted for 13.7% damage in the Control, and thrips damage was highest in the control with 9.2%.

The level of damage by date caused by lepidopterans and stink bug is shown in Table 5. Lepidopteran damage was fairly consistent across harvest dates, while BMSB increased with each successive harvest date, ranging from 6.2% to 29.9% damage in the control from 31 July to 28 August. The three Danitol applications to the foliar treatment resulted in excellent control of BMSB. While the Venom applications made through the drip system in early July may have suppressed stink bug damage through late July, there was no difference from the control by 14 August. The supplement Danitol applications to the drip treatment helped to suppress BMSB damage, but clearly the July application in the foliar treatment played an important role in minimizing damage.

Table 1. Mean potato aphid populations on tomatoes treated with different insecticide programs. Mills River, NC. 2014.

Insecticide	Rate/A	Applic. date	Applic method	Aphids/10 leaves						CAD
				7/16	7/23	8/6	8/13	8/20	8/27	
Admire 4.6SC	10.5 oz	6/11	Drip	2.0	0.0a	3.3a	4.5a	20.8a	29.0a	327.3a
Coragen 1.67SC	4.0 oz	6/11, 7/23	Drip							
Venom 70SG	6.0 oz	7/8	Drip							
Admire 4.6SC	10.5 oz	6/11	Drip	4.8	0.5a	14.3a	2.8a	9.5a	8.0a	301.9a
Coragen 1.67SC	4.0 oz	6/11, 7/23	Drip							
Venom 70SG	6.0 oz	7/8	Drip							
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar							
Radiant 1.67SC	6.0 oz	8/18	Foliar							
Dimethoate 4E	16.0 oz	6/13, 6/20	Foliar	5.8	32.5a	35.3b	76.8b	138.5b	83.3b	2565.5b
Radiant 1SC	6.0 oz	6/30, 7/15, 8/4, 8/18	Foliar							
Coragen 1.67SC	3.5 oz	7/7, 7/29	Foliar							
Danitol 2.4EC	10.6 oz	7/22, 8/11, 8/25	Foliar							
Control	—	—	—	2.8	40.0a	87.5b	105.8b	149.5b	200.3b	3845.6b

Means with the same column followed by the same letter are not significantly different by LSD (P = 0.05).

Table 2. Mean thrips populations on tomatoes treated with different insecticide programs. Mills River, NC. 2014.

Insecticide	Rate/A	Applic. date	Applic method	Thrips per flower 6/18	6/25	7/2	7/9	7/16	7/23	8/6	CTD
Admire 4.6SC	10.5 oz	6/11	Drip	0.4a	1.1a	2.2b	2.5a	0.8b	0.5b	0.1a	53.6 b
Coragen 1.67SC	4.0 oz	6/11, 7/23	Drip								
Venom 70SG	6.0 oz	7/8	Drip								
Admire 4.6SC	10.5 oz	6/11	Drip	0.3a	1.0a	1.4a	2.2a	1.0b	0.7 bc	0.2a	48.1b
Coragen 1.67SC	4.0 oz	6/11, 7/23	Drip								
Venom 70SG	6.0 oz	7/8	Drip								
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar								
Radiant 1.67SC	6.0 oz	8/18	Foliar								
Dimethoate 4E	16.0 oz	6/13, 6/20	Foliar	0.3a	0.4a	0.9a	0.9a	0.2a	0.0a	0.0a	16.9a
Radiant 1SC	6.0 oz	6/30, 7/15, 8/4, 8/18	Foliar								
Coragen 1.67SC	3.5 oz	7/7, 7/29	Foliar								
Danitol 2.4EC	10.6 oz	7/22, 8/11, 8/25	Foliar								
Control	—	—	—	0.5a	1.2a	2.6b	2.3a	1.1b	1.0c	0.2a	64.0c

Means with the same column followed by the same letter are not significantly different by LSD (P = 0.05).

Table 3. Mean twospotted spider mite populations on tomatoes treated with different insecticide programs. Mills River, NC. 2014.

Insecticide	Rate/A	Applic. date	Applic method	Mites per leaflet 7/9	7/16	7/23	8/6	8/13	8/20	CMD
Admire 4.6SC	10.5 oz	6/11	Drip	0.1a	0.0a	0.5a	13.5a	15.4a	45.5a	413.6a
Coragen 1.67SC	4.0 oz	6/11, 7/23	Drip							
Venom 70SG	6.0 oz	7/8	Drip							
Admire 4.6SC	10.5 oz	6/11	Drip	0.0a	0.2a	1.1a	21.8a	10.4a	41.1a	457.4a
Coragen 1.67SC	4.0 oz	6/11, 7/23	Drip							
Venom 70SG	6.0 oz	7/8	Drip							
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar							
Radiant 1.67SC	6.0 oz	8/18	Foliar							
Dimethoate 4E	16.0 oz	6/13, 6/20	Foliar	0.0a	0.3a	0.7a	16.1a	19.7a	39.6a	454.7a
Radiant 1SC	6.0 oz	6/30, 7/15, 8/4,	Foliar							
Coragen 1.67SC	3.5 oz	8/18	Foliar							
Danitol 2.4EC	10.6 oz	7/7, 7/29	Foliar							
		7/22, 8/11, 8/25								
Control	—	—	—	0.0a	0.4a	0.8a	11.6a	16.3a	30.8a	354.7a

Means with the same column followed by the same letter are not significantly different by LSD (P = 0.05).

Table 4. Mean yield and percentage of marketable and culled fruit from tomatoes treated with different insecticide programs. Mills River, NC. 2014.

Insecticide	Rate/A	Applic. date	Applic. method	Total Yield (Tons/A)	% of total yield		% fruit damage (culls)			
					Market.	Culls	Lep	Stink bug	Thrips	Other
Admire 4.6SC	10.5 oz	6/11	Drip	35.6a	65.6a	34.4b	4.8a	14.3b	3.8a	11.5a
Coragen 1.67SC	4.0 oz	6/11, 7/23	Drip							
Venom 70SG	6.0 oz	7/8	Drip							
Admire 4.6SC	10.5 oz	6/11	Drip	31.8a	67.4a	32.6b	2.0a	8.6b	6.9bc	15.0a
Coragen 1.67SC	4.0 oz	6/11, 7/23	Drip							
Venom 70SG	6.0 oz	7/8	Drip							
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar							
Radiant 1.67SC	6.0 oz	8/18	Foliar							
Dimethoate 4E	16.0 oz	6/13, 6/20	Foliar	36.5a	78.2b	21.8a	3.3a	1.5a	4.8ab	12.2a
Radiant 1SC	6.0 oz	6/30, 7/15, 8/4, 8/18	Foliar							
Coragen 1.67SC	3.5 oz	7/7, 7/29	Foliar							
Danitol 2.4EC	10.6 oz	7/22, 8/11, 8/25	Foliar							
Control	—	—	—	41.5a	59.7a	40.3b	7.2a	13.7b	9.2c	10.3a

Means with the same column followed by the same letter are not significantly different by LSD (P = 0.05).

Table 5. Mean percentage lepidopteran and stink bug damaged tomato fruit by date on tomatoes treated with different insecticide programs. Mills River, NC. 2014.

				% Lepidopteran damage				% Stink bug damage			
Insecticide	Rate/A	Applic. date	Applic. method	7/31	8/14	8/21	8/28	7/31	8/14	8/21	8/28
Admire 4.6SC	10.5 oz	6/11	Drip	4.4ab	2.7a	3.1a	3.5a	1.3a	6.7b	24.8b	39.0b
Coragen 1.67SC	4.0 oz	6/11, 7/23	Drip								
Venom 70SG	6.0 oz	7/8	Drip								
Admire 4.6SC	10.5 oz	6/11	Drip	1.1a	1.5a	1.7a	2.2a	4.8a	11.1b	12.5ab	8.9a
Coragen 1.67SC	4.0 oz	6/11, 7/23	Drip								
Venom 70SG	6.0 oz	7/8	Drip								
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar								
Radiant 1.67SC	6.0 oz	8/18	Foliar								
Dimethoate 4E	16.0 oz	6/13, 6/20	Foliar	3.9ab	1.6a	1.7a	1.6a	1.1a	1.9a	1.6a	0.0ba
Radiant 1SC	6.0 oz	6/30, 7/15, 8/4, 8/18	Foliar								
Coragen 1.67SC	3.5 oz	7/7, 7/29	Foliar								
Danitol 2.4EC	10.6 oz	7/22, 8/11, 8/25	Foliar								
Control	—	—	—	6.9b	3.0a	3.1a	3.5a	6.2a	10.0b	17.7b	29.9b

Means with the same column followed by the same letter are not significantly different by LSD (P = 0.05).

Comparison of Drip Chemigation versus Foliar Sprays for Pepper Insect Control

Tomato, *Solanum lycopersicon* L. 'Florida 47'

Green peach aphid (PA): *Myzus persicae* (Sulzer)
Thrips (FT): *Frankliniella tritici* (Fitch) and *Frankliniella occidentalis* (Pergande)
Insidious flower bug (IFB): Orius insidiosus (Say)
Tomato fruitworm (TFW): *Helicoverpa zea* (Boddie)
Stink bugs (SB): *Halyomorpha halys* Stål and *Euschistus servus* (Say)

The trial was conducted at the Mountain Horticultural Crops Research Station in Mills River, NC. Six-wk-old tomato transplants (cv. Paladin) were set on 30 May in black plastic mulch with drip irrigation. Plots consisted of two 25-ft long rows on 5-ft centers, with a non-treated row separating treatment rows. Rows consisted of double rows with plants spaced 1 ft apart within rows, and treatments were replicated four times and arranged in a RCBD. The objective of the experiment was to compare control of the insect complex attacking tomato in western NC using drip irrigation of neonicotinoids and Coragen to foliar sprays of a more diverse group of insecticides. A combination of drip chemigation plus supplemental foliar treatments and a non-treated control were also included. Insecticides, application methods and dates of applications are shown in the tables. Except for the control, transplants used in all treatments were treated with Admire 4.6F (0.44 oz/10,000 plants) as a transplant tray drench four days before planting in the field. Drip applications were made with a CO_2 powered injector into a one-inch ploy tube connected to treatment drip lines, and foliar applications were made with a CO_2 powered backpack sprayer delivering 25 to 90 GPA (volume increased as plants grew) through 3 hollow cone nozzels per side of each row, effectively applying materials through 6 nozzles per row. Plants were staked and strung as needed, and sprayed with a standard season-long fungicide program.

Flower thrips were monitored by removing 10 flowers per plot, placing them in a vial of 50% ETOH, and counting dislodged adults and immatures as well as predatory insidious flower bugs (*Orius insidiosus*) under a stereomicroscope. Green peach aphids were monitored by recording the number of apterous aphids on 10 leaves per plot. Season cumulative thrips-, aphid- and mite-days were calculated by multiplying the average counts on consecutive sample dates by the sample interval (days) and summing values from all dates. Mature fruit were harvested from all plots on 31 Jul, and 14 and 21 August, then weighed, graded and assessed for insect damage. All data were subjected to two-way ANOVA and means were separated by LSD ($P = 0.05$).

Results

The drip only treatment received four total insecticide applications, including Admire + Coragen 3-wks after planting, Scorpion 6.5-wks after planting, and a second application of Coragen on 5 August. In addition to these same drip applied insecticides, the drip + foliar treatment received two supplemental foliar sprays of Danitol for stink bug. The foliar only treatment received a total of 10 applications of four different insecticides.

The cool temperatures in 2014 contributed to relatively low insect pressure throughout the season. Green peach aphid populations were low, with populations peaking at only 15.5 aphids per leaf on 13 August. The Admire applied 3-wk after planting provide excellent season-long suppression of aphids, while the foliar treatment did not different significantly from the control (Table 1). Thrips, consisting predominately of *F. tritici*, were also low, and differences among treatments were recorded only one sample date (23 Jul), when the foliar treatment had significantly fewer thrips than all other treatments; this was likely due to the Radiant treatment on 15 July (Table 2). Insidious flower bugs were also of low intensity, peaking at only about 4 per flower on 23 July (Table 3). Numbers on 23 July and seasonal cumulative IFB days were significantly lower in the foliar treatment compared with all other treatments.

Across all treatments, total yield averaged 21.8 tons per acre, and there were no differences in either total or marketable yield among treatments (Table 4). Lepidopteran damage was extremely low in all treatments, but brown marmorated stink bug resulted in a total of 16.4% damage in the control. Damage did not appear until the mid August harvest, when the percentage of fruit with stink bug damage increased to almost 18% in the control. The highly aggregated distribution of BMSB in plots was evident by the absence of significant differences among treatments on 14 August. Nonetheless, the Scorpion application made on 15 July in the drip treatments appeared to suppress BMSB damage through the 14 August harvest, but damage increased considerably by 2 September (Table 5). Interestingly, the two Danitol applications made to the foliar treatment suppressed BMSB damage on 2 September, while it had no effect in the drip + foliar treatment, but damage was highly variable with no significant differences among treatments.

Table 1. Mean green peach aphid populations on peppers treated with different insecticide programs. Mills River, NC. 2014.

Insecticide	Rate/A	Applic. date	Applic method	Aphids per 10 leaf					CAD
				7/16	7/23	8/6	8/13	8/20	
Admire 4.6SC	10.5 oz	6/23	Drip	0a	0.0a	0.0a	0.0a	0.3a	0.9a
Coragen 1.67SC	4.0 oz	6/23, 8/5	Drip						
Scorpion 35SL	10.5 oz	7/15	Drip						
Admire 4.6SC	10.5 oz	6/23	Drip	0a	0.3a	0.0a	0.3a	0.3a	6.1a
Coragen 1.67SC	4.0 oz	6/23, 8/5	Drip						
Scorpion 35SL	10.5 oz	7/15	Drip						
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar						
Dimethoate 4E	16.0 oz	6/13, 6/20	Foliar	0.3a	0.5a	7.3a	15.5a	12.3a	237.1b
Radiant 1SC	6.0 oz	6/30, 7/15, 8/4	Foliar						
Coragen 1.67SC	3.5 oz	7/7, 7/29, 8/18	Foliar						
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar						
Control	—	—	—	0a	1.0a	1.0a	1.0a	3.3a	54.3b

Means with the same column followed by the same letter are not significantly different by LSD (P = 0.05).

Table 2. Mean thrips populations in pepper flowers treated with different insecticide programs. Mills River, NC. 2014.

Insecticide	Rate/A	Applic. date	Applic method	Thrips per 10 flowers					CTD
				7/2	7/9	7/16	7/23	8/6	
Admire 4.6SC	10.5 oz	6/23	Drip	9.3a	4.5a	3.0a	7.5b	3.9a	191.2a
Coragen 1.67SC	4.0 oz	6/23, 8/5	Drip						
Scorpion 35SL	10.5 oz	7/15	Drip						
Admire 4.6SC	10.5 oz	6/23	Drip	9.0a	8.0a	2.0a	6.3b	5.1a	203.1a
Coragen 1.67SC	4.0 oz	6/23, 8/5	Drip						
Scorpion 35SL	10.5 oz	7/15	Drip						
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar						
Dimethoate 4E	16.0 oz	6/13, 6/20	Foliar	3.0a	3.8a	1.8a	0.5a	7.6a	107.6a
Radiant 1SC	6.0 oz	6/30, 7/15, 8/4	Foliar						
Coragen 1.67SC	3.5 oz	7/7, 7/29, 8/18	Foliar						
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar						
Control	—	—	—	9.0a	5.8a	2.3a	7.0b	4.8a	194.3a

Means with the same column followed by the same letter are not significantly different by LSD (P = 0.05).

Table 3. Mean predatory *Orius insidiosus* bus in pepper flowers treated with different insecticide programs. Mills River, NC. 2014.

Insecticide	Rate/A	Applic. date	Applic method	*O. insidiosus* per 10 flowers 7/2	7/9	7/16	7/23	8/6	CIFBD
Admire 4.6SC	10.5 oz	6/23	Drip	0	1.5a	0.8a	4.0b	1.6a	68.8b
Coragen 1.67SC	4.0 oz	6/23, 8/5	Drip						
Scorpion 35SL	10.5 oz	7/15	Drip						
Admire 4.6SC	10.5 oz	6/23	Drip	0	1.0a	1.5a	4.0b	2.0a	73.3b
Coragen 1.67SC	4.0 oz	6/23, 8/5	Drip						
Scorpion 35SL	10.5 oz	7/15	Drip						
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar						
Dimethoate 4E	16.0 oz	6/13, 6/20	Foliar	0	0.8a	0.3a	0.8a	1.6a	25.8a
Radiant 1SC	6.0 oz	6/30, 7/15, 8/4	Foliar						
Coragen 1.67SC	3.5 oz	7/7, 7/29, 8/18	Foliar						
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar						
Control	—	—	—	0	2.3a	1.5a	3.0b	1.5a	68.3b

Means with the same column followed by the same letter are not significantly different by LSD (P = 0.05).

Table 4. Mean yield and percentage of marketable and culled fruit from peppers treated with different insecticide programs. Mills River, NC. 2014.

Insecticide	Rate/A	Applic. date	Applic. method	Total Yield (Tons/A)	% of Total		% of Total		
					Marketable	Culls	Lep	Stink bug	Other
Admire 4.6SC	10.5 oz	6/23	Drip	21.8a	81.8a	18.2a	1.5a	13.1a	3.6a
Coragen 1.67SC	4.0 oz	6/23, 8/5	Drip						
Scorpion 35SL	10.5 oz	7/15	Drip						
Admire 4.6SC	10.5 oz	6/23	Drip	18.7a	85.6a	14.4a	1.6a	8.3a	4.5a
Coragen 1.67SC	4.0 oz	6/23, 8/5	Drip						
Scorpion 35SL	10.5 oz	7/15	Drip						
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar						
Dimethoate 4E	16.0 oz	6/13, 6/20	Foliar	24.1a	85.1a	14.9a	1.4a	5.5a	8.0a
Radiant 1SC	6.0 oz	6/30, 7/15, 8/4	Foliar						
Coragen 1.67SC	3.5 oz	7/7, 7/29, 8/18	Foliar						
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar						
Control	—	—	—	22.5a	76.9a	23.1a	1.7a	16.4a	5.0a

Means with the same column followed by the same letter are not significantly different by LSD (P = 0.05).

Table 5. Mean percentage stink bug damaged peppers by date in plots treated with different insecticide programs. Mills River, NC. 2014.

Insecticide	Rate/A	Applic. date	Applic. method	% Stink bug damage		
				7/31	8/14	9/2
Admire 4.6SC	10.5 oz	6/23	Drip	0a	6.3a	33.9a
Coragen 1.67SC	4.0 oz	6/23, 8/5	Drip			
Scorpion 35SL	10.5 oz	7/15	Drip			
Admire 4.6SC	10.5 oz	6/23	Drip	0a	3.5a	25.5a
Coragen 1.67SC	4.0 oz	6/23, 8/5	Drip			
Scorpion 35SL	10.5 oz	7/15	Drip			
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar			
Dimethoate 4E	16.0 oz	6/13, 6/20	Foliar	0.4a	7.6a	5.5a
Radiant 1SC	6.0 oz	6/30, 7/15, 8/4	Foliar			
Coragen 1.67SC	3.5 oz	7/7, 7/29, 8/18	Foliar			
Danitol 2.4EC	10.6 oz	8/11, 8/25	Foliar			
Control	—	—	—	0a	17.9b	21.4a

Means with the same column followed by the same letter are not significantly different by LSD (P = 0.05).

Tomato Miticide Trial

Tomato, *Lycopersicon esculentum* Mill. 'Florida-47'

Twospotted spider mite (TSSM), *Tetranychus urticae* Koch
Predatory mite, *Phytoseiulus persimilis* Athias-Henriot

This study was conducted at the Mountain Research Station, Waynesville, NC. Six-wk-old 'FL-47' tomato transplants were set on 28 May on black plastic mulch with drip irrigation. Plots consisted of single 20-ft long rows on 10-ft centers. Plants were spaced 1.5 ft within rows, and treatment rows were separated by a non-treated row of tomatoes. Each treatment was replicated four times and arranged in a RCBD. Tomatoes were staked and strung as needed and sprayed with a standard fungicide program. Two days before planting, transplants were infested with TSSM while in transplant trays. Miticide treatments are shown in Table 1. With the exception of the Levo and PFR-97 treatments, which were applied on a preventive weekly schedule beginning on 8 July when TSSM densities averaged 0.2 mites per leaflet, initial treatment applications were made at a threshold of approximately 3 mites per leaflet. A second application was applied if or when mites reach approximately 10 per leaflet. With the exception of the Athena and Gladiator treatments, all other treatments were sprayed with a similar insecticide program consisting of alternating weekly applications of Coragen (5 oz/A), Radiant (6 oz/A), and Avaunt (3.5 oz/A), with one application of Admire (1.5 oz/A) applied for aphids on 5 August. The Athena and Gladiator treatments were sprayed weekly with Brigade 2EC (6.4 oz/A) and Mustang Maxx 0.8EC (4 oz/A), respectively, which was not included when Athena and Gladiator applications were made.

All treatment applications were made with a CO_2 backpack sprayer equipped with a 3-nozzle wand used to apply materials to both sides of treatment rows – i.e., materials were effectively applied through 6 hollow cone nozzles per row at 30 psi. Levo and PFR-97 applications on 8 and 14 July were made at 50 GPA, while miticide treatments made on 21 July were at 70 GPA, and all remaining applications at 100 GPA. Mite populations were monitored by observing 10 leaflets per plot with a 10X visor lens and counting all motile TSSM. Data was analyzed using a two-way ANOVA and means were separated by LSD (P=0.05). Data were transformed before ANOVA using either sqrt or log transformation, but results in tables are shown as back transformations.

On 22 August, a second trial was conducted in a previously established tomato trial that was planted on 21 May, and which was established to compare different neonicotinoid insecticides applied via drip irrigation on 8 July. The plot had mite densities uniformly dispersed among treatments that averaged about 5 mites per leaflet. The plot was had populations of the predatory mite *Phytoseiulus persimilis*, which was inoculated in an adjacent plot. Miticide treatments applied on 22 August and included Acramite 50WP (1 lb/A), Nealta 1.67SC (13.7 oz/A), Nealta (13.7oz/A) + Cohere (10 oz/A), Nealta (13.7 oz/A) + LI-700 (1 qt/A), and a non-treated control. TSSM and *P. persimilis* were monitored as described above at 3 and 7 days after treatment, and data were subjected to two-way ANOVA and means separated by LSD (P = 0.05).

Results

The Brigade applications made previous to the Athena treatment were effective in suppressing TSSM populations, which is why Athena was not applied until 5 August. The combination of Brigade and one Athena application helped to maintained TSSM populations at very low levels, never exceeding 5 mites/leaflet. Among those treatments applied on 21 July, Gladiator, Acramite, and Nealta + Cohere + Dimethoate had the most effective knockdown effect, while Nealta was less effective when applied alone versus with Cohere or LI-700. Acramite appeared to have the strongest residual activity. Among the products applied preventively with multiple applications, Levo did suppress mites and delayed the buildup of populations, while PFR-97 did not differ from the control on any sample date. Seasonal total cumulative mite days for all treatments are shown in Fig. 1, and illustrate the rate of TSSM increase following applications.

It should be noted that PFR-97 is an arthropod fungal pathogen, and thus likely sensitive to some of the maintenance fungicides applied weekly to plots, including mancozeb, chlorothalonil, and strobilurin. PFR-97 applications were generally made three to four days before and after fungicide applications. Also, Levo, which contains the active ingredient oxymatrine from the roots of the plant *Sophora flavescens*, exhibited phytotoxic effects to tomato foliage when applied at the 50 GPA rate, or a concentration of formulated product of 0.65% (2.54 oz product per 3 gal water). Phytotoxicity was not observed later in the season when product was applied at 100 GPA, or a concentration of 0.33%.

Results from the second trail in which Acramite and several Nealta treatments were applied to a tomato plot infested with both TSSM and the predator *Phytoseiulus persimilis* are shown in Fig 2 and 3, respectively. At 3-days after treatment, all treatments significantly reduced mite densities below the control (Fig. 2), where mites averaged 23 mites/leaflet. By 7-days after treatment there was no difference among treatments, with TSSM densities in the control declining to about 15 mites/leaflet and densities in all miticide treatments increasing. This trial also provided the opportunity to gauge the effect of treatments on field populations of *Phytoseiulus persimilis*. Although the limited data set makes it difficult to make conclusions about the effect of treatments on predator populations, none of the treatments appeared to have devastating effects *P. persimilis*. There were no significant differences among treatments at 3 or 7-DAT, and during this time predator densities increased by a factor of 1.6-fold across all treatments.

Table 1. Mean twospotted spider mite populations on tomatoes treated with different acaricides. Waynesville, NC. 2014.

			Mites per leaflet							Cumulative mite-days
Treatment	Rate/A	Applic. Date[1]	7/15	7/24	7/28	8/4	8/11	8/18	8/25	
Athena	10 oz	8/5	0.0a	0.4a	1.3ab	2.8a	4.7a	3.7a	4.7b	104.2a
Gladiator	19 oz	7/21, 8/5	0.5a	1.2ab	2.8abc	9.3bcd	5.9ab	8.8bc	4.8b	214.4ab
Nealta	13.7 oz	7/21, 8/5	1.8a	8.8cd	13.2e	26.5d	9.7b	7.0ab	3.1a	450.6bc
Nealta + Cohere	13.7 oz 10 oz	7/21, 8/5	1.7a	4.8bcd	5.6cde	12.4bcd	11.1b	10.4bc	3.6ab	319.0ab
Nealta + LI700	13.7 oz 1 qt	7/21, 8/5	1.1a	3.1bc	5.8cde	22.5d	9.2ab	7.6ab	4.7b	348.3abc
Nealta + Cohere + Dimethoate	13.7 oz 10 oz 1 pt	7/21, 8/5	0.4a	1.1ab	2.5abc	5.2abc	11.0ab	9.8bc	4.8b	222.9ab
Acramite 50WP	1 lb	7/21	1.0a	2.1bc	0.9a	3.6ab	9.4ab	12.3bc	5.1bc	217.5a
Levo	42 oz	7/8, 7/14, 7/21, 7/28, 8/5, 8/12	0.9a	4.8bcd	6.6bcd	14.0cd	31.6c	33.9de	10.4d	664.2cd
PFR-97	1 lb	7/8, 7/14, 7/21, 7/28, 8/5, 8/12	1.2a	10.3d	15.2e	21.0d	55.5c	19.5cd	8.4cd	857.0d
Control	—	—	1.4a	4.1bcd	9.9de	30.5d	36.8c	34.5e	10.1d	836.8d

Means within the same column followed by the same letter are not significantly different by LSD (P = 0.05).

[1]Applications made on 8 and 14 July were made at 50 GPA, those on 21 July at 71 GPA, and all others at 100 GPA.

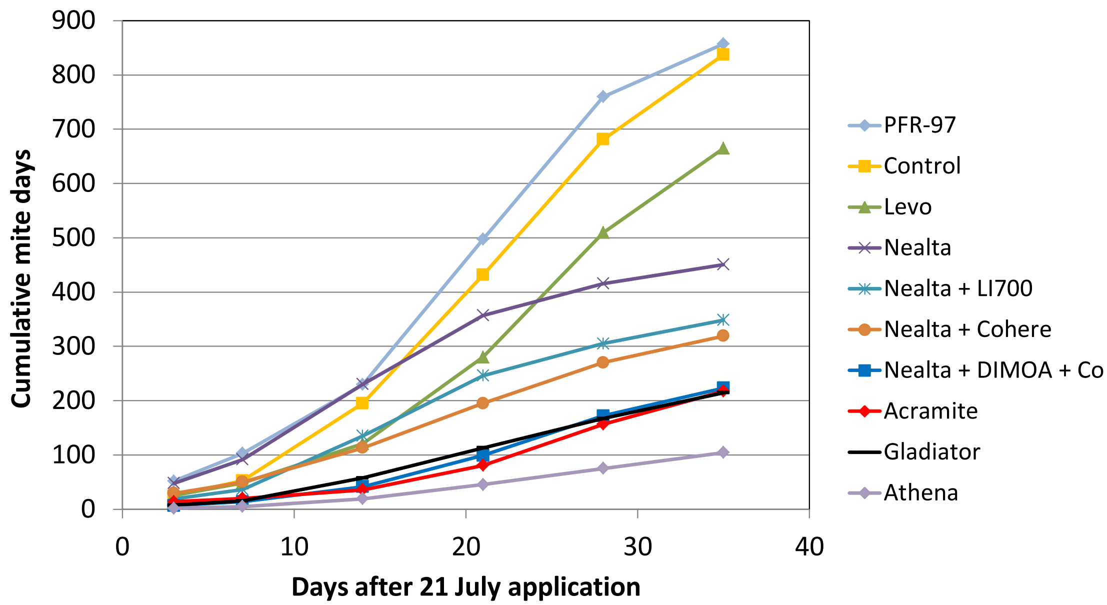


Fig. 1. Cumulative mite days on tomatoes treated with various acaricides. Waynesville, NC 2014.

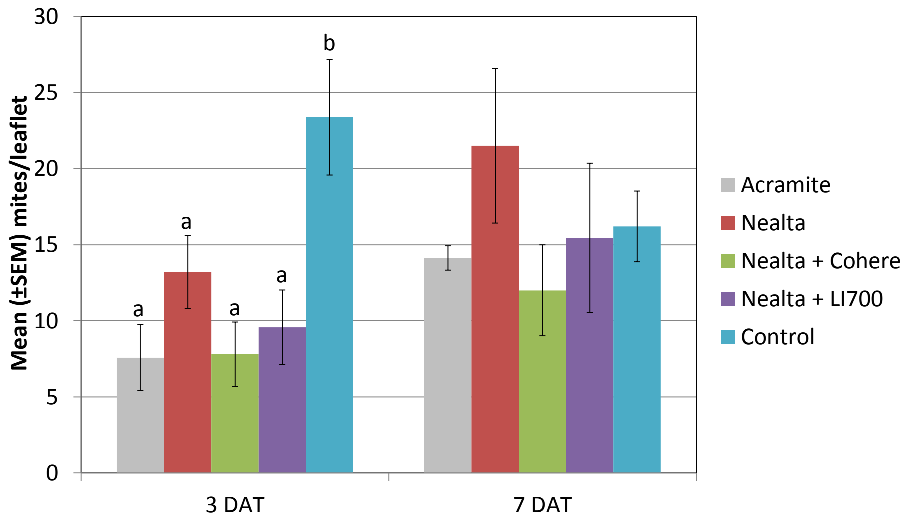


Fig. 2. Mean (±SEM) twospotted spider mites per leaflet on tomatoes at 3 and 7 days after treatment. Letters at 3-DAT signify singificant differences ($LSD_{P=0.05}$). Mills River, NC. 2014

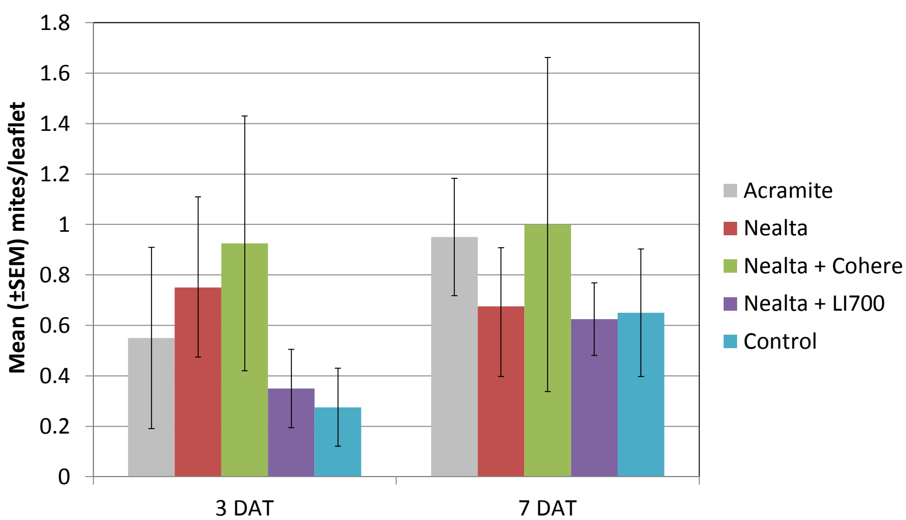


Fig. 3. Mean (±SEM) *Phytoseiulus persimilis* per leaflet on tomatoes at 3 and 7 days after treatment. ANOVA's not significant on either date. Mills River, NC. 2014

Comparison of Chemigation versus Foliar Application of Insecticides for Tomato Insect Control – 2014 On Farm Tests

Commercial vegetable production in the piedmont and mountains of North Carolina consists predominately of fruiting vegetables and cucurbits grown for the fresh market. These high value crops have a low tolerance for damage and demand high levels of insect control. Historically, control has been achieved predominately with scheduled, usually weekly, foliar applications of insecticides. This system has served the vegetable industry well in that it has provided the high levels of insect control needed for the profitable production of crops. However, there are potential environmental and human-health costs associated with foliar insecticide sprays that are not captured in production economic analyses. These costs include risks of spray drift and pesticide-contaminated soil erosion moving into sensitive environmental resources, exposure of non-target organism to pesticides, and exposure of farm workers to pesticides accumulating on plant surfaces. This latter issue is of particular concern in crops such as tomatoes, peppers, and cucurbits that have high labor inputs.

The use of drip irrigation systems for the delivery of systemic insecticides for insect control offers several advantages over foliar spraying, including longer residual activity of insecticides, elimination of adverse effects associated with spray drift and soil erosion, and reduced exposure of farmworkers to pesticides. The availability of two different groups of insecticides with different modes of action (i.e., neonicotinoids and diamides) that control a diversity of insect pests offers the opportunity for board spectrum insect control and potentially a new, reduced-risk approach to insect management for vegetable production. The objective of this study was to compare the level of insect control and profitability resulting from insecticides applied via drip irrigation versus conventional foliar spraying in commercial tomato fields.

Materials and Methods

<u>On-Farm Studies</u>: Comparisons between chemigation and conventional foliar insecticide management systems were conducted at five locations – one farm each in Madison, Macon, and Rowan County, and two farms in the Mills River area of Henderson County. At each site, a minimum of two tomato fields ranging in size from 3 to ~15 acres were used as non-replicated treatments – one was designated the chemigation treatment and the other the conventional treatment. At the Rowan and one Henderson County sites there were two fields each of chemigation and Conventional treatments, but results from these locations were treated as a single replicate by pooling results across the two fields. Planting dates at the Rowan (Row), Macon (Mac), Madison (Mad), Henderson-D (Hend-D) and Henderson-J (Hend-J) sites were 26 April, 5 May, 1 June, 10 June and 21 June, respectively.

In chemigation treatments, insecticides were applied by growers through drip irrigation systems according to the schedule shown in Table 1, while in the conventional treatment all insecticides were applied via foliar spray systems. The three applications of Coragen at Hend-D and Hend-J compared to only two at the other locations were made because of high late-season populations of cabbage looper. Decisions regarding insecticides applied to the chemigation treatment were made by the project director (JFW), while the grower cooperator made decisions regarding the choice and timing of insecticides sprayed on the conventional treatment. Foliar insecticide treatments in conventional plots varied among growers, but generally consisted of weekly sprays of various insecticides including Dimethoate, Coragen, Radiant, Lannate, and various pyrethroids.

Table 1. Schedule of insecticide applications made through drip irrigation system to chemigation treatments in on-farm tomato and pepper studies.

Weeks after transplanting	Insecticide (rate/acre)	Target pest(s)
0 (Transplant tray treatment)	[1]AdmirePro 4.6SC (0.44 oz per 10,000 plants)	Thrips, flea beetles
2 to 3 wks	Coragen (4 oz/) + [1]Admire Pro (10.5 oz)	Fruitworm, Armyworms, Whiteflies Aphids, Flea beetles Whitefiles
5 to 6 wks (or 21 days before 1st harvest)	Venom 70SG (6 oz) **or** Scorpion 35SL (10.5 oz)	Stink bugs, whiteflies, flea beetle
8 wks	Coragen (5 oz)	Fruitworm, Armyworms
11 wks	[2]Coragen (5 oz)	Cabbage looper

[1]Where generic imidacloprid formulations were used, rates were adjusted according to the label.

2The 11-wk application was made at the Hend-D and and Hend-J locations only.

Data Collection: Each study site was visited at approximately about 10-day intervals to monitor for pest populations and estimate crop damage caused by insects. At each scouting visit, insect and mite populations were monitored at a minimum five random sites per treatment, with one additional sample site for each two-acre increase in field size above five acres. At each sample site, twospotted spider mites and immature whiteflies were recorded on 10 leaflets, and the number of aphids and thrips on 10 leaves. In addition, 10 flowers were removed, placed in 50% ETOH and the number of thrips and insidious flower bugs counted. Insect densities are presented as season cumulative insect days. Finally, 50 fruit were examined for damage by insects – lepidopteran and stink bugs – at each monitoring site (i.e., minimum of 250 fruit per treatment).

Growers provided pesticide application records for both treatments, which were used to determine the total insecticide active ingredients applied and cost for each treatment. These records were also used for surrogate estimates of risk of the insecticide programs to farmworkers and the environment. Risk to farmworkers was based on how many days per season each of the fields managed with the two application programs were inaccessible due to restrictions on re-entry of fields after pesticide applications. Each pesticide has an established re-entry interval on the label, and the cumulative number of days per season for all pesticide applications was calculated. To estimate the relative environmental impact of chemigation and conventional management programs, pesticide records were used to calculate seasonal cumulative Environmental Impact Quotient (EIQ) field ratings. EIQ values for each insecticide were obtained from the New York State IPM Program list of EIQ values, available at the Cornell IPM website. The EIQ method is a widely accepted measure of environmental impact of pesticides.

A partial budget analysis was used to evaluate the economic impact resulting from using chemigation versus conventional insect management programs. The analysis involved comparing the costs of chemigation with conventional programs and evaluating the value of the fruit from each system. Previous small plot replicated experiments have not detected differences in total yields between chemigation and conventional insecticide application with the insecticides used in these studies, so total yield was held constant for both treatments. Yields varied for each location depending on the historical average for each farm, which varied from 1800 to 2500 boxes (25 lb) per acre. Marketable yield was adjusted based on estimates of insect damage during scouting visits to fields. For example, if 5% of fruit was damaged by insects, marketable yield was reduced by 5% (e.g., at 5% damage, marketable yield would be reduced from 2500 to 2375 boxes per acre). Hence, the value of marketable fruit harvested from each plot served as gross profit. The value of fruit was based on average USDA Agricultural Marketing Service price reports during the harvest periods of these studies, and averaged 47¢ per lb across dates. Net profits were estimated by subtracting all costs from gross profits. With the exception of pesticide costs and box and brokerage charges, all other production costs were held constant.

Results

Insecticide Inputs. No foliar insecticide applications were made to the Chemigation treatment at any location, although miticides were applied at the Mac, Mad and Row sties. Insecticide programs varied considerably among cooperators, both in the type of materials applied and frequency of applications. Total foliar sprays applied to the conventional treatments ranged from 5 to 17; averaging 10 across all locations. With the exception of the Mad site, total pounds of active ingredients of insecticides and miticides applied to the chemigation treatment were lower than the conventional treatment, and across all locations the average pounds of active ingredient applied to the chemigation and conventional treatment was 1.04 and 1.76, respectively (Fig. 1). Neonicotinoids and diamides accounted for the majority of insecticides applied to chemigation treatments, while organophosphates and carbamates accounted for about 67% of insecticides applied to the conventional treatments.

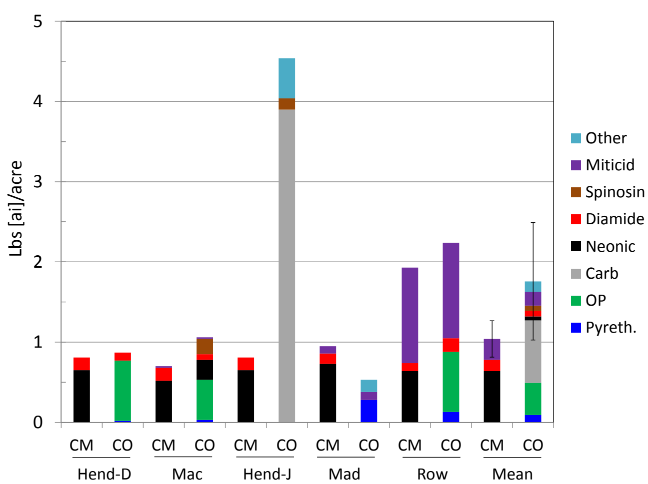


Fig. 1. *Total pounds of insecticide (active ingredient) applied to chemigation (CM) and conventional (CO) treatments.*

The reduced-impact of the chemigation program to the environment was evident in the significantly reduced Environmental Impact Quotient (EIQ) field rating value of 23.7 for the chemigation versus 45.0 for the foliar spray program (Fig. 2). EIQ ratings were lower in the chemigation versus foliar spray treatments at all locations except Mad. The reduced insecticide inputs and application method of the chemigation treatments also resulted in a significant reduction in the number of days that fields were inaccessible to field workers because of reentry intervals following application. Averaged across all locations, total reentry days accumulating in the chemigation and conventional treatments were 1.9 and 12.9, respectively (Fig. 3). The greatest disparity was at the Hend-J site, which relied on frequent applications of methomyl that has a 2-day reentry interval.

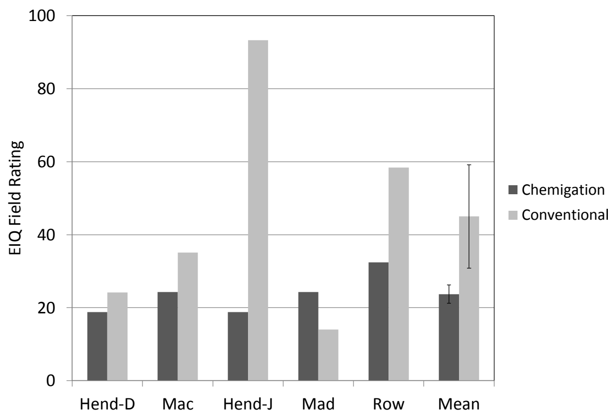


Fig. 2. *Environmental impact quotient field resulting from insecticides applied via chemigation and conventional foliar sprays.*

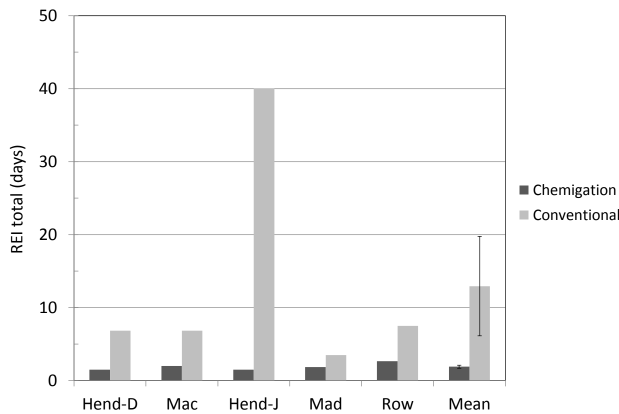


Fig. 3. *Cumulative number of days that fields were in accessible due to reentry interval restrictions in of insecticides applied by chemig-ation and conventional foliar sprays.*

Indirect Pest Control. Only three indirect insect pests were present at one or more study sites – potato aphids, thrips, and twospotted spider mites. Potato aphid populations were very low at all locations and never exceeded threshold levels. Across all locations, mean season-total aphid-days averaged 4.44 and 2.8 in the chemigation and conventional treatments, respectively (Fig. 4). Thrips populations were also low at all locations except Row, where cumulative thrips days reached 950 in the chemigation treatment and 66.5 in the conventional (Fig. 5). However, thrips were all common flower thrips (*Frankliniella tritici*), which rarely cause damage to fruits. Averaged across all locations, thrips numbers were higher in the with insecticides applied via chemigation and chemigation treatments, but differences

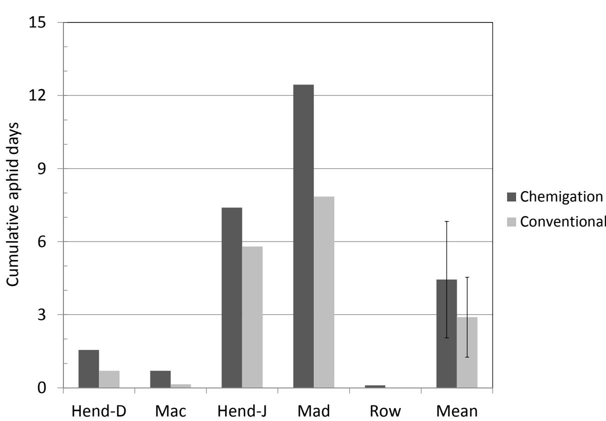


Fig. 4. *Cumulative potato aphid-days in tomatoes treated with conventional foliar sprays.*

were not significant. Finally, twospotted spider mite populations built to high densities in both the chemigation and conventional treatments at the Row site, where miticide applications were made to both treatments in late June and early July (Fig. 6). Although mite populations were slightly higher in chemigation versus conventional treatments at all locations, differences were not significant. These trials are consistent with previous studies that have shown that with the array of insecticides currently available for drip chemigation, flower thrips and spider mites are two pests that require foliar sprays for control.

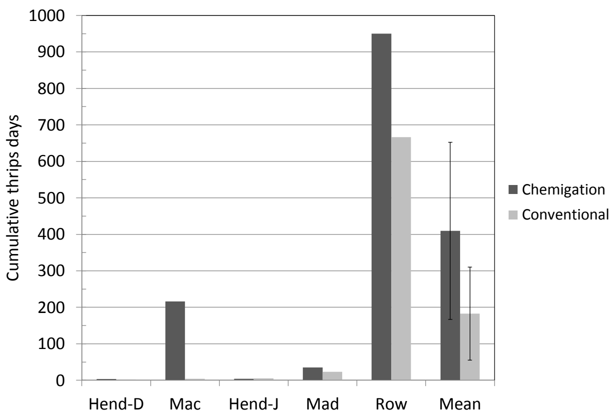


Fig. 5. *Cumulative potato aphid-days in tomatoes where insecticides were applied via chemigation vs. conventional foliar sprays.*

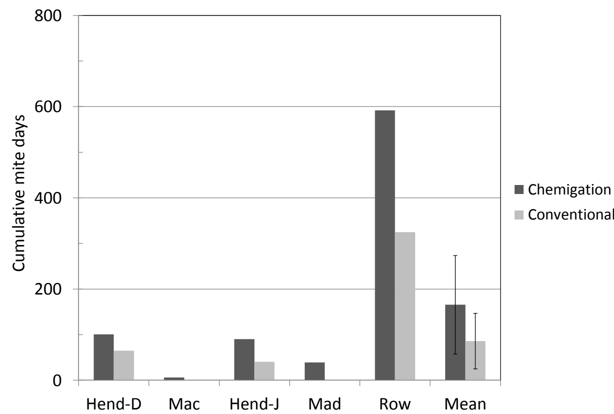


Fig. 6. *Cumulative thrips-days in tomatoes where insecticides were applied via chemigation vs. conventional foliar sprays.*

Fruit Damage and Profitability. Stink bugs and lepidopteran pests accounted for all fruit damage. Tomato fruitworm was the primary cause of lepidopteran damage at all locations except Hend-D and Hend-J, where a September infestation of cabbage looper accounted for the majority of fruit damage. Averaged across all locations, total fruit damage in the chemigation and conventional treatments averaged 1.3 and 2.3%, respectively (Fig. 7). The late season cabbage looper infestations at both Henderson locations required three Coragen drip applications in the chemigation treatments. The detection of live larvae feeding on foliage in early September, approximately 24 days after the second Coragen drip application, suggested the residual activity of late-season Coragen drip applications is no more than 3 wks.

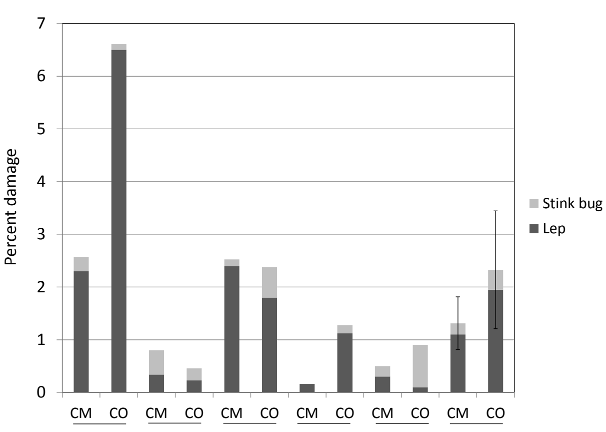


Fig. 7. *Damage to tomato fruit caused by stink bugs and lepidopteran pests in fields with insecticides applied via chemigation (CM) vs. conventional (CO) foliar sprays.*

Net profitability was based on total income generated from marketable yields (i.e., total yield minus insect damaged fruit in each treatment) minus all fixed and variable costs. Variable costs that differed among treatments included 1) packing and box and brokerage costs that varied with marketable yield and 2) insecticide costs. The costs of insecticide plus miticide inputs across all locations were nearly identical for the two treatments, averaging $161.25 and $158.63 in the chemigation and conventional treatments, respectively (Fig. 8). Net profitability generated from the two treatments weas also nearly identical, with the chemigation and conventional treatments returning an average of $3,072 and $2,958 per acre (Fig. 9), a difference of only 3.7%. The greatest disparity in net profits was at the Mac site where chemigation generated $653/acre more than the conventional treatment, and the least disparity was at the Hend-D site where the conventional generated $7.80/acre more than the chemigation treatment.

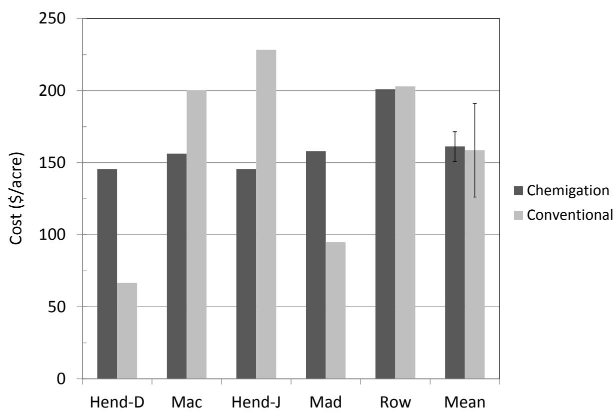


Fig. 8. *Cost of insecticides applied to tomatoes using chemigation (CM) vs. conventional (CO) foliar sprays.*

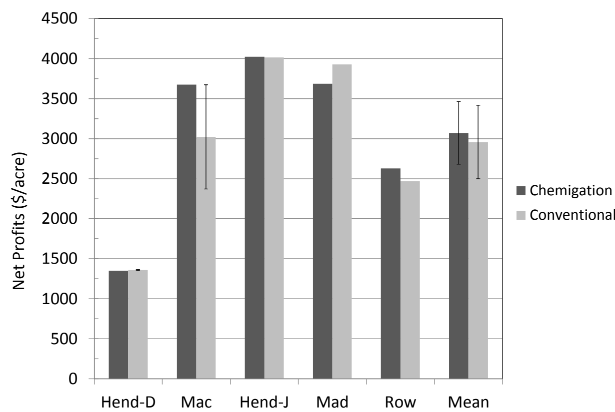


Fig. 9. *Net profits from tomatoes grown with insecticides applied via chemigation (CM) vs. conventional (CO) foliar sprays.*

Conclusions

Results from these trials were consistent with those conducted in 2013 on the same farms. There were no significant differences in either the level of insect damage or net profitability in the two treatments; although in both years damage was slightly lower and net profits were slightly higher in the chemigation vs. conventional foliar treatment. However, chemigation treatments resulted in significant reductions in total insecticide inputs, cumulative number of days fields were inaccessible due to reentry intervals, and reduced impacts on the environment based on lower EIQ ratings. Drip chemigation of insecticides is a delivery system that reduces risk of farmworker exposure to pesticides as well as negative impacts of insecticides on the environment, while at the same time providing a high level of insect control and profitability. Chemigation is particularly well suited to the fresh market fruiting vegetable industry in North Carolina that has high labor inputs and is located adjacent to sensitive water resources.

Acknowledgements

Appreciation is expressed to cooperating growers for their cooperation in completing these trials, which required a significant time commitment and adjustment of their production operations. The PIs also thank Bayer Crop Science, Valent USA, Gowan Company and DuPont Agricultural Company for donating product used in these trials. This study was funded, in part, by a grant from the EPA Regional Agriculture IPM Program.

Apple Insecticide Trial

Apple, *Malus domestica* Borkhauser 'Rome Beauty'

Rosy Apple Aphid (RAA): *Dysaphis plantaginea* (Passerini)
European Red Mite (ERM): *Panonychus ulmi* (Koch)
Green Apple Aphid (GAA): *Aphs pomi* De Geer and *A. spiraecola* Patch
Potato Leafhopper: *Empoasca fabae* (Harris)
Internal-feeding Lepidopterans (LEP):
  Oriental Fruit Moth (OFM), *Grapholita molesta* (Busck)
  Codling Moth (CM): *Cydia pomonella* (L.)
Plum Curculio (PC): *Conotrachelus nenuphar* (Herbst)
Plant Bugs (PB): *Lygus lineolaris* (Palisot de Beauvois)
Apple Maggot (AM): *Rhagoletis pomonella* (Walsh)
Leafrolling Lepidopterans (LR):
  Tufted Apple Bud Moth (TABM): *Platynota idaeusalis* (Walker)
  Redbanded Leafroller (RBLR): *Argyrotaenia velutinana* (Walker)
Brown Marmorated Stink Bug (BMSB): *Halyomorpha halys* (Stål)

This trial was conducted at the Mountain Horticultural Crops Research Station in Mills River, NC, in a mature block of 'Rome Beauty' apples where trees were spaced 13-ft apart within rows on 26-ft centers. Estimated tree-row-volume was approximately 200 GPA. Plots consisted of 2 adjacent trees within a row, and at least one non-treated tree separated treatment plots. Rows with treatments were separated by a non-sprayed row. Each treatment was replicated 4 times and arranged in a RCBD. Insecticides and application dates for all treatments are listed in the tables. Applications were made with a tractor-mounted air-blast sprayer delivering 96 GPA. RAA were monitored by counting the number of live colonies observed on one sample trees in each plot on 28 May and 4 Jun. ERM were counted on 10 leaves per plot with a 10x visor lens. PLH were counted on 10 terminal shoots per plot, and GAA were assessed by counting the number of aphids (and aphid predators) on the most infested leaf on 10 shoots per plot. WAA were assessed by counting the number of live colonies observed during a 1-minute search in each sample plot. An early season assessment for fruit damage caused by plum curculio was conducted on 28 May by observing 50 fruit per plot and recording the number with PC feeding or oviposition scars. An assessment for early season damage caused by internal-feeding lepidopterans was conducted on 18 Jun, which coincided with the end of first generation codling moth flight. At harvest on 23 Sep, 75 fruit per plot were harvested and evaluated for insect damage. All data were subjected to a two-way ANOVA, and means were separated by LSD ($P \leq 0.05$).

RAA populations were relatively high, with almost 30 colonies/tree recorded in the control plots on 4 Jun (Table 1). Due to high variability within replications, however, there were no significant differences among treatments. ERM populations were extremely low in this trial, with a peak density of <0.5 mite/leaf occurring on 26 Jun. PLH populations were relatively high in June with an average of about 24 learfhoppers per 10 shoots in the control on 18 June. All insecticide treatments significantly reduced numbers compared with the control. GAA populations were also relatively high. The highest densities were observed on the season-long Compound X and Altacor treatments and lowest in the control (Table 2), suggesting that these treatments induced aphid populations in some manner. It is unlikely that these higher densities were due to differences in generalist predator populations, because predator densities were extremely low in all treatments – data not shown, but a total of only one predator (a coccinellid) was observed in the control over the four sample dates. WAA were also relatively high in this trial, with the highest densities occurring in the Compound X and Delegate treatments. The low densities in the control again suggest that the WAA outbreaks were induced by certain treatments. Direct damage to fruit was extremely low. Mid-season fruit assessments for PC damage averaged only 1.5% across all treatments on 28 May, and internal lep damage on 18 June averaged 0.5% across all treatments. Other than damage by brown marmorated stink bug at harvest, which affected about 6.5% of fruit across all treatments (Table 3), direct damage to fruit by insects was extremely low and no significant differences existed among treatments.

Table 1. Mean populations of rosy apple aphid (RAA), European red mite (ERM), and potato leafhopper (PLH) on 'Rome Beauty' apples treated with different insecticide programs. Mills River, NC. 2014.

			RAA/tree		ERM/10 leaves			PLH/10 shoots		
Material	Rate/A	Application dates	28 May	4 Jun	28 May	12 Jun	26 Jun	12 Jun	18 Jun	26 Jun
Compound X	—	see note[1]	0.3a	11.8a	0.3a	0.0a	3.0a	0.0a	2.0a	0.3a
Compound X	—	see note[1]	0.5a	13.5a	0.3a	0.0a	0.0a	0.3a	1.5a	0.5a
Altacor 35WDG	3.0 oz	see note[1]	0.5a	14.3a	0.5a	0.0a	0.0a	0.5a	2.0a	0.3a
Delegate 25WDG	6.5 oz	see note[1]	1.8a	21.3a	0.5a	0.0a	0.0a	1.0a	4.0a	0.5a
Actara Closer Delegate 25WDG Intrepid	4.5 oz 5.0 fl oz 5.2 oz 12.0 oz	12 May (PF) 2 Jun, 7 Jul see note[2] 7 Jul	0.5a	7.8a	0.3a	0.0a	0.3a	1.8a	3.3a	0.5a
Control	—	—	4.3a	27.8a	0.5a	0.0a	1.0a	13.8b	23.5b	1.8a

[1] Compound X, Altacor, and Delegate-alone were applied on 12 May (Petal Fall), 19, 22, and 27 May; 2, 6, 16, 23, and 30 Jun; 7, 15, 22, and 29 Jul; 5, 12, 21, 28 Aug; and 5 Sep.

[2] In the combination treatment, Delegate was applied on 22 May, 2 and 16 Jun, 22 Jul, and 5 and 21 Aug.

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Table 2. Mean populations of green apple aphids (GAA) and woolly apple aphids (WAA) on 'Rome Beauty' apples treated with different insecticide programs. Mills River, NC. 2014.

Material	Rate/A	Application dates	GAA/most-infested leaf on 10 shoots				WAA colonies/ 1 minute search	
			4 Jun	12 Jun	18 Jun	26 Jun	25 Jul	14 Aug
Compound X	—	see note[1]	10.5a	169.5a	240.8d	436.5c	15.0ab	29.0bc
Compound X	—	see note[1]	27.0a	247.8a	173.3cd	204.3ab	27.3b	45.5c
Altacor 35WDG	3.0 oz	see note[1]	27.0a	35.0a	60.8ab	150.0ab	4.8ab	1.8a
Delegate 25WDG	6.5 oz	see note[1]	42.0a	36.3a	58.3ab	24.0a	32.0b	17.8b
Actara Closer Delegate 25WDG Intrepid	4.5 oz 5.0 fl oz 5.2 oz 12.0 oz	12 May (PF) 2 Jun, 7 Jul see note[2] 7 Jul	0.5a	10.8a	25.5a	45.5ab	1.5a	0.8a
Control	—	—	1.3a	23.8a	14.3a	14.0a	0.8a	0.8a

[1] Compound X, Altacor, and Delegate-alone were applied on 12 May (Petal Fall), 19, 22, and 27 May; 2, 6, 16, 23, and 30 Jun; 7, 15, 22, and 29 Jul; 5, 12, 21, 28 Aug; and 5 Sep.

[2] In the combination treatment, Delegate was applied on 22 May, 2 and 16 Jun, 22 Jul, and 5 and 21 Aug.

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Table 3. Mean percent insect damage on 'Rome Beauty' apples treated with different insecticide programs. Mills River, NC. 2014.

			% damage at harvest (23 Sep)						
Material	Rate/A	Application dates	Internal-feeding lep	Leafroller	Plum curculio	Plant bug	Apple maggot	San Jose scale	Stink bug
Compound X	—	see note[1]	0.0a	2.0a	1.7a	1.3a	0.0a	0.0a	4.7a
Compound X	—	see note[1]	0.0a	0.3a	0.3a	1.3a	0.0a	0.0a	7.7a
Altacor 35WDG	3.0 oz	see note[1]	0.3a	0.3a	0.0a	0.7a	0.0a	0.0a	5.3a
Delegate 25WDG	6.5 oz	see note[1]	0.7a	1.3a	1.3a	2.0a	0.0a	0.0a	8.3a
Actara Closer Delegate 25WDG Intrepid	4.5 oz 5.0 fl oz 5.2 oz 12.0 oz	12 May (PF) 2 Jun, 7 Jul see note[2] 7 Jul	0.3a	1.3a	1.7a	1.7a	0.0a	0.0a	3.3a
Control	—	—	1.3a	3.0a	2.7a	0.7a	0.0a	0.0a	8.0a

[1] Compound, Altacor, and Delegate-alone were applied on 12 May (Petal Fall), 19, 22, and 27 May; 2, 6, 16, 23, and 30 Jun; 7, 15, 22, and 29 Jul; 5, 12, 21, 28 Aug; and 5 Sep.

[2] In the combination treatment, Delegate was applied on 22 May, 2 and 16 Jun, 22 Jul, and 5 and 21 Aug.

Means in the same column followed by the same letter are not significantly different by LSD (p=0.05).

Apple Miticide Trial

Apple, *Malus domestica* Borkhauser 'Golden Delicious'

European Red Mite (ERM): *Panonychus ulmi* (Koch)
Predatory Mite (PM): *Neoseiulus fallacis* (Garman)

The trial was conducted in a mature block of 'Delicious' apples at the Mountain Horticultural Crops Research Station, Mills River, NC. Trees were approximately 15 ft tall with a tree-row-volume of about 250 GPA. Plots consisted of single trees, and treatment trees were separated by at least 2 non-sprayed trees. Each treatment was replicated four times in a RCBD. To aid in the buildup of ERM populations, all treatments were sprayed with Rimon 0.83EC (20 oz/A) plus Lannate LV (3 pts/A) at petal fall on 12 May, and on 22 May, and 5 and 23 June. No other insecticides were applied, but a season-long standard fungicide program was applied. Three acaricide treatments and a non-treated control were tested, including the biologically based acaricide PFR-97 20WDGapplied at 1 lb/A on 28 May, 5 and 14 June, and a single application of Nealta 1.67SC (13.5 oz/A) and Acramite 50WP (1 lb/A) on 28 May. At the time of the initial application of treatments on 28 May, ERM densities averaged 2.8 mites per leaf. All applications were made with a tractor-mounted airblast sprayer delivering 100 GPA. On each sample date, 10 leaves per tree were removed, placed through a mite brushing machine, and the number of ERM eggs and motiles (immatures and adults) were counted, along with predatory mites. Mite-days were calculated by multiplying the average mite population on consecutive sample dates by the sample interval (days), and then adding mite days on successive sample dates for cumulative mite-days. All data were subjected to a two-way ANOVA and means were separated by LSD ($P = 0.05$). When necessary, data were transformed using square root or log transformations.

Results

ERM populations were relatively high in this trial, peaking at >40 mites/leaf in the control on 11 June, and remaining at >20 mites per leaf for the three subsequent weeks. Acramite and Nealta provided similar levels of ERM control, both of which significantly reduced populations below the control on numerous sample dates. Although mite densities were slightly lower in the Acramite compared with Nealta treatment, these differences were not significant on any sample date (Table 1, 2, 3 and 4), nor were season total cumulative mite days significantly different. Seasonal mite-day accumulations are shown in Fig. 1. PFR-97, a fungal entomopathogen, did not appear to exhibit ERM activity in this trial, with population densities of all life stages not significantly different from the control. In fact, season total cumulative mite-days in the PFR-97 treatment were slightly higher than the control, but these differences were not different. Maintenance fungicide applications applied to plots, including Captan, may have negatively affected this fungal pathogen.

Populations of the predatory mite *Neoseiulus fallacis* were relatively low in this trial, with peak densities in the control of only 0.8 mites per leaf on 8 July (Table 5). Cumulative predatory mite-days did not differ significantly among treatments. Low predator densities were likely due to the multiple Lannate applications.

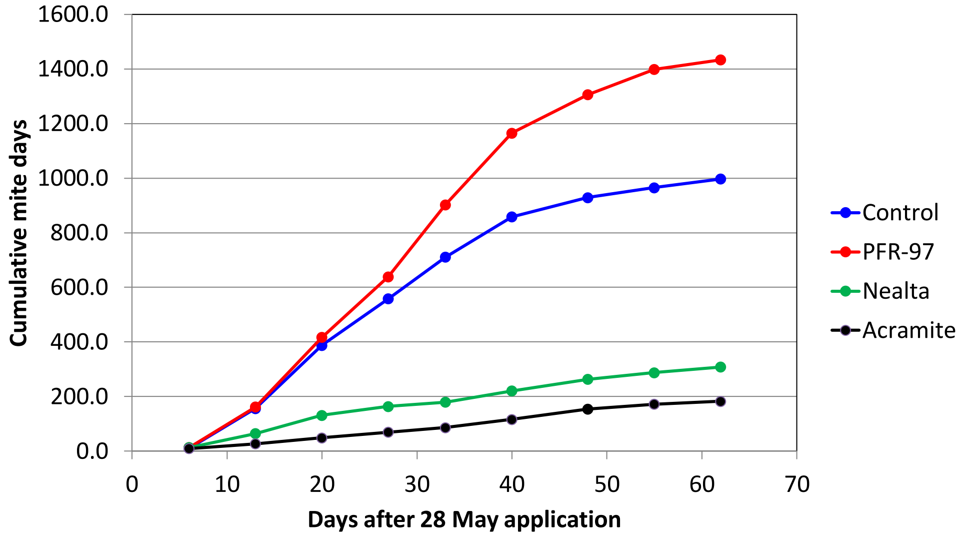


Fig. 1. Mean ERM cumulative mite-days on 'Delicious' apples. Mills River, NC. 2014

Table 1. Mean European red mite motiles (adults + immatures) on 'Delicious' apples treated with various miticides. Mills River, NC. 2014.

			Mean per leaf									
Treatment	Rate/A	Applic. date	4 Jun	11 Jun	18 Jun	25 Jun	1 Jul	8 Jul	16 Jul	23 Jul	30 Jul	CMD
Nealta 1.67SC	13.5 oz	5/28	2.5a	12.2ab	6.9a	2.4a	2.9a	8.9ab	1.7a	5.2a	0.7a	295.1a
Acramite 50WP	1 lb	5/28,	1.0a	4.1a	2.2a	3.6a	2.2a	6.4a	3.1a	2.0a	1.0a	173.1a
PFR-97 20WDG	1 lb	5/28, 6/5, 6/14	2.6a	39.9b	32.9b	30.6b	57.4b	17.7b	17.6b	8.6a	1.5a	1419.5b
Control	—		1.5a	40.2b	25.9b	22.8b	28.3b	14.0b	3.6a	6.8a	2.4a	986.2b

Means within the same column are not significantly different by LSD (P = 0.05).

Table 2. Mean European red mite adults on 'Delicious' apples treated with various miticides. Mills River, NC. 2014.

			Mean per leaf									
Treatment	Rate/A	Applic. date	4 Jun	11 Jun	18 Jun	25 Jun	1 Jul	8 Jul	16 Jul	23 Jul	30 Jul	CMD
Nealta 1.67SC	13.5 oz	5/28, 6/14	1.3a	1.8a	1.5a	0.6a	1.1a	5.1a	0.8a	3.7a	0.6a	111.1a
Acramite 50WP	1 lb	5/28,	0.4a	0.9a	0.9a	0.3a	0.8a	3.7a	0.8a	1.0a	0.8a	64.2a
PFR-97 20WDG	1 lb	5/28, 6/5, 6/14	2.3a	5.4a	13.3c	6.7b	12.5b	11.8b	4.9b	3.4a	0.9a	415.6b
Control	—		1.3a	4.7a	6.8b	4.4b	7.2ab	10.7b	2.0ab	3.2a	1.5a	282.3b

Means within the same column are not significantly different by LSD (P = 0.05).

Table 3. Mean European red mite immatures on 'Delicious' apples treated with various miticides. Mills River, NC. 2014.

			Mean per leaf									
Treatment	Rate/A	Applic. date	4 Jun	11 Jun	18 Jun	25 Jun	1 Jul	8 Jul	16 Jul	23 Jul	30 Jul	CMD
Nealta 1.67SC	13.5 oz	5/28, 6/14	1.3a	10.4ab	5.3a	1.8a	1.8a	3.8a	1.0a	1.5ab	0.1a	184.0a
Acramite 50WP	1 lb	5/28,	0.6a	3.2a	1.4a	3.3a	1.4a	2.7a	2.3a	1.0a	0.2a	108.9a
PFR-97 20WDG	1 lb	5/28, 6/5, 6/14	0.4a	34.5b	19.6b	23.9b	44.9b	5.9a	12.7b	5.2c	0.6a	1003.9b
Control	—		0.2a	35.5b	19.1b	18.4b	21.1b	3.3a	1.7a	3.5bc	0.8a	703.9b

Means within the same column are not significantly different by LSD (P = 0.05).

Table 4. Mean European red mite eggs on 'Delicious' apples treated with various miticides. Mills River, NC. 2014.

			Mean per leaf								
Treatment	Rate/A	Applic. date	4 Jun	11 Jun	18 Jun	25 Jun	1 Jul	8 Jul	16 Jul	23 Jul	30 Jul
Nealta 1.67SC	13.5 oz	5/28, 6/14	9.4a	14.7ab	13.2ab	9.7a	8.0a	37.5b	11.8a	7.1a	5.2a
Acramite 50WP	1 lb	5/28,	7.0a	3.8a	3.3a	10.6a	7.1a	14.9a	8.7a	5.0a	5.7a
PFR-97 20WDG	1 lb	5/28, 6/5, 6/14	15.1a	39.8bc	49.5c	83.9b	83.4b	51.1b	45.4b	28.1b	9.8ab
Control	—		10.8a	42.1c	34.8bc	78.9b	50.8b	31.5b	24.7b	18.3ab	15.7b

Means within the same column are not significantly different by LSD (P = 0.05).

Table 5. Mean predatory mites (*Neoseiulus fallacis*) on 'Delicious' apples treated with various miticides. Mills River, NC. 2014.

			Mean per leaf									
Treatment	Rate/A	Applic. date	4 Jun	11 Jun	18 Jun	25 Jun	1 Jul	8 Jul	16 Jul	23 Jul	30 Jul	CMD
Nealta 1.67SC	13.5 oz	5/28, 6/14	0.03a	0.00a	0.13a	0.18a	0.30a	0.20a	0.10a	0.23a	0.13a	8.31a
Acramite 50WP	1 lb	5/28,	0.00a	0.10ab	0.10a	0.48a	0.10a	0.03a	0.15a	0.33a	0.65b	11.00a
PFR-97 20WDG	1 lb	5/28, 6/5, 6/14	0.00a	0.03a	0.08a	0.20a	0.50a	0.40b	0.30a	1.18a	0.08a	18.99a
Control	—		0.00a	0.45b	0.63a	0.50a	0.20a	0.80b	0.15a	0.13a	0.05a	20.25a

Means within the same column are not significantly different by LSD (P = 0.05).

Comparison of Mating Disruption Product and Pheromone Trap Lures for Codling Moth and Oriental Fruit Moth in Apples

Codling moth (CM) and oriental fruit moth (OFM) are the two major lepidopteran pests of apples in North Carolina. Two different strategies are used to manage these pests. Approximately half of the grower community uses dual-pheromone mating disruption in combination with supplemental insecticide applications applied when populations approach potentially damaging levels. The remaining growers rely solely on insecticides for control, with application timing based on phenology model predictions and pheromone trap captures.

The standard product for mating disruption in NC orchards has been Isomate CM/OFM TT dispensers applied at 200 per acre. Product and application cost is a limitation to the more widespread use of mating disruption, despite the benefits apparent to most long-time users of mating disruption. Several alternative products are available to aid in cost reduction of mating disruption either through reduced pheromone load on an area basis or via application costs by deploying fewer dispensers per unit area, including puffers or misters, and more recently Trece CideTrak Meso dispensers. Meso dispensers are applied at relatively low rates – 30 dispensers per acre – and contain less pheromone. The inclusion of the host plant volatile pear ester (referred to as DA) compensates for the lower per-acre rate of pheromone release by increasing the activity of the CM pheromone. One objective of this work was to compare the performance of standard CideTrak dispensers to Meso dispensers.

A second objective was to evaluate several different lures for monitoring codling moth and OFM in mating disruption orchards. In NC, pheromone trapping for assessing mating disruption efficacy and for making management decisions has relied exclusively on using traps baited with standard L2 lures (Trece, Adair, OK). However, several studies have demonstrated enhanced capture of codling moth and OFM when pheromone lures were combined with plant volatiles, other pheromones and/or acetic acid (see Knight et al. 2014, *J. Appl. Entomol.*, 138: 783-794). For instance, addition of pear ester, which is attractive to both male and female codling moths, with codlemone has resulted in increased moth capture compared to codlemone alone. In addition, OFM attraction to its pheromone has been shown to be enhanced with the addition of codlemone, and capture of both species was increased with the addition of acetic acid lures.

Materials and Methods

Mating Disruption Trial. At each of three locations (replicates), three blocks (4 to 7 acres each) of mature, mixed-variety apple trees were assigned to one of three treatments: 1) CideTrak CM/OFM at 200 dispensers/acre, which resulted in a total per-acre deployment of 46 grams of CM pheromone (codlemone) and 20 grams of OFM pheromone (3-component blend); 2) CideTrak Meso dispensers applied at 30 dispensers/acre, equivalent to 22.5 grams of CM pheromone,15 grams of OFM pheromone, and 15 gms of pear ester kairomone (DA) per acre; and 3) non-disrupted control. At each location all three blocks were roughly adjacent to one another. Two of the replications (Fruitland 1 and 2) were in different areas of the same farm, while the third (Sugarloaf) was managed by a different grower several miles away. Dispensers were hung on 24 and 25 April (Fruitland 1 and 2) and 23 April (Sugarloaf). Although insecticide use varied between the two farms, the same insecticide program was followed across all three treatment blocks in each replication. The spray program in Fruitland 1 and 2 consisted of minimal insecticide use, while the Sugarloaf location received a full-season spray program consisting of two applications each of Delegate and Assail, and one application each of Intrepid, Provado and Altacor.

Effectiveness of mating disruption treatments was assessed with moth captures in pheromone traps and fruit damage assessments at harvest in September. Traps consisted of Pherocon VI Delta-style traps hung in the upper third of the canopy and baited with one of four lures: 1) CMDA combo lure containing approximately 3 mg each of CM pheromone and the pear ester kairomone, 2) CMDA combo lure plus a separate acetic acid lure (AA), 3) CMDA/OFM combo lure plus AA, and 4) a standard OFM L2 lure. All traps were checked weekly and liners were replaced as necessary to maintain a clean surface. All lures, including AA, were replaced at 8-week intervals. Damage assessments were obtained by examining 50 fruit from each of 4 trees per block on 24 September (Fruitland) or 5 trees per block on 11 September (Sugarloaf). Fruit harvested in September were all cut to detect internal damage. Trap data were subjected to ANOVA and means were separated by LSD (P=0.05). Some data sets were transformed using $\sqrt{x}$ before ANOVA, but means are presented as back transformations.

Lure Evaluation Trial. A second trial was conducted for the sole purpose of comparing codling moth and OFM trap captures using enhanced lures to standard L2 lures. While the above mating disruption trial compared several different enhanced lures, it did not include the standard CM L2 lure. The trial was conducted in three different commercial orchards, two in Henderson County and one in Polk County, from early May through September. Biofix for OFM and codling moth in this area occurred on 7 and 28 April, respectively. Hence, the span of this study did not include first generation OFM flight or the first two weeks of codling moth flight. Each orchard test site had used mating disruption for both codling moth and OFM (Isomate CM/OFM TT) within the previous one or two years, but with one exception it was not used in 2014. The exception was in the Hend-GN orchard where mating disruption was used in only half of the orchard; mating disruption was used in the entire orchard for the previous six years. In each orchard, two replications of five different traps (10 traps total per orchard) baited with different lures were tested. Lure treatments consisted of the following combinations of pheromone, pear ester and acetic acid lures:

1. CM L2: Standard Trécé CM L2 loaded with 3 mg of codlemone.
2. OFM L2: Standard Trécé OFM L2 loaded with 0.3 mg of the three component blend of OFM pheromone.
3. CMDA: Standard Trécé CMDA lure loaded with 3 mg each of codlemone and pear ester.
4. CMDA + AA: Standard CMDA lure plus an acetic acid lure supplied by Trece.
5. CMDA/OFM + AA: The pheromone lure was loaded with codlemone, pear ester, and OFM pheromone, and an acetic acid lure.

All lures were deployed in Delta-style Phercon VI traps attached to bamboo poles and hung in the top third of the tree canopy. Traps were evenly spaced throughout the orchards a minimum of 60 m apart. Traps were checked weekly and all lures (as well as acetic acid dispensers) were replaced at 8-wk intervals throughout the course of the study. Sticky liners were replaced as needed. Data from the two sites in each orchard were averaged and the three orchards was treated as replicates. Data were subjected to ANOVA and means were separated by LSD (P=0.05). OFM data were transformed by log (x+1).

Results

Mating Disruption Trial. The Fruitland orchard used in this study had very high CM and OFM populations, with season total trap captures of coding moth (CMDA baited traps) and OFM (OFM-L2 baited traps) averaging 107 and 711 moths per trap, respectively. OFM populations were also high at the Sugarloaf site, with a season total of 657 moths/trap in the OFM-L2 trap, but codling moth populations were low, with a season total of only 12 moths/trap in the CMDA trap.

For codling moth pheromone trap captures, there was no significant effect for either mating disruption or pheromone lure (Table 1). Season total moth captures in the various pheromone dispenser treatments and in traps baited with different lures is shown in Fig. 1. The lack of differences in pheromone dispenser effects may have been due to high codling moth populations not only in treatment blocks, but also in non-treated surrounding blocks. Although lure effects were not significantly, trap captures followed the same trend observed in 2013, where lures containing both codling moth and OFM pheromone captured fewer codling moths than either the same lure with acetic acid or the standard L2 lure. Codling moths were active from May through late August (Fig. 2), during which time two generations were completed.

Results with OFM were more clear than those of codling moth, with both the mating disruption dispenser and pheromone lure effects being significant, but the interaction was not significant (Table 1). Significantly fewer moths were captured in the CideTrak treatment compared with the Meso or control, and the Meso treatment captured fewer than the control (Fig. 3). In addition, the CMDA/OFM+AA lure was significantly more attractive to OFM moths than the standard OFM L2 lure. OFM were active throughout the trapping period from late April through early October (Fig. 4). The reduced OFM captures in Meso and CideTrak treatments were consistent throughout the year, suggesting that pheromone was emitted from dispensers throughout the study period. While the CM/OFM+AA lures captured more moths than the OFM L2 lures, seasonal trap captures of both lures exhibited the same seasonal trends (Fig. 5).

Lure Evaluation Trial. Codling moth populations were low in all orchards, ranging from a cumulative total of only 2.0 to 9.0 moths per trap in CM L2 lures in the Hend-CL and Hend-GN sites, respectively (Table 2). Due to the low numbers, there were no significant differences among treatments in total codling moth trap captures (F=1.56; df = 4,8; P = 0.27). Overall captures were highest in CMDA/+AA traps, with CM L2 and CMDA traps capturing a total of 4.5 and 4.3 moths. Weekly cumulative captures is shown in Fig. 6.

OFM populations were considerably higher than codling moth, with total captures in OFM L2 lures ranging from 44.5 to 125.0 moths per trap at Polk-BL and Hend CL, respectively. The high degree of attractiveness of the CMDA/OFM+AA lures was apparent with these traps capturing significantly more moths than the CM L2 traps (Table 2; F=54.95; df=4,8; P<0.01). Weekly cumulative trap captures are illustrated in Fig. 7, which shows how the CMDA/OFM+AA lures are much more effective at detecting the relatively large late-season OFM populations.

Conclusions

This was the first year of mating disruption in either orchard, and, with the exception of codling moth populations at the Sugarloaf site, both OFM and codling moth densities were high. The contrasting results with codling moth and OFM, in which mating disruption treatments did not significantly affect pheromone trap captures for codling moth but did for OFM, is indicative of the relative ease of disrupting in-flight communication of OFM compared with codling moth. Despite the high densities of OFM, seasonal trap captures in the CideTrak and Meso treatments were reduced by 98.3 and 81.8% below the control, respectively. The CideTrak treatment only suppressed codling moth trap capture by about 40% of control capture.

The effects of lures used as attractants in traps were similar to those observed in previous years. Under low codling moth populations typical in mating disruption orchards, there was no significant difference in trap captures between CMDA or CMDA+AA in mating disruption blocks, nor were significant differences detected among CM L2, CMDA or CMDA+AA in non-mating disruption orchards. Perhaps lure effects may separate out under higher codling moth densities, but studies to date do not provide a clear benefit to using enhanced codling moth lures in mating disruption orchards.

Trapping studies with OFM demonstrated that the combination lure CMDA/OFM with the addition of acetic acid increased OFM trap capture by 2X to 3X, and this was consistent throughout the season. Unfortunately, we did not include a CMDA/OFM lure with without acetic acid to differentiate the different components of attractants. Nonetheless, the significance of these high trap captures, particularly late in the season, as an indicator of population density or potential for damage is not year clear. Future studies will hopefully provide a more clear interpretation of trap captures with enhanced OFM lures.

Table 1. ANOV statistics for mating disruption effects and pheromone trap lure effects for codling moth and oriental fruit moth. Henderson County, NC. 2014

Insect	Factor	df (trt, error)	F	P
Codling moth	Mating disruption	2, 18	0.19	0.83
	Lure	2, 18	1.73	0.21
	Interaction	4, 18	0.52	0.73
Oriental fruit moth	Mating disruption	2, 12	39.72	<0.001
	Lure	1, 12	4.70	0.05
	Interaction	2, 12	0.77	0.484

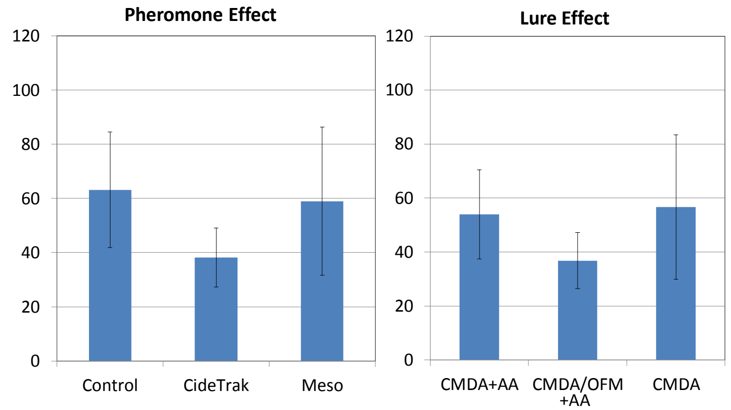


Fig. 1. Mean (±SEM) season total codling moth pheromone trap captures in apples treated with different mating disruption dispensers (pheromone effect) and in traps baited with different lures (lure effect). Henderson County, NC. 2014.

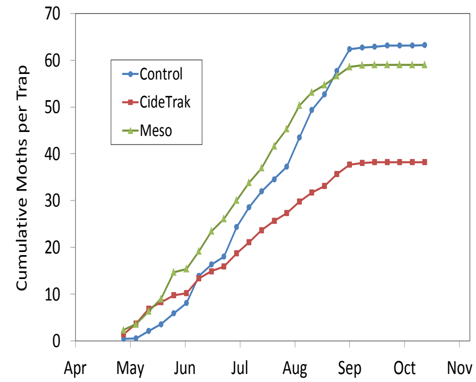


Fig. 2. Mean codling moth pheromone trap captures in blocks of apples treated with different phermone dispesers for mating disruption. Henderson County, NC. 2014.

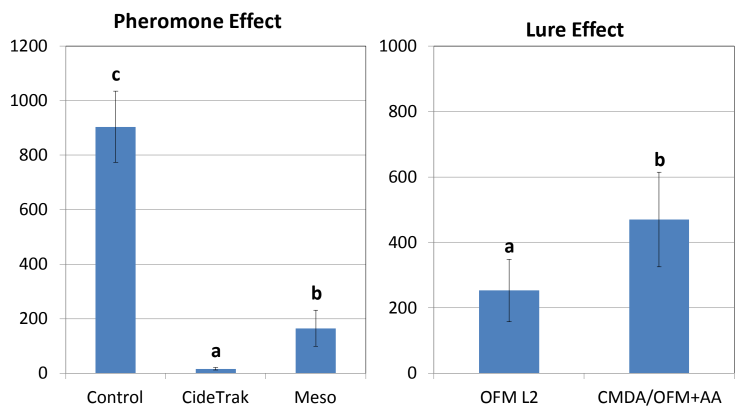


Fig. 3. Mean (±SEM) season total OFM pheromone trap captures in apples treated with different mating disruption dispensers (pheromone effect) and in traps baited with different lures (lure effect). Henderson County, NC. 2014.

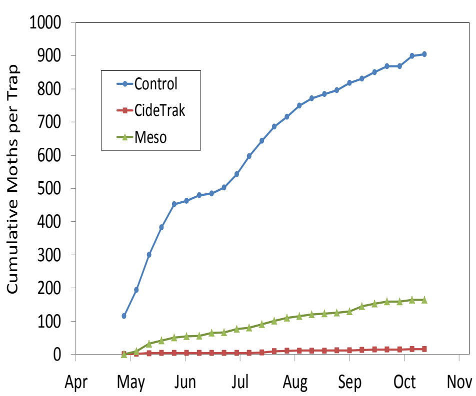


Fig. 4. Mean OFM pheromone trap captures in blocks of apples treated with different pheromones for mating disruption . Henderson County, NC. 2014.

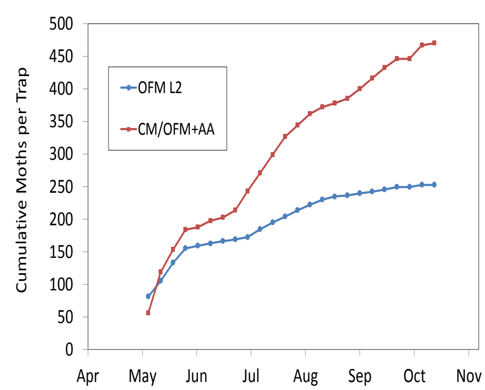


Fig. 5. Mean oriental fruit moth captures in traps baited with different lures across all mating disruption treatments. Henderson County, NC. 2014.

Table 2. Mean season total moth codling moth and oriental fruit moth captures in traps baited with difference lures. 2014.

Orchard	Treatment	Codling moth	Oriental fruit moth
Hend-CL	CM L2	2.0	0.5
	CMDA	2.5	1.0
	CMDA+AA	0.5	12.5
	CMDA/OFM+AA	2.5	485.5
	OFM L2	0	125.0
Hend-GN	CM L2	9.0	0
	CMDA	4.5	0.5
	CMDA+AA	7.0	2.0
	CMDA/OFM+AA	0.5	268.5
	OFM L2	0.5	57.5
Polk-BL	CM L2	2.5	0
	CMDA	6.0	2.0
	CMDA+AA	20.5	3.5
	CMDA/OFM+AA	0	66.0
	OFM L2	0	44.5
All locations	CM L2	4.5a	0.2a
	CMDA	4.3a	1.2a
	CMDA+AA	9.3a	6.0a
	CMDA/OFM+AA	1.0a	273.7c
	OFM L2	0.2a	75.7b

Means within the same column under all locations followed by the same letter are not significantly different by LSD (P = 0.05).

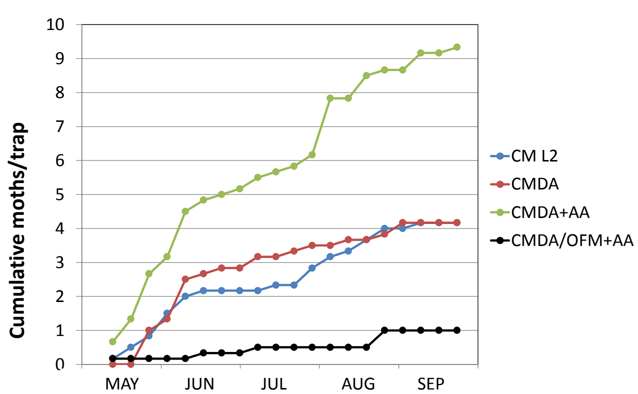


Fig. 6. Mean cumulative codling moth captures in traps baited with different lures. Henderson and Polk County, NC. 2014.

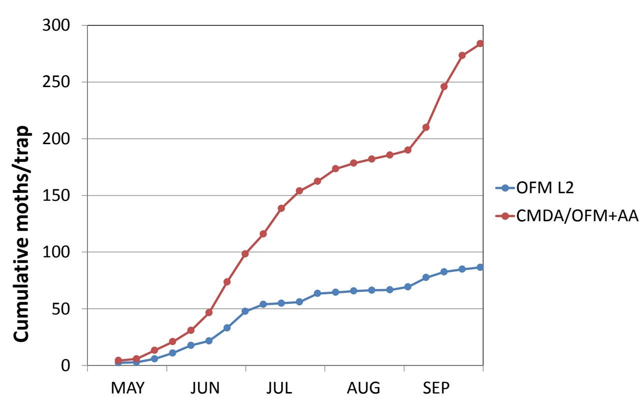


Fig. 7. Mean cumulative oriental fruit moth captures in traps baited with different lures. Henderson and Polk County, NC. 2014.

Evaluation of Sprayable Pheromone for Mating Disruption and Lures for Monitoring Oriental Fruit Moth in Apples

The use of sprayable pheromone for managing oriental fruit moth (OFM) in apples, particularly late-season populations, has become a common practice among those growers not using hand-applied or puffer dispensers for season-long disruption of codling moth and OFM. Recommendations for use of sprayable pheromone in NC were largely developed from studies conducted in the early 2000s using a microencapsulated formulation of OFM pheromone no longer available, and were evaluated with pheromone traps baited with lures containing 100 and 300 ug of OFM pheromone. These studies indicated that sprayable pheromone applied at approximately 6 gm AI per acre provided about 4 wks residual control based on moth captures. Since that time, Suterra CheckMate-OFM F, a microencapsulated flowable formulation, is the only commercially available sprayable pheromone for OFM mating disruption. In addition, several new and experimental lures that are more attractive to OFM than standard 100 and 300 ug lures are now available. The purpose of this study was to evaluate two formulations of sprayable pheromone using different monitoring lures.

Materials and Methods

The experiment was conducted in a 7.5 ha (18.5 acre) mature, mixed-variety block of 'Rome Beauty' and 'Golden Delicious' trees with a tree-row-volume of approximately 300GPA in Edneyville, NC. Nine 0.25 ha plots (50 x 52 meters) that were separated by approximately 40 meters were established within the block. A non-treated control and two sprayable pheromone treatments, CheckMate-OFM F (Suterra LLC, Bend, OR) and Trece MEC OFM (Trécé, Inc, Adair, OK), were assigned to plots that allowed for three treatments each replicated three times and arranged in a RCBD. A single application of both sprayable pheromones were applied on 4 August; CheckMate OFM-F was applied at 2.47 fl oz/ha or 16.8 gm AI pheromone/ha (= 1.0 fl oz or 6.8 gm AI pheromone per acre) and Trece OFM MEC was applied at 2.8 fl oz/ha or 15.2 gm AI pheromone per ha (=1.12 fl oz or 6.06 gm AI pheromone per acre). Applications were made with an airblast sprayer delivering 486 liters/ha (52 gal/acre).

Three Delta style pheromone traps (Pherocon VI) were erected in each plot, one each baited with an OFM L2 lure, OFM/CMDA lure, and TRE1123 lure. The latter was a three-component lure consisting of CMDA/OFM and two unknown components. Traps were hung at a height of ~1.8 m above ground and spaced 20 meters apart within plots. Traps were erected on the day of pheromone application (4 August) and monitored at approximately weekly intervals through 4 October. Lures were not changed during the 9-week monitoring period. Weekly trap counts and season total counts were subjected to ANOVA and means were separated by LSD (P = 0.05).

Results

OFM populations were low in this trial, with a season total average of only 11 moths/trap captured in traps baited with CM L2 lures placed in control plots. Based on ANOVA using season total trap counts, both sprayable pheromone and monitoring lure effects were significant, but the interaction was not (Table 1). Season total captures of moths in pheromone traps are shown in Fig. 1, where it is evident that trap captures were significantly lower in both the CheckMate and Trece MEC treatments compared with the control, but there was no difference between the CheckMate and Trece treatments. In addition, traps baited with lure TRE1123 caught significantly more moths than either OFM L2 or CMDA/OFM, which did not differ from one another.

The higher trap captures with TRE1123 lures in both sprayable pheromone-treated and non-treated plots is shown in Fig. 2. Regardless of lure type, both pheromone products suppressed trap captures for the entire 9 wk period, but captures were suppressed to the greatest extent during the first 4 to 5 wk after application. This is most evident in Fig. 3, which illustrates reduction of moth captures in traps placed in sprayable pheromone treatments compared to those in the control for each week. It was not possible to compare trap shutdown among lure types, because not all traps in control plots captured moths every week.

Table 1. ANOVA results of season total moth captures in plots treated with different sprayable pheromone treatments and in traps baited with different lures.

Experiment	Factor	df	F	P
Trial 1	Sprayable pheromone	2	4.16	0.032
	Lure	2	3.59	0.487
	Interaction	4	0.76	0.563

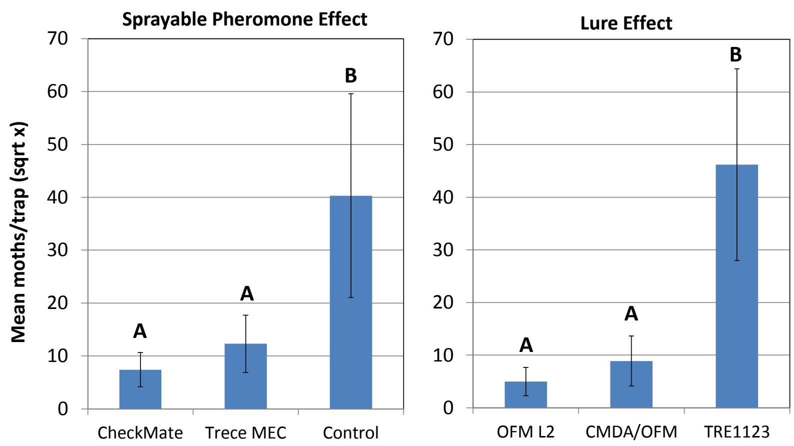


Fig. 1. Mean (±SEM) cumulative OFM moths per trap in blocks treated with different sprayable pheromones (Pheromone effect) and in traps containing different lures. Means followed by the same letter with treatment effect are not significantly different by LSD (P = 0.05).

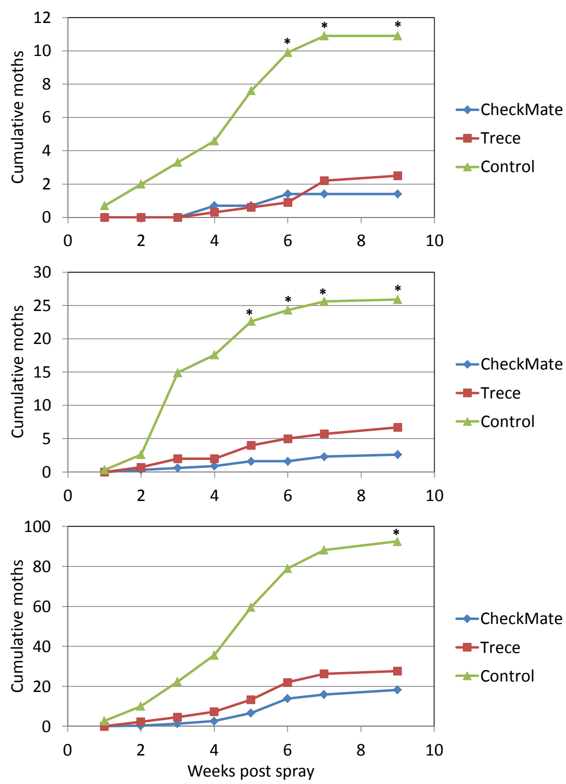


Fig. 2. Mean cumulative trap captures with different pheromone lures in non-treated blocks and blocks treated with CheckMate OFM and Trece MEC OFM.

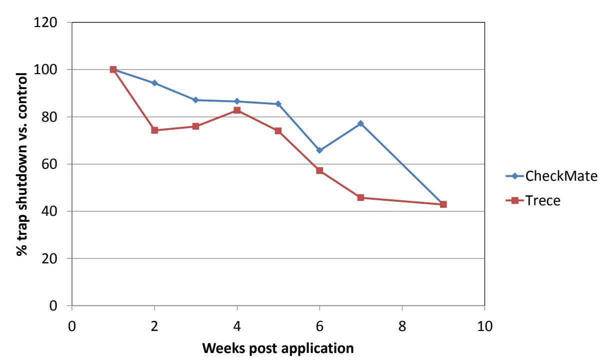


Fig. 3. Mean reduction in capture of moths in pheromone-treated plots compared to captures in control plots. Values are means across lure treatments.

Evaluation of Lures for Monitoring Oriental Fruit Moth

Oriental fruit moth (OFM) is a major pest of apples and peaches in North Carolina. Management is achieved either through insecticide applications timed to coincide with egg laying of specific generations, or the use of mating disruption. Mating disruption approaches consist of either hand-applied dual pheromone (codling moth and OFM) dispensers applied early in the season before bloom and which provide season-long disruption, or the use of sprayable OFM pheromone during the mid or late season that provide three to four wks of residual activity.

Pheromone traps baited with CM L2 lures are commonly used as one measure of mating disruption efficacy, and can be useful in helping to determine the need for supplemental insecticide applications. Mating disruption is considered to be particularly effective against OFM, and as a rule OFM pheromone trap captures are usually zero or near zero in mating disruption orchards. However, recent studies evaluating lures containing codling moth pheromone and/or acetic acid in addition to OFM lures have resulted in higher captures. Hence, the objective of this study was to evaluate several experimental lures for monitoring OFM in both mating disruption and non-disrupted orchards.

Materials and Methods

Two separate trials were conducted in commercial apple orchards – Trial 1 monitored trap captures with experimental lures from 2 June to 14 July and coincided with flight of the second and third generations. This trial included four different experimental lures (TRE 1103, 1104, 1105 and 1106) all deployed with acetic acid dispensers, and a standard OFM L2 lure without acetic acid. Treatments TRE1103, 1104, and 1105 also included a separate unknown lure, making them 3-component lures. Two replicates of each treatment were deployed in each of three orchards that were anticipated to have low to moderate OFM populations:

1) **Staton orchard** used Isomate TT CM/OFM dispensers at 200 per acre for mating disruption of OFM and codling moth, and this was the 8th consecutive year of mating disruption in this orchard.

2) **Nix orchard**, used mating disruption (Isomate TT CM/OFM) for the previous four years, but in 2014 only half the orchard was treated with Isomate dispensers while the remaining portion was not treated with dispensers. One replicate of treatments was placed in the mating disruption section and one in the non-mating disruption section.

3) **McCraw orchard** was a test site for evaluating mating disruption products in 2013, but did not use mating disruption in 2014.

Treatment lures were placed in Delta style traps (Pherocon VI, Trece), and each trap was separated by a distance of approximately 20 meters. Traps were deployed on 2 July and checked weekly to record moth captures and to maintain a clean sticky surface. Traps were also rotated among positions each week to minimize location effects. Weekly trap counts and season total counts were subjected to two-way ANOVA, and means were separated by LSD (P = 0.05). For season total trap captures, ANOVA was analyzed to test for location and lure treatment effects; location was separated into replicates placed in non-mating disrupted blocks (McCraw and one replicate of Nix orchard) and disrupted orchards (Staton orchard and one replicate of Nix orchard). In instances where data were transformed, means are presented as back transformations.

Trial 2 consisted of four treatments, each replicated a total of six times, three times each in the Staton and Nix orchards described above. All replicates in the Staton orchard were in an Isomate TT CM/OFM treated orchard, and in the Nix orchard one replicate was in a section of orchard treated with Isomate TT CM/OFM and two replicates in a section treated with Suterra CheckMate OFM-F in mid July and late August. Treatments consisted of TRE 1103 and 1123, both of which were 3-component lures, one of which was acetic acid. The two remaining treatments, TRE 1130 and TRE113, were both deployed as single lures. Lures were placed in Delta traps, traps rotated among locations within replicates weekly, and checked weekly for moth capture. Data were subjected to ANOVA and means separated by LSD (P=0.05).

Results

ANOVA results for season total moth captures in Trial 1 are shown in Table 1. The location, lure and location x lure interaction effects were all significant. Trap captures were significantly higher in non-disrupted (109.9±18.2) than disrupted (5.1±1.9) orchards, and captures in lure 1103 (96.8±38.2) were significantly higher than all other lures except 1105 (90.0±39.4), and captures in OFM L2 lures (7.5±4.7) were significantly lower than all other lures. The interactive effects are shown in Fig. 1, which shows that the significant differences between 1104 and 1105 and between 1106 and OFM L2 in non-disrupted orchards were not significant in mating disruption orchards. Mean weekly trap captures in all treatment and locations are shown in Table 2.

For Trial 2, ANOVA for season total captures were also significantly affected by location, lure and location x lure interaction effects (Table 1). Trap captures were significantly higher in the Nix (75.5±17.9) compared to Staton orchard (2.8±1.1), and moth captures in lure 1131 (2.3±1.4) was significantly lower than all other lures, and captures in lure 1103 (67.5±28.6) was significantly higher than 1130 (30.2±17.7). The interactive effects are shown in Fig. 2, where there was no difference in trap capture between 1123 and 1130 in the Nix orchard, but these lures did significantly differ in the lower OFM population Staton orchard. Mean weekly trap captures in both orchards are shown in Table 3.

Shown in Fig. 3 is a plot of weekly captures of moths in traps baited with TRE1103 and OFM L2 lures in individual replicates. Captures where both OFM L2 and TRE1103 were zero were deleted from the data set, resulting in a total of 70 comparisons; 30 from mating disruption blocks and 37 from non-disrupted blocks. In every instance, TRE1103 lures captured more moths than the standard OFM L2. Correlation of these captures in these two traps was significant (df = 1, 67; F = 74.4, P <0.001), with a correlation coefficient of r = 0.721.

Table 1. ANOVA statistics for Trial 1 and Trial 2.

Experiment	Factor	df	F	P
Trial 1	Location	1	207.98	<0.001
	Lure	4	17.35	<0.001
	Lure x location	4	4.61	0.008
Trial 2	Location	1	60.00	<0.001
	Lure	3	9.81	<0.001
	Lure x location	3	3.48	0.041

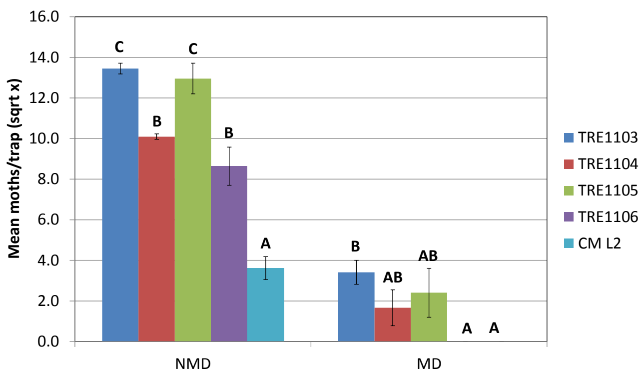


Fig. 1. Trial 1 mean (±SEM) season total OFM captured in traps baited with different lures in non-mating disrupted and disrupted orchards. Means with the same letter in the same orchard are not significantly different by LSD (P=0.05).

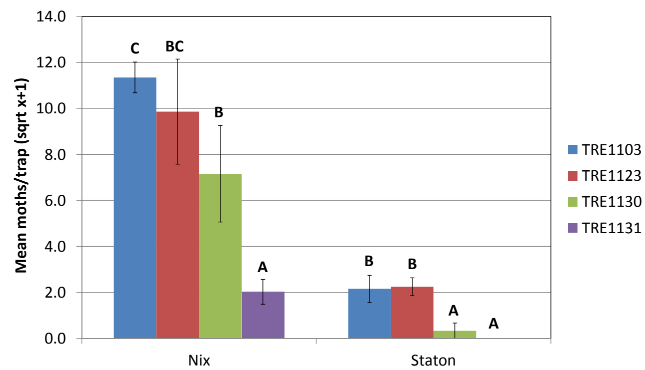


Fig. 2. Trial 2 mean (±SEM) season total OFM captured in traps baited with different lures in Nix and Staton Orchard. Means followed by the same letter in the same orchard are not significantly different by LSD (P=0.05).

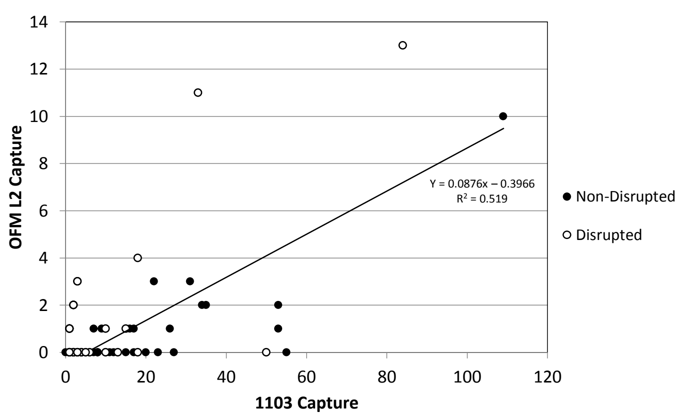


Fig. 3. Relationship between weekly captures of OFM in traps baited with OFM L2 lures versus TRE1103.

Table 1. Mean OFM trap captures using 5 different pheromone lures. Henderson County, NC. 2014.

Orchard type	Treatment[a]	OFM per trap 9-Jun	16-Jun	23-Jun	30-Jun	7-Jul	14-Jul	Season Total
Non-disruption	1103+AA	8.3	6.0	21.7	63.3	48.7	33.3	181.3
	1104+AA	3.0	7.0	19.7	32.0	29.0	11.3	102.0
	1105+AA	5.3	8.7	32.0	65.7	35.7	24.0	171.3
	1106+AA	6.7	4.0	12.0	36.0	15.7	5.7	80.0
	OFM (std)	1.3	0.3	3.7	5.3	4.3	0.0	15.0
Mating Disruption	1103+AA	0.3	0.7	4.3	2.7	1.3	3.0	12.3
	1104+AA	0.0	0.0	0.7	3.0	0.7	0.0	4.3
	1105+AA	0.0	0.3	0.0	5.3	1.7	1.3	8.7
	1106+AA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	OFM (std)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All locations	1103+AA	4.3d	3.3a	13.0c	33.0c	25.0c	18.2d	96.8c
	1104+AA	1.5b	3.5a	10.2bc	17.5bc	14.8bc	5.7bc	53.2bc
	1105+AA	2.7c	4.a	16.0c	35.5c	18.7c	12.7cd	90.0bc
	1106+AA	3.3c	2.0a	6.0ab	18.0ab	7.8ab	2.8ab	40.0ab
	OFM (std)	0.7a	0.2a	1.8a	2.7a	2.2a	0.0a	7.5a

Means within the same column in the All Locations section followed by the same letter are not significantly different by LSD (P=0.05).

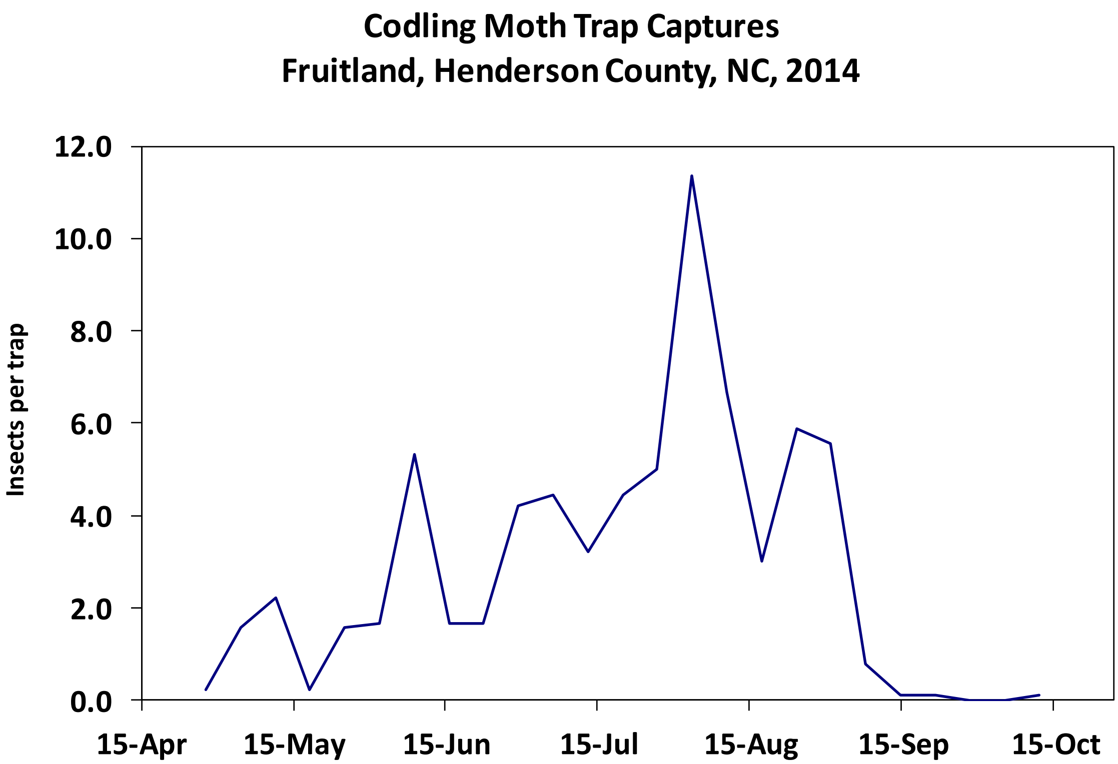
[a]Treatments 1103, 1104 and 1105 included an additional lure containing an unknown attractant.

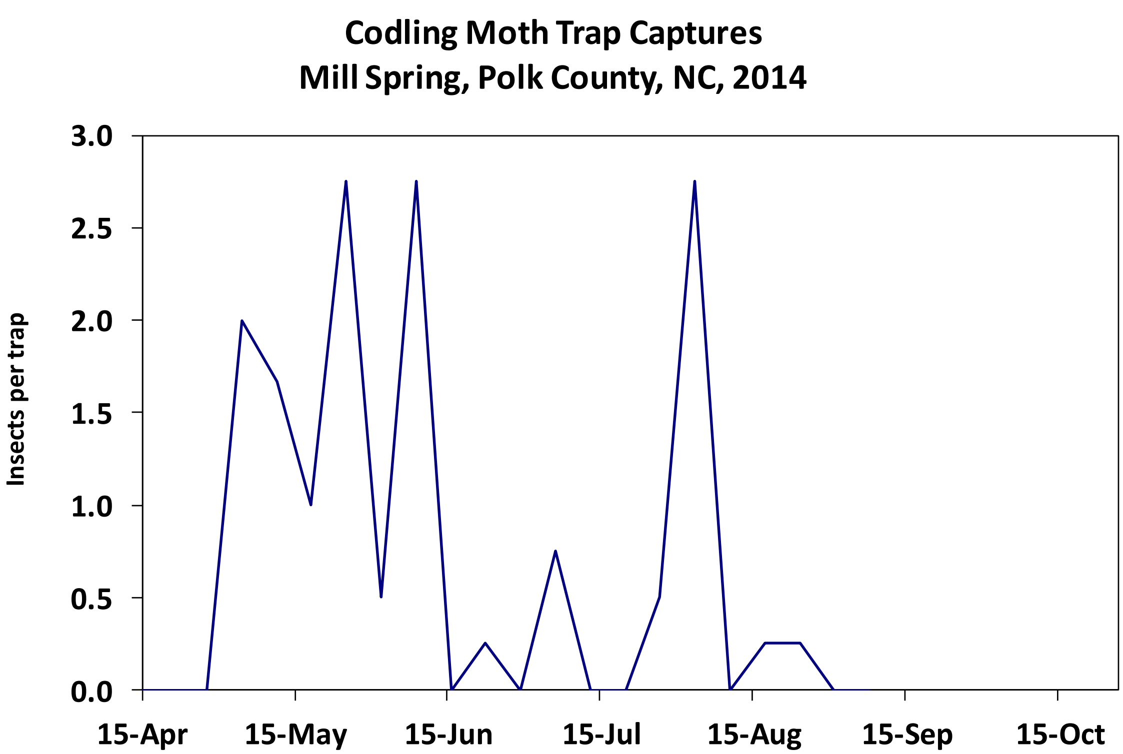
Table 2. Mean OFM trap captures using 4 different pheromone lures. Henderson County, NC. 2014.

		OFM per trap										Season
Orchard	Treatment[a]	28-Jul	4-Aug	11-Aug	18-Aug	25-Aug	1-Sep	8-Sep	15-Sep	22-Sep	6-Oct	Total
Nix	1103	11.7	10.3	6.7	9.0	5.0	4.7	19.3	39.7	14.7	8.7	129.7
	1123	11.0	2.0	2.3	11.0	4.7	2.7	27.3	27.7	15.7	3.3	107.7
	1130	8.0	9.7	2.7	8.3	7.3	2.7	8.0	7.3	3.7	2.3	60.0
	1131	0.0	0.7	0.0	0.7	0.3	0.0	1.0	1.3	0.7	0.0	4.7
Staton	1103	0.0	0.7	0.0	0.3	1.0	1.3	0.7	1.3	0.0	0.0	5.3
	1123	0.0	0.0	0.0	0.0	0.0	0.3	0.0	1.3	0.0	0.0	4.3
	1130	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
	1131	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All locations	1103	5.8b	5.5c	3.3b	4.7b	3.0b	3.0b	10.0bc	20.5c	7.3b	4.3b	67.5c
	1123	5.5b	1.0ab	1.2ab	5.5b	2.3ab	1.5a	13.7c	14.5bc	7.8b	1.7ab	56.0c
	1130	4.0ab	4.8bc	1.3ab	4.2ab	3.7b	1.3b	4.0ab	3.7ab	1.8ab	1.2a	30.2b
	1131	0.0a	0.3a	0.0a	0.3a	0.2a	0.0a	0.5a	0.7a	0.3a	0.0a	2.3a

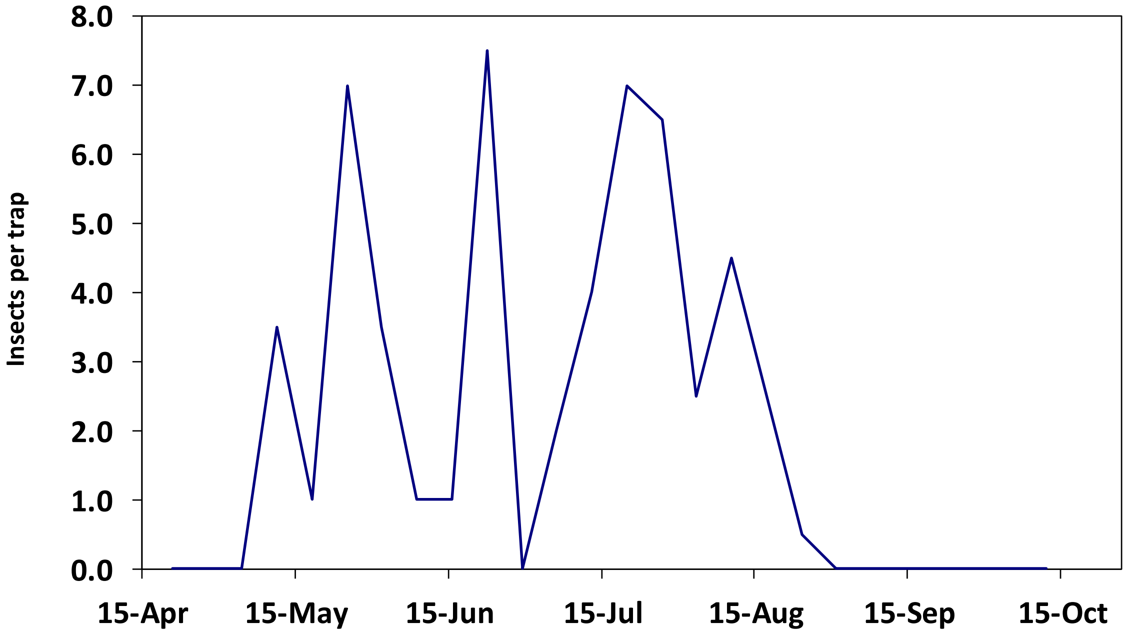
Means within the same column in the All Locations section followed by the same letter are not significantly different by LSD (P=0.05).

[a]Treatments 1103 and 1123 were both 3 component lures, while 1130 and 1131 were single component lures.

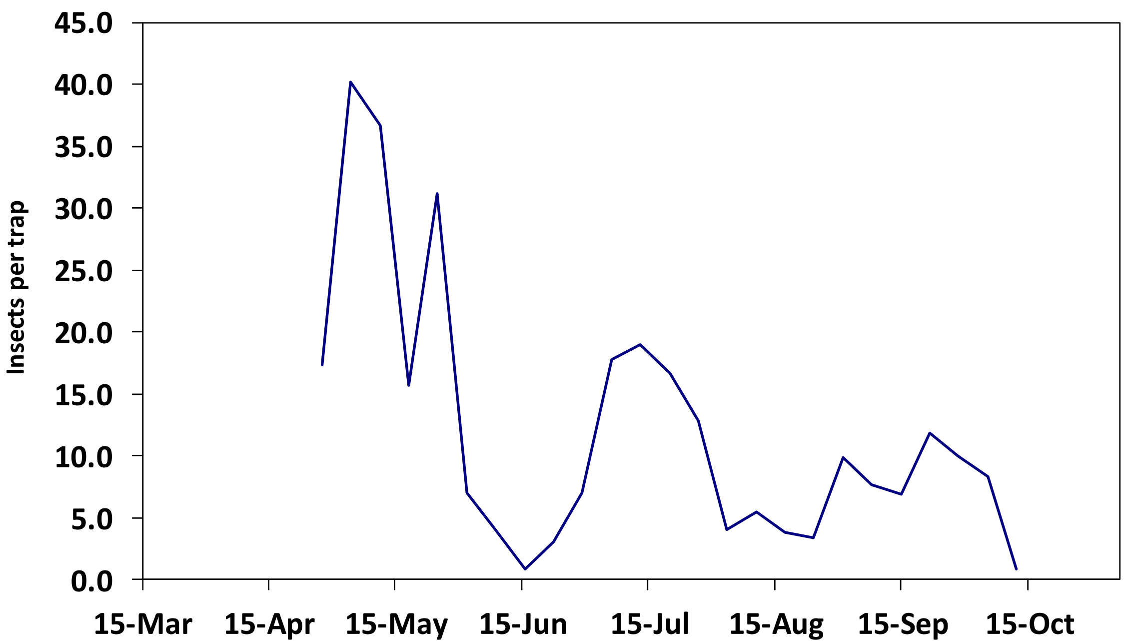

Codling Moth Trap Captures
Fruitland, Henderson County, NC, 2014
Insects per trap
12.0
10.0
8.0
6.0
4.0
2.0
0.0
15-Apr
15-May
15-Jun
15-Jul
15-Aug
15-Sep
15-Oct

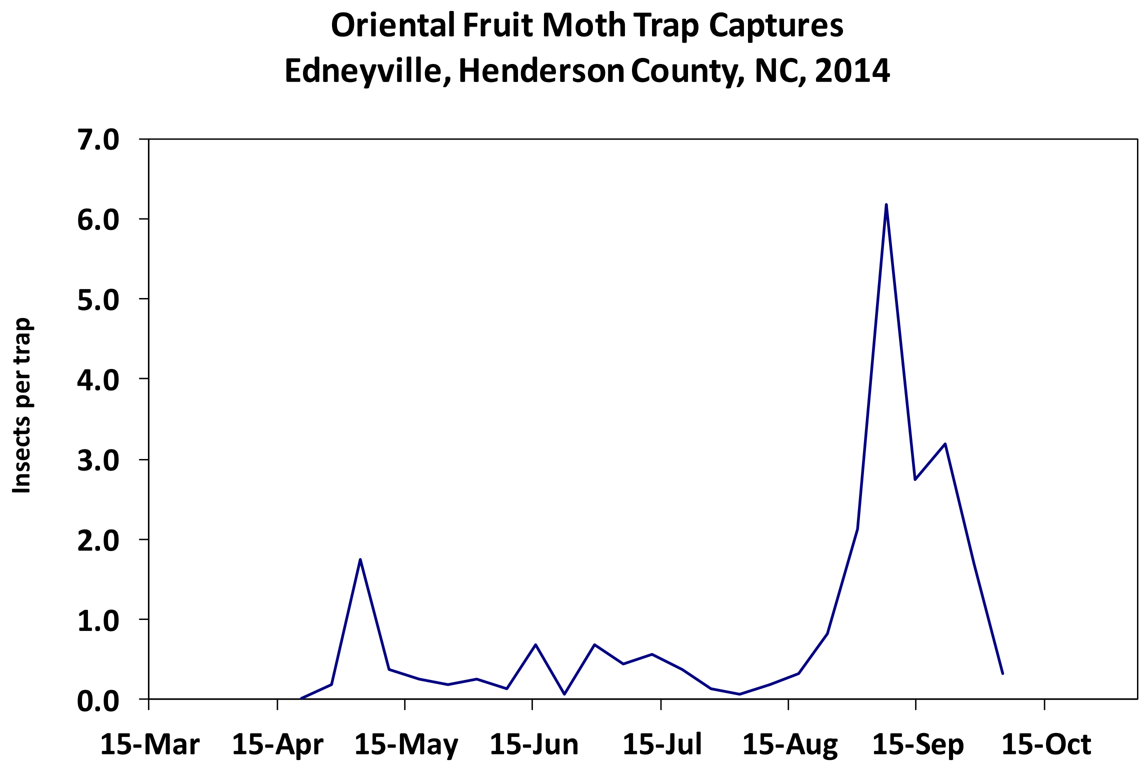

Codling Moth Trap Captures
Mill Spring, Polk County, NC, 2014
Insects per trap
3.0
2.5
2.0
1.5
1.0
0.5
0.0
15-Apr
15-May
15-Jun
15-Jul
15-Aug
15-Sep
15-Oct

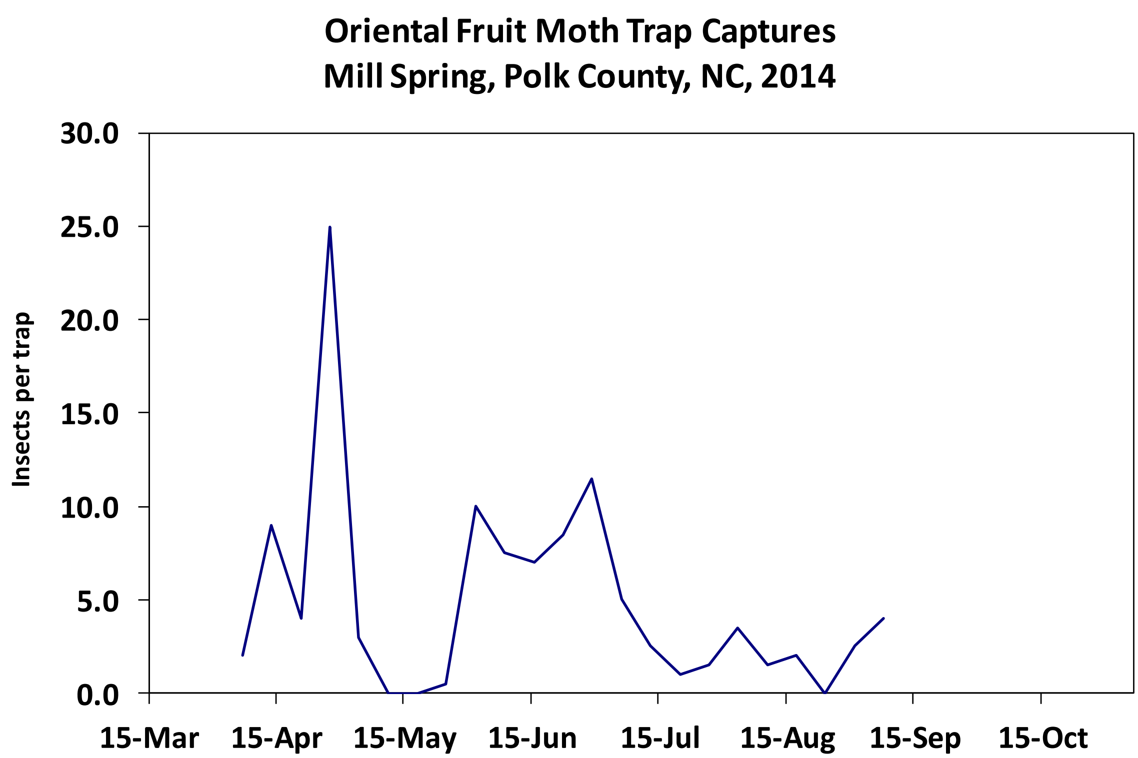
Codling Moth Trap Captures
Mountain Horticultural Crops Research Station
Mills River, Henderson County, NC, 2014



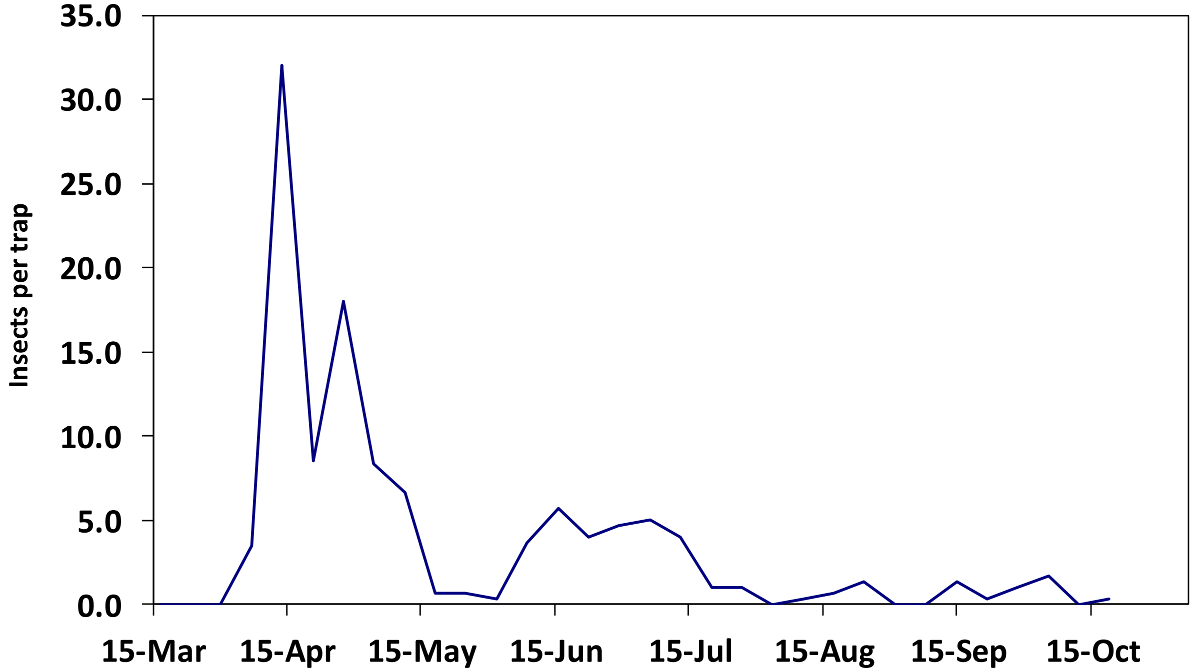
Oriental Fruit Moth Trap Captures
Fruitland, Henderson County, NC, 2014



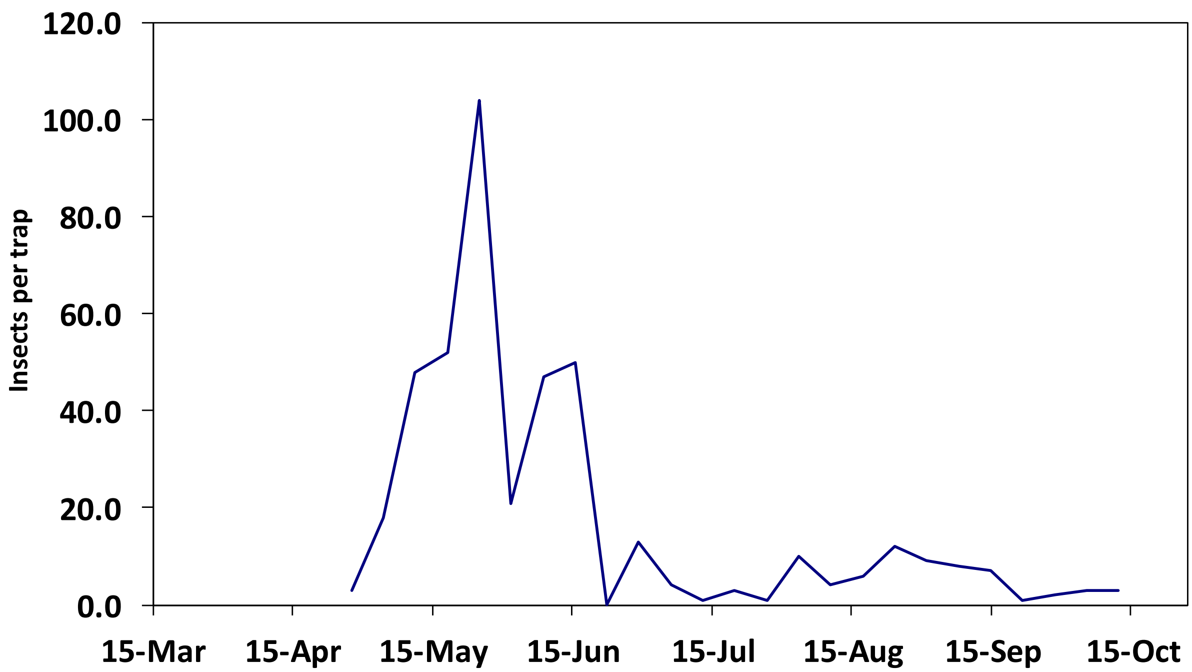

Oriental Fruit Moth Trap Captures
Edneyville, Henderson County, NC, 2014
Insects per trap
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
15-Mar
15-Apr
15-May
15-Jun
15-Jul
15-Aug
15-Sep
15-Oct


Oriental Fruit Moth Trap Captures
Mill Spring, Polk County, NC, 2014
Insects per trap
30.0
25.0
20.0
15.0
10.0
5.0
0.0
15-Mar
15-Apr
15-May
15-Jun
15-Jul
15-Aug
15-Sep
15-Oct

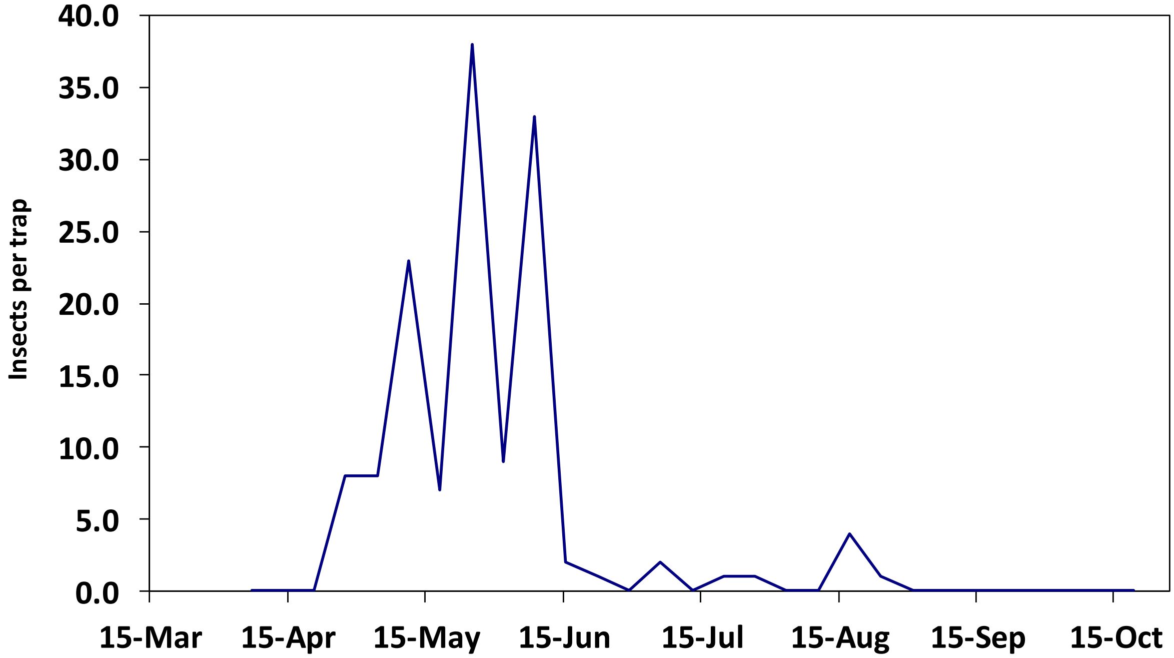
Oriental Fruit Moth Trap Captures
Mtn Horticultural Crops Research Station - Apple and Peach Avg
Mills River, Henderson County, NC, 2014



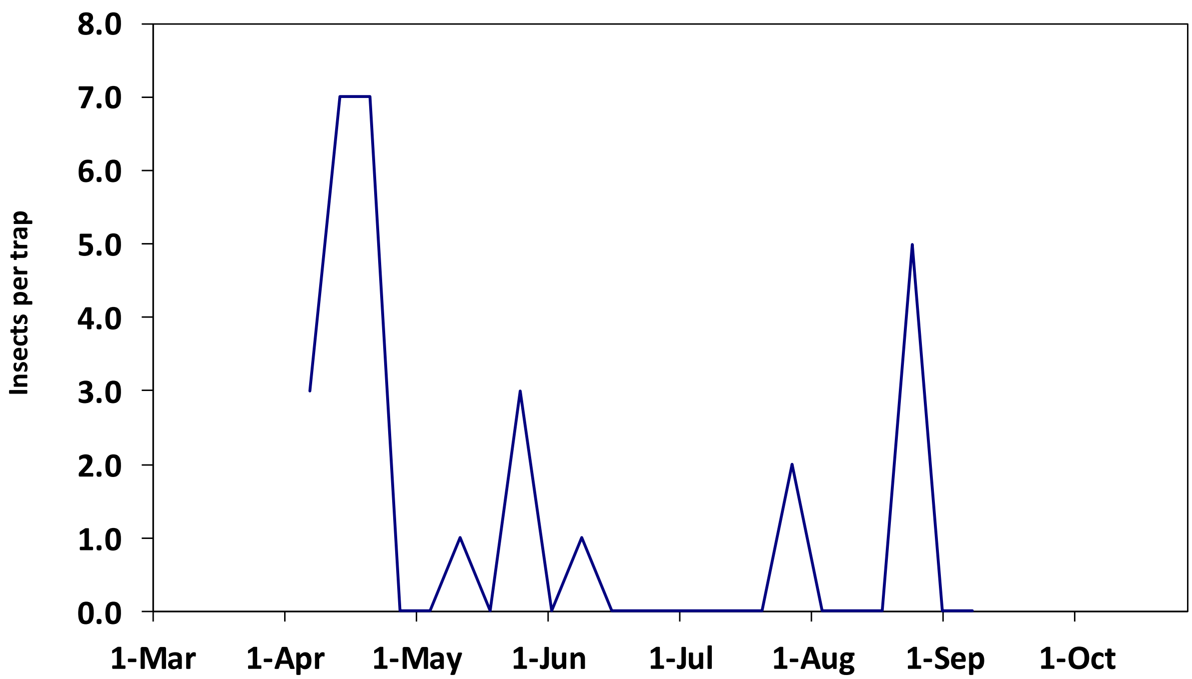
Tufted Apple Bud Moth Trap Captures
Edneyville, Henderson County, NC, 2014



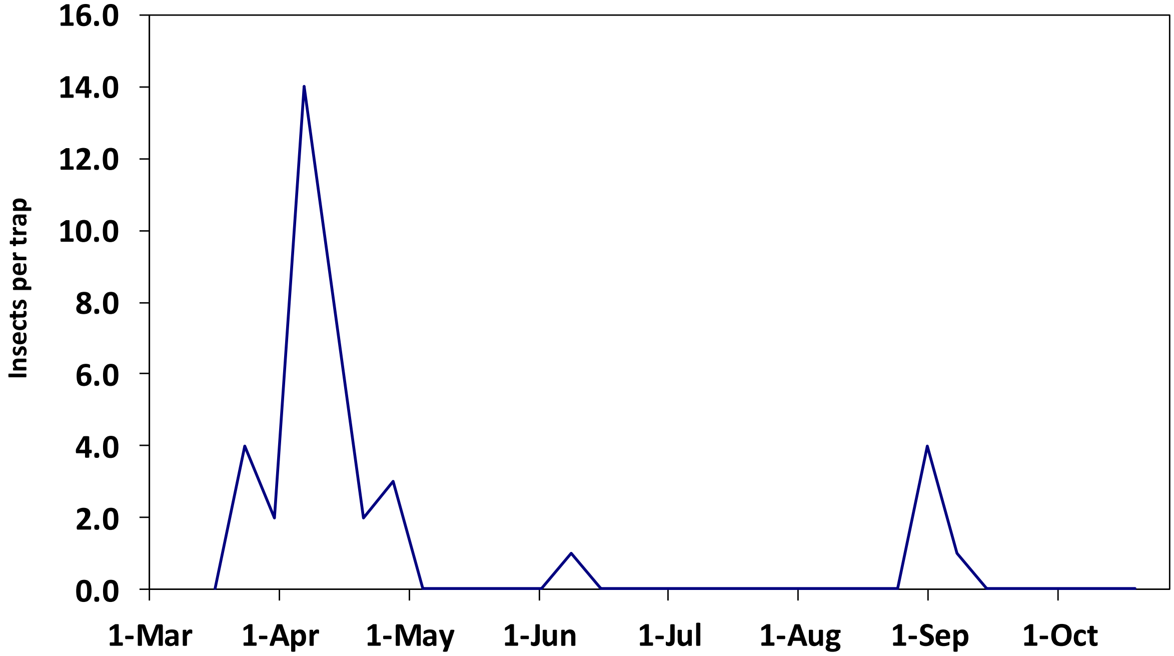
Tufted Apple Bud Moth Trap Captures
Mountain Horticultural Crops Research Station
Mills River, Henderson County, NC, 2014



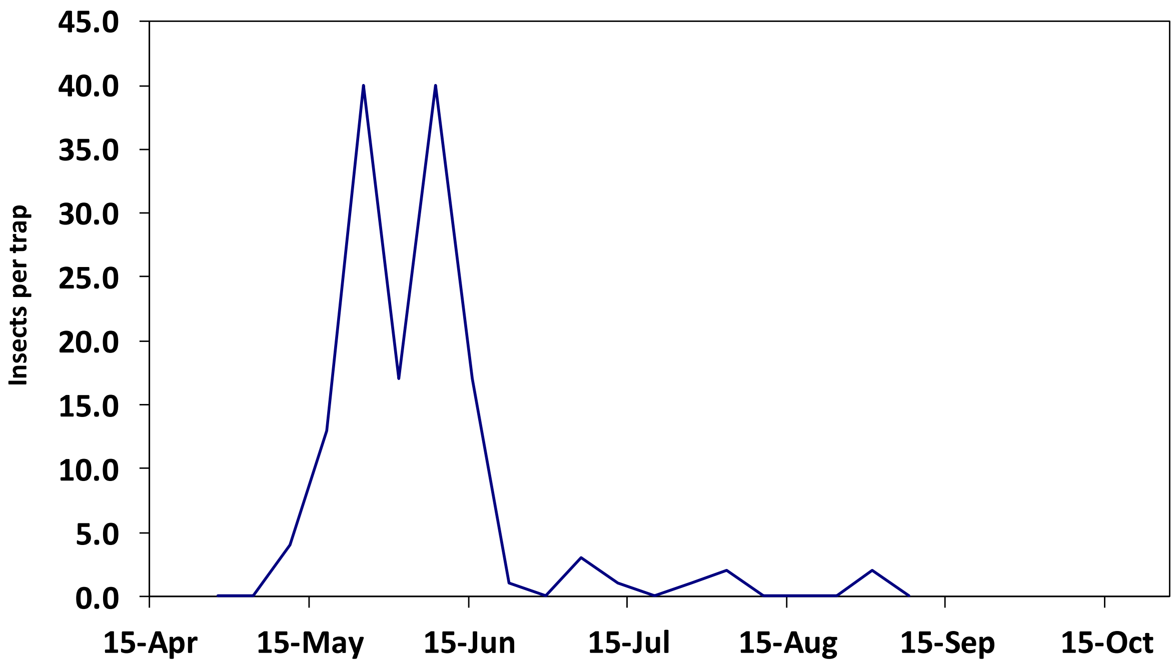
Redbanded Leafroller Trap Captures
Mill Spring, Polk County, NC, 2014



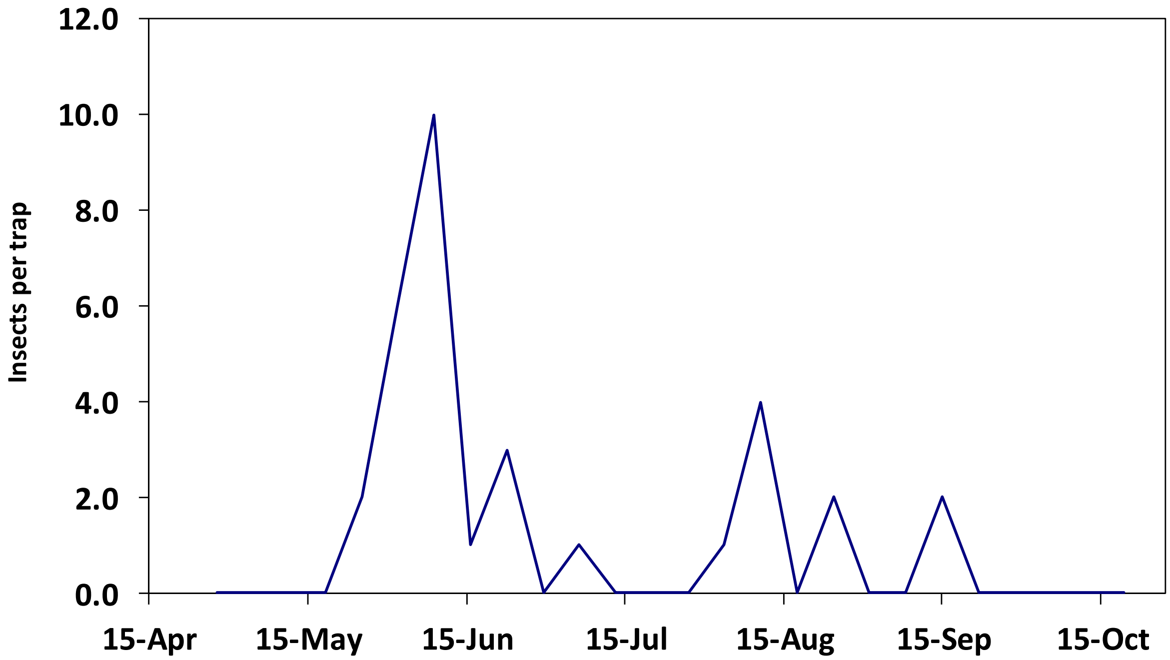
Redbanded Leafroller Trap Captures
Mountain Horticultural Crops Research Station
Mills River, Henderson County, NC, 2014



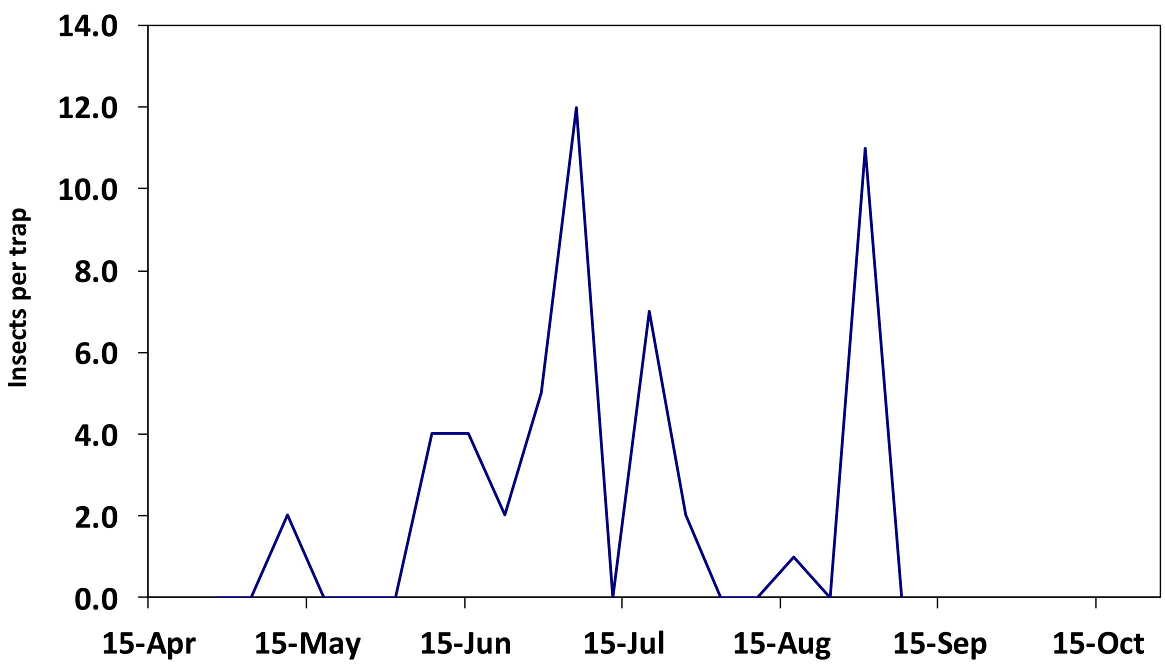
Obliquebanded Leafroller Trap Captures
Mill Spring, Polk County, NC, 2014



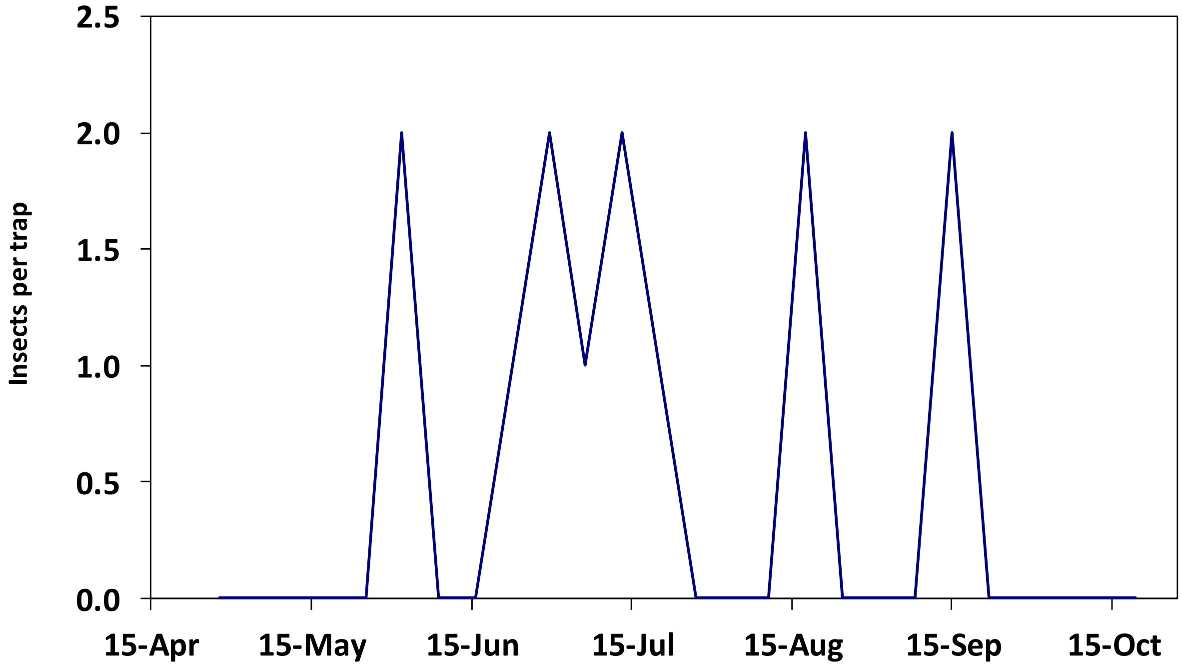
Obliquebanded Leafroller Trap Captures
Mountain Horticultural Crops Research Station
Mills River, Henderson County, NC, 2014



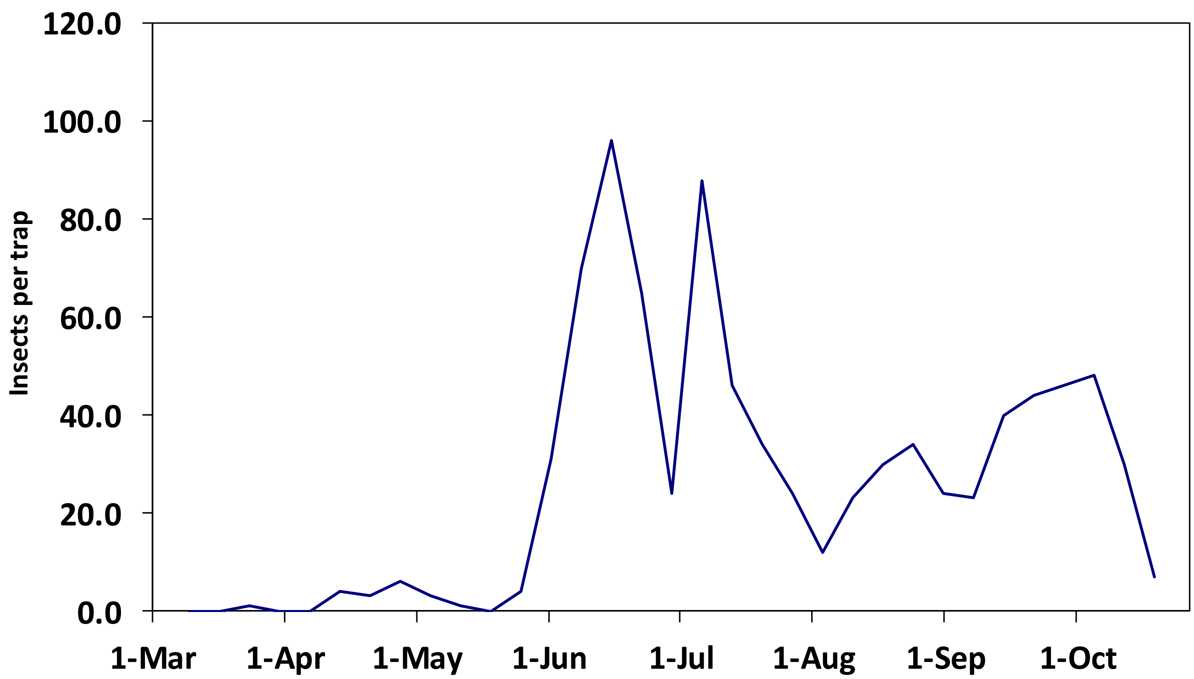
Lesser Appleworm Trap Captures
Mill Spring, Polk County, NC, 2014

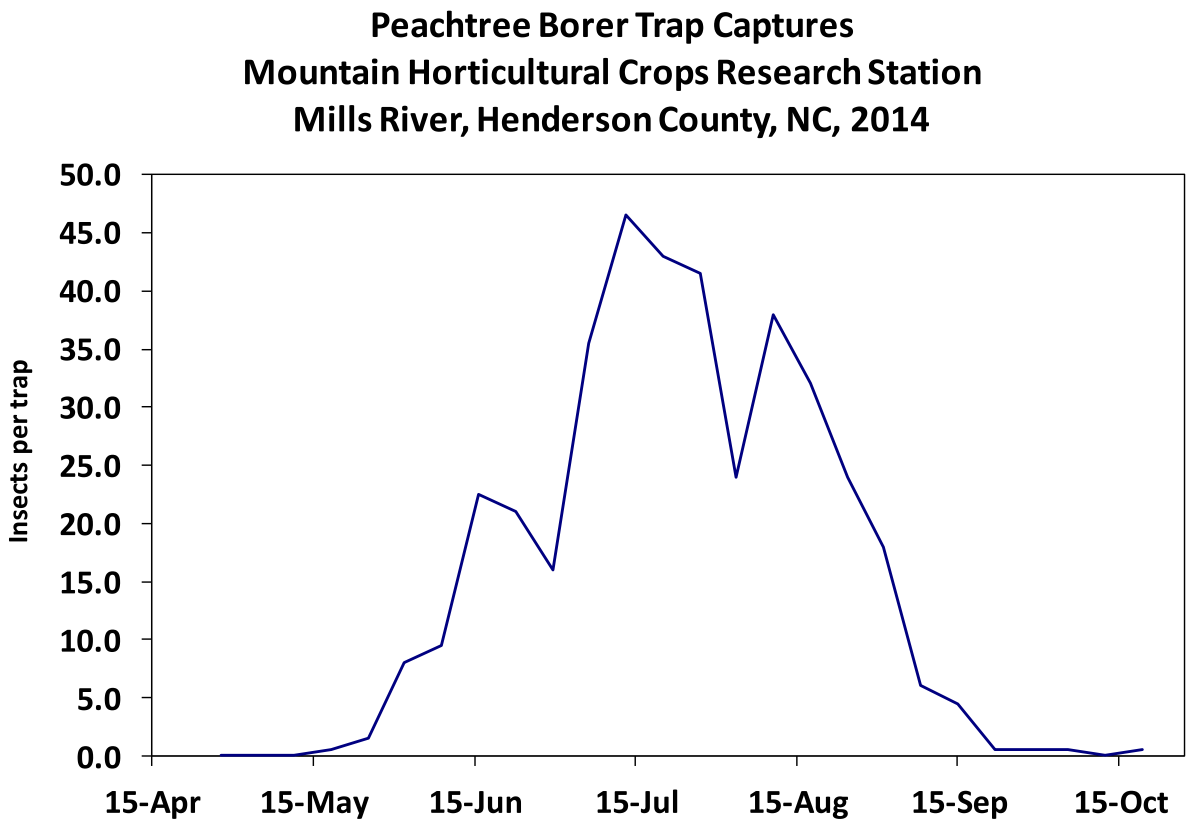


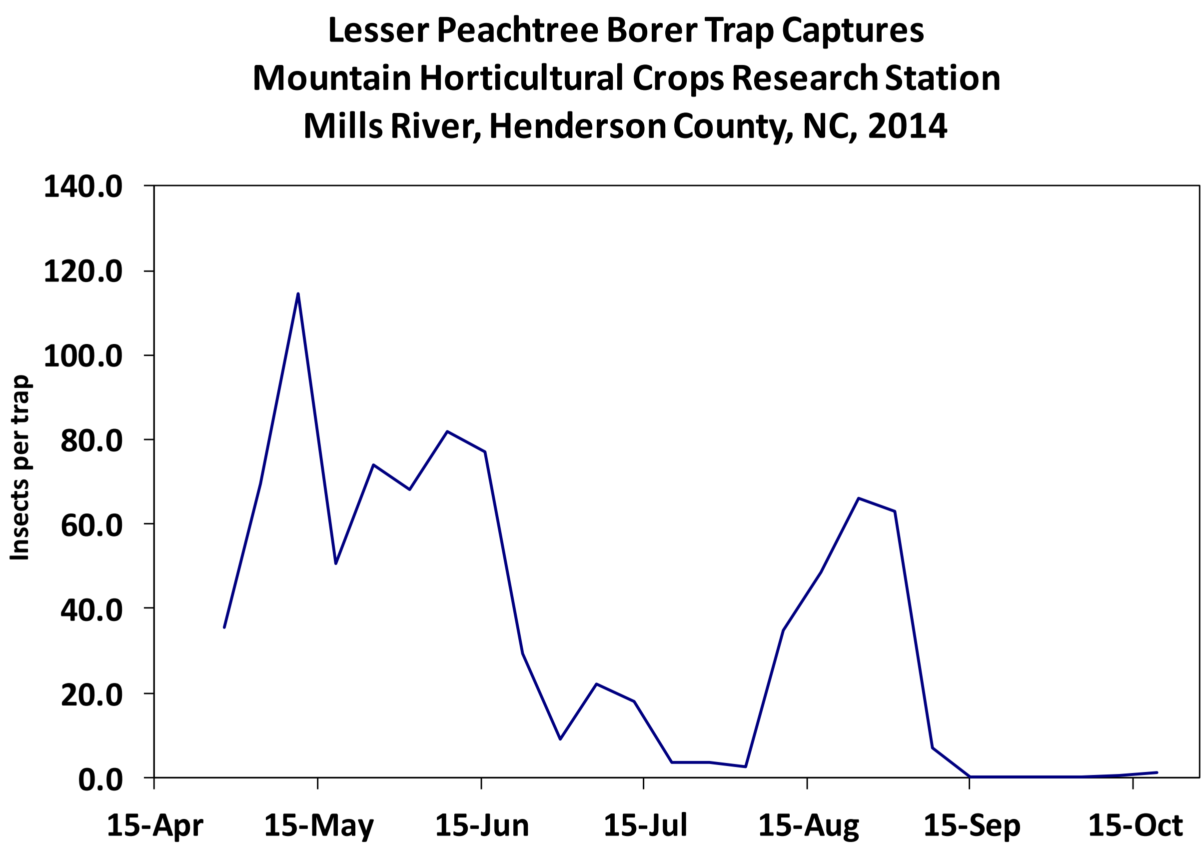
Lesser Appleworm Trap Captures
Mountain Horticultural Crops Research Station
Mills River, Henderson County, NC, 2014



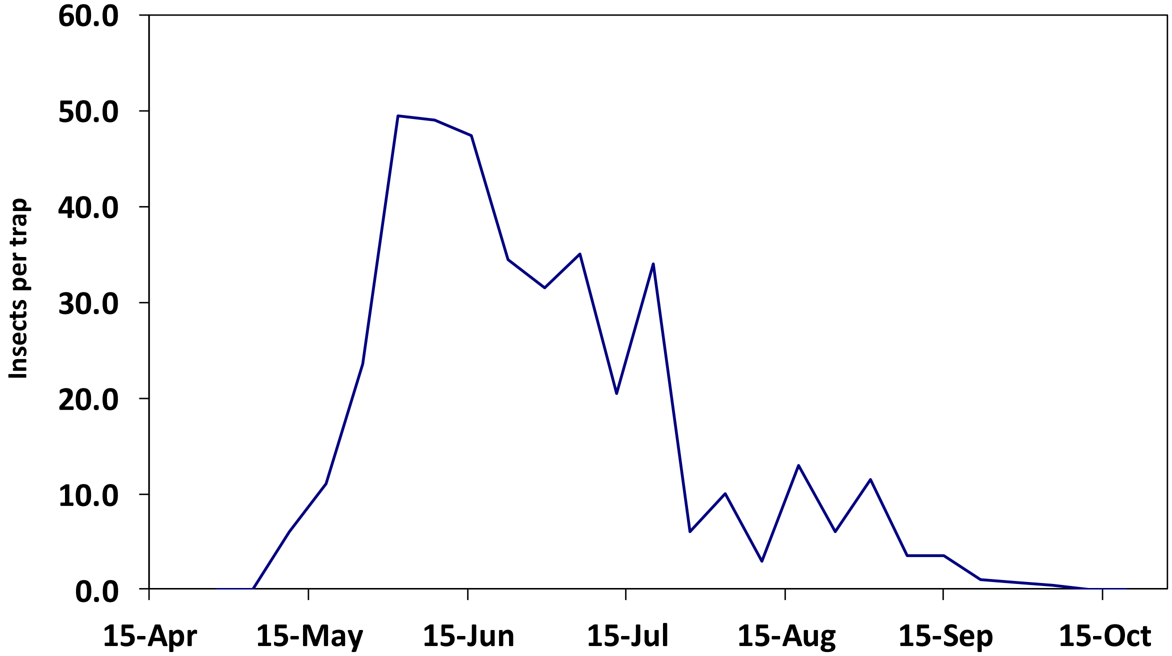
Spotted Tentiform Leafminer Trap Captures
Mountain Horticultural Crops Research Station
Mills River, Henderson County, NC, 2014



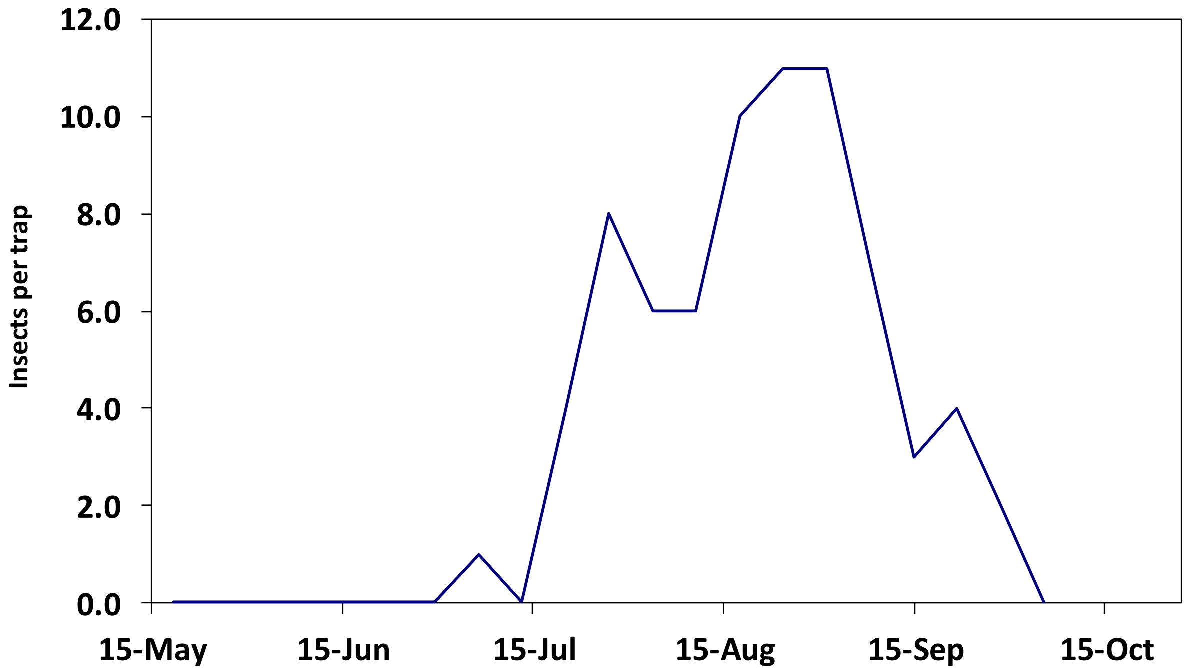

Peachtree Borer Trap Captures
Mountain Horticultural Crops Research Station
Mills River, Henderson County, NC, 2014
Insects per trap
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
15-Apr
15-May
15-Jun
15-Jul
15-Aug
15-Sep
15-Oct


Lesser Peachtree Borer Trap Captures
Mountain Horticultural Crops Research Station
Mills River, Henderson County, NC, 2014
Insects per trap
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
15-Apr
15-May
15-Jun
15-Jul
15-Aug
15-Sep
15-Oct

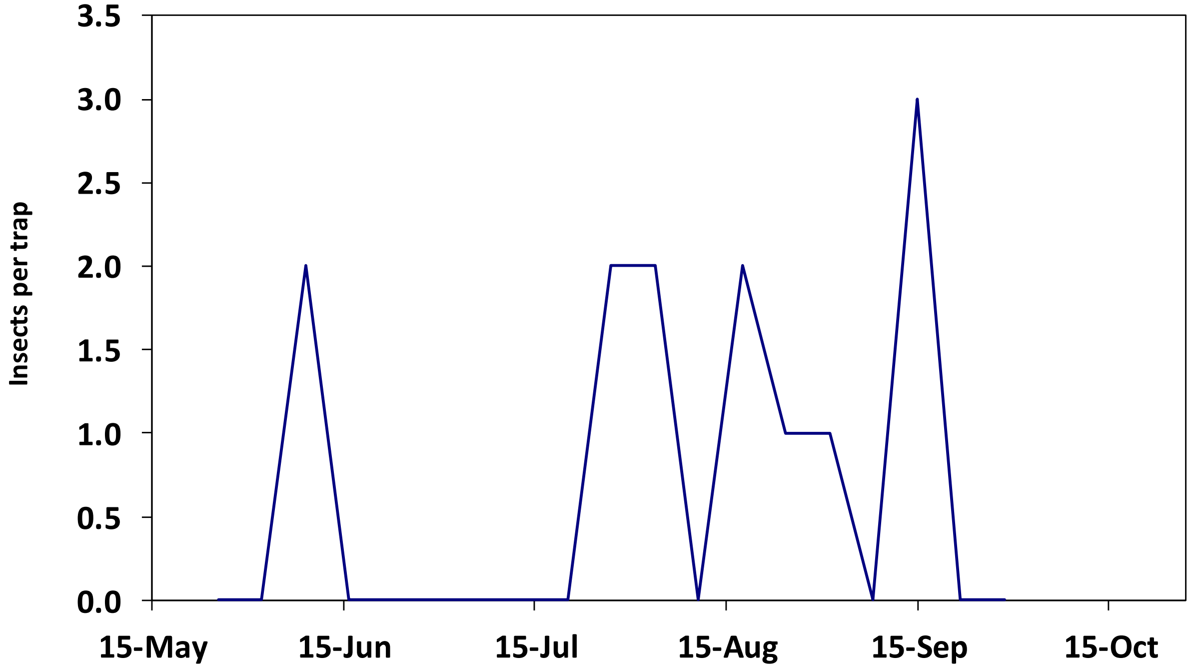
Dogwood Borer Trap Captures
Mountain Horticultural Crops Research Station
Mills River, Henderson County, NC, 2014



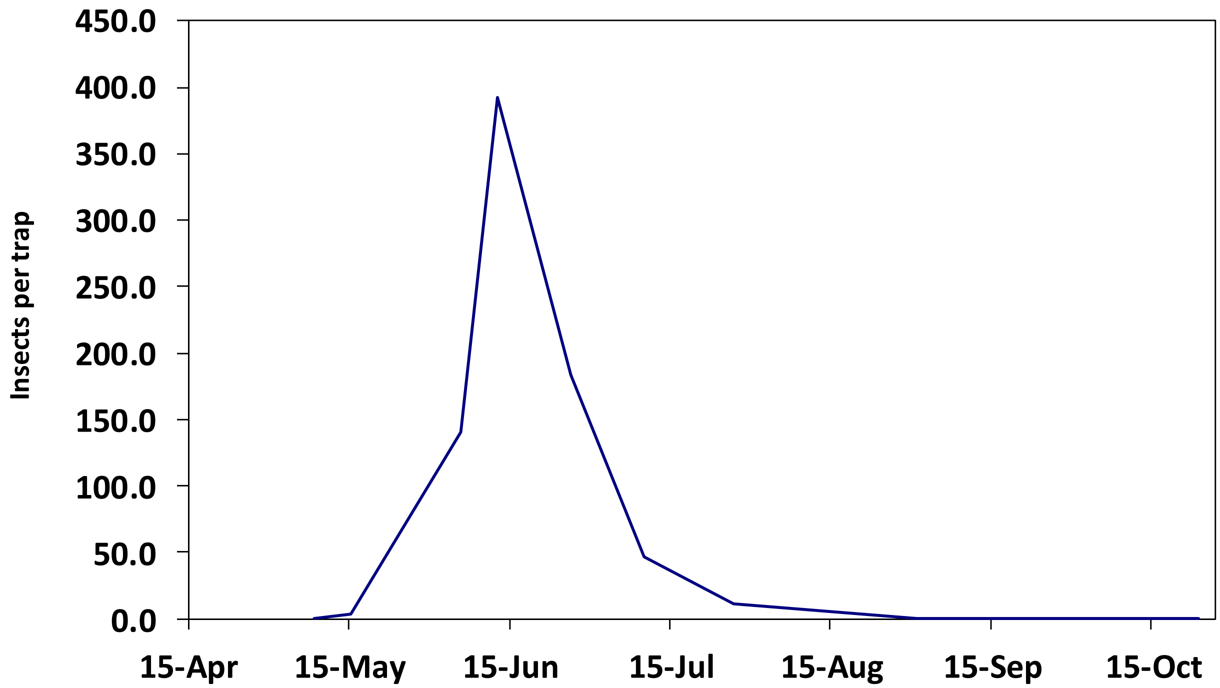
Apple Maggot Trap Captures
Abandoned Orchard
Fruitland, Henderson County, NC, 2014

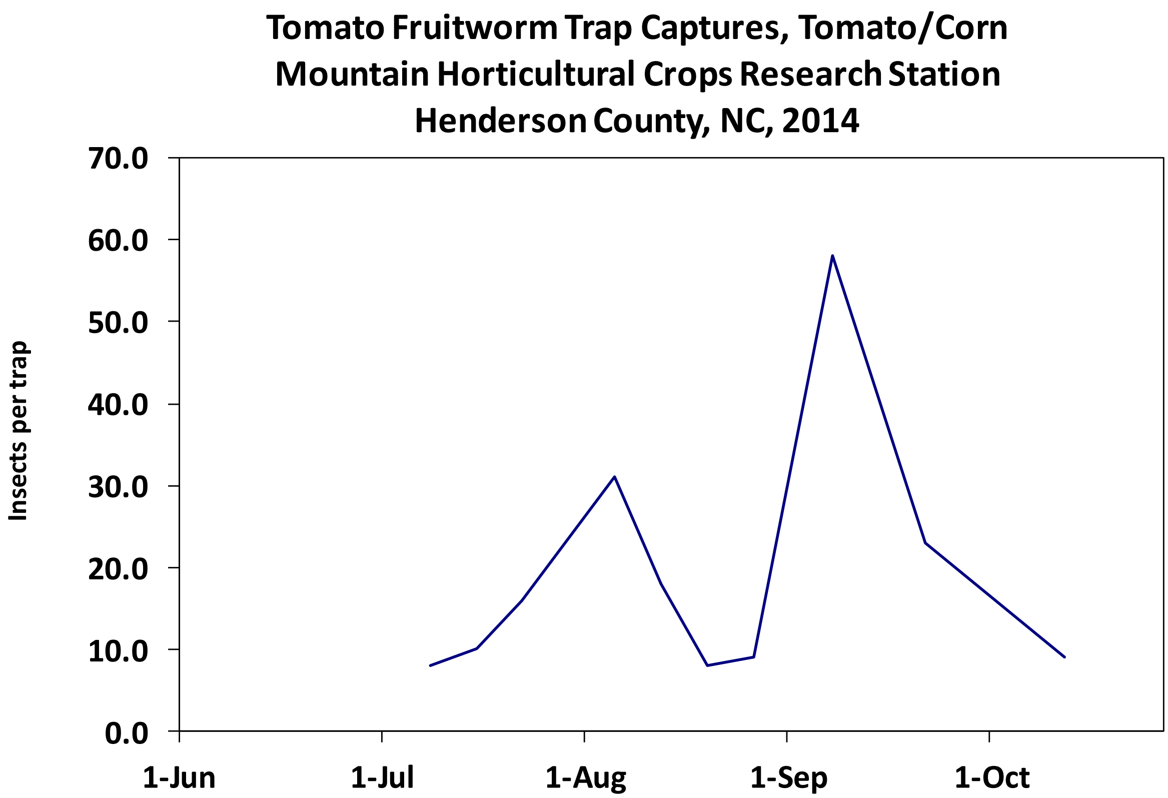


Apple Maggot Trap Captures
Commercial Orchard
Edneyville, Henderson County, NC, 2014

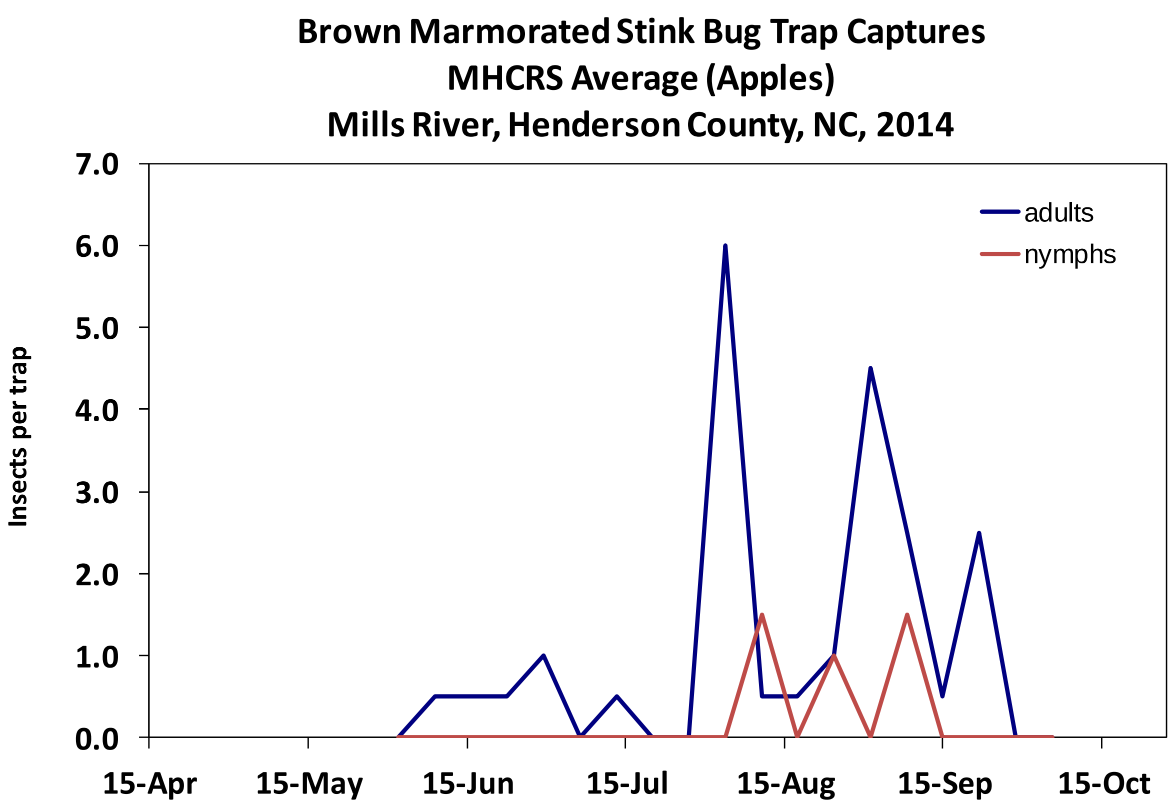


Thrips Trap Captures, Tomato Field
Mountain Horticultural Crops Research Station
Henderson County, NC, 2014





Tomato Fruitworm Trap Captures, Tomato/Corn
Mountain Horticultural Crops Research Station
Henderson County, NC, 2014
Insects per trap
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct



Brown Marmorated Stink Bug Trap Captures
MHCRS Average (Apples)
Mills River, Henderson County, NC, 2014
Insects per trap
adults
nymphs
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
15-Apr
15-May
15-Jun
15-Jul
15-Aug
15-Sep
15-Oct