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

2013

ANNUAL REPORT

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Acknowledgments

This report is a summary of pest management-related studies conducted on fruit and vegetable crops in 2013 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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2013 Weather Data – Mountain Horticultural Crops Research Station, Mills River, NC

March				April				May				June			
	Temp (°F)		Rain		Temp (°F)		Rain		Temp (°F)		Rain		Temp (°F)		Rain
Day	**High**	**Low**	**(in.)**	**Day**	**High**	**Low**	**(in.)**	**Day**	**High**	**Low**	**(in.)**	**Day**	**High**	**Low**	**(in.)**
1	42.3	27.5		1	67.0	39.0		1	64.2	55.9		1	80.6	62.1	0.04
2	33.1	23.5		2	63.0	37.0		2	61.9	53.8	0.01	2	72.9	63.1	1.05
3	55.8	25.5		3	55.0	38.0		3	59.5	52.9	0.01	3	78.3	62.1	0.02
4	52.0	33.4	0.69	4	58.0	37.0	0.69	4	55.6	48.0	0.61	4	80.2	56.8	
5	37.2	28.2		5	40.0	35.0		5	51.3	45.7	3.83	5	78.6	63.0	0.87
6	41.7	28.8		6	56.0	30.0		6	64.4	43.0	0.17	6	77.4	63.9	0.02
7	51.3	28.0		7	66.0	33.0		7	66.2	40.8	0.12	7	82.0	63.0	3.95
8	61.9	23.7		8	67.0	40.0		8	68.9	46.0	0.01	8	81.1	59.5	0.12
9	62.8	33.1		9	72.0	42.0		9	74.8	49.6	0.71	9	78.3	60.1	3.55
10	56.3	47.8	0.93	10	80.0	45.0		10	77.4	50.0		10	80.6	65.7	0.63
11	52.0	38.3	0.14	11	82.0	48.0	1.03	11	73.2	53.2	0.36	11	80.6	60.8	0.02
12	47.7	27.7		12	75.0	59.0	0.49	12	61.2	40.8		12	90.1	60.6	
13	45.5	25.3		13	67.0	47.0		13	61.7	36.5		13	90.0	62.2	0.11
14	69.4	26.8		14	70.0	36.0	0.05	14	72.1	35.1		14	76.1	55.8	0.01
15	76.6	41.2		15	68.0	41.0	0.18	15	83.7	48.0		15	83.5	51.1	
16	73.4	45.9		16	75.9	56.7		16	78.3	49.8		16	82.8	56.7	
17	46.6	38.5	0.42	17	75.7	53.2	0.19	17	79.9	50.4		17	79.0	65.3	0.17
18	57.9	35.4		18	73.9	55.4	0.01	18	68.0	57.6	1.01	18	79.3	63.9	0.02
19	55.6	30.2		19	66.7	43.3	0.72	19	75.4	59.7	0.38	19	79.5	59.2	
20	37.4	21.7	0.02	20	57.2	37.4		20	81.0	60.8		20	79.5	58.6	
21	48.9	24.8		21	60.6	32.2		21	83.5	58.8		21	81.7	60.1	
22	57.0	36.1	0.04	22	64.6	38.1		22	81.0	58.6	1.06	22	84.7	57.0	
23	45.3	38.5	1.02	23	70.3	33.3		23	79.0	60.4	0.01	23	83.3	57.0	0.03
24	40.1	30.2		24	70.5	41.4		24	64.6	43.9		24	84.2	64.9	
25	38.8	28.9		25	65.5	41.9		25	73.6	43.0		25	84.2	61.9	
26	43.3	29.5		26	66.2	36.9		26	73.6	49.5	0.04	26	85.3	63.1	0.83
27	51.4	27.9		27	55.4	50.2	0.91	27	79.7	46.0		27	86.7	64.2	0.10
28	57.2	25.0	0.01	28	52.7	46.9	1.95	28	81.3	54.9		28	87.4	63.3	0.04
29	62.4	39.9	0.13	29	70.0	50.5	0.02	29	81.7	55.0		29	82.0	61.3	
30	67.1	46.4	0.30	30	73.4	48.0		30	81.0	54.3		30	82.9	57.9	0.01
31	63.5	38.5						31	81.7	60.4					
			3.70				6.24				8.34				11.59

2013 Weather Data – Mountain Horticultural Crops Research Station, Fletcher, NC

July				August				September				October			
	Temp (^{o}F)		Rain		Temp (^{o}F)		Rain		Temp (^{o}F)		Rain		Temp (^{o}F)		Rain
Day	**High**	**Low**	**(in.)**	**Day**	**High**	**Low**	**(in.)**	**Day**	**High**	**Low**	**(in.)**	**Day**	**High**	**Low**	**(in.)**
1	80.6	64.2	1.03	1	80.4	64.4	0.62	1	87.6	65.3	0.26	1	78.3	53.1	
2	82.0	64.4	0.24	2	84.2	62.1		2	82.4	64.8	0.01	2	79.2	53.1	
3	75.9	62.1	3.48	3	82.4	64.4		3	80.4	61.9	0.20	3	79.7	54.1	
4	74.7	62.4	2.42	4	79.3	62.2		4	85.8	59.2		4	82.9	54.9	
5	81.7	66.6	0.35	5	82.2	60.6		5	82.2	59.5		5	82.0	57.0	
6	81.3	66.6	2.11	6	84.4	66.9		6	81.9	55.4		6	78.8	57.6	0.60
7	80.2	68.0	0.15	7	73.4	66.9	0.99	7	82.9	57.7		7	64.4	50.9	1.20
8	87.8	67.1		8	82.0	65.7	0.35	8	80.8	57.6		8	71.1	47.7	
9	88.7	66.6	0.90	9	85.3	66.6	1.00	9	84.0	60.6		9	75.2	43.0	
10	84.4	66.2	1.14	10	82.9	67.3	1.89	10	85.6	60.6		10	70.9	44.4	
11	79.5	65.8	0.01	11	81.3	66.7	0.37	11	83.1	61.7	0.17	11	73.2	45.7	
12	80.8	64.4	0.06	12	85.1	66.9	1.53	12	80.4	62.4	0.03	12	72.7	47.7	
13	75.7	62.6	0.06	13	84.4	66.2	0.14	13	76.1	59.5		13	71.2	58.5	0.40
14	75.0	64.8	1.14	14	75.7	61.0		14	75.0	51.4		14	68.2	54.5	
15	82.9	64.9	0.01	15	68.0	56.8		15	77.7	50.0		15	66.7	54.7	
16	88.5	64.0		16	73.4	55.2		16	77.9	54.1		16	69.4	50.5	
17	87.6	66.6	0.66	17	68.4	58.6	0.14	17	68.9	59.2		17	68.0	53.8	
18	86.9	65.7		18	77.7	61.7	0.21	18	67.8	57.0	0.01	18	70.3	48.0	
19	90.3	66.2		19	73.8	64.0	1.61	19	78.3	60.3		19	64.8	47.7	
20	84.6	66.7	0.04	20	80.4	64.2	0.01	20	82.8	61.0		20	65.8	40.5	
21	82.2	68.0	0.51	21	76.8	66.4	0.06	21	68.5	59.2	1.46	21	67.5	37.0	
22	82.2	65.7	0.49	22	82.6	64.2		22	71.8	53.1		22	67.5	46.0	
23	84.9	64.6	0.03	23	82.9	62.4		23	74.3	50.0		23	57.6	36.5	
24	84.0	64.8		24	78.6	57.2		24	74.7	51.6		24	52.9	34.7	
25	85.8	62.6		25	77.9	52.3		25	63.0	58.6	1.23	25	46.0	26.2	
26	82.6	59.5	1.04	26	81.1	54.1		26	71.6	52.0		26	58.5	22.3	
27	81.7	65.8	0.72	27	81.7	55.2		27	77.7	51.8	0.01	27	65.8	39.9	
28	82.6	62.8		28	84.7	61.9		28	71.1	52.3		28	62.1	44.1	0.20
29	81.9	60.6		29	85.3	66.2		29	72.9	50.7		29	69.4	42.4	
30	81.9	57.0		30	80.8	69.3	0.04	30	73.6	51.8		30	74.5	48.9	
31	77.7	65.5	0.26	31	84.4	66.4	0.22					31	65.7	50.7	0.10
			16.85				9.18				3.38				2.40

TOMATO FOLIAR INSECTICIDE/MITICIDE TRIAL – 2013

Tomato, *Lycopersicon esculentum* Mill. 'Red Defender'

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

This study was conducted at the Mountain Horticultural Crops Research Station in Mills River, NC. Six-wk-old 'Red Defender' tomato transplants were set on 21 May on black plastic mulch with drip irrigation. Plots consisted of single 25-ft long rows on 10-ft centers. 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. To encourage the buildup of TSSM populations, all plots, including the control, were sprayed with Sevin. Treatments consisted of different combinations of insecticides and miticides, and materials and rates are shown in Table 1. Miticide treatments in treatments 1 and 2 consisted of two applications each of Athena EW (a mixture of bifenthrin and avermectin) and Gladiator EW (a mixture of zeta-cypermethrin and avermectin), respectively. Mite management in treatments 3 and 4 consisted of preventive applications of Biomite and TriTek, respectively, applied weekly with insecticides. Treatments 5-8 consisted of preventive applications of Grandevo at 2 lb/A for mite control, with treatment variation consisting of different water volume (25, 50 and 100 GPA) or application interval (one vs. two applications per week during the time of initial mite build up period). 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 nozzles per row. Different nozzles were used to vary gallonage. TSSM populations were monitored by observing 10 terminal leaflets (3rd most recently expanded leaf) per plot with a 10X visor lens and recording the number of motile mites. Season total mite days were calculated by multiplying average mite density by sample interval (days) and summing values for each date. Potato aphids were monitored by recording the number of apterous aphids on 10 leaves per plot. Season cumulative aphid days were calculated as described for mites. On 1 and 29 August, 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).

Record rainfall occurred during the course of this trial, with a total of 39.03 inches of rain between 21 May and 31 August. Consequently, tomato foliage was in relatively poor condition due to early and late blight infestations. Consequently, both aphid and mite populations were relatively low, with populations in the control peaking at only 5 aphids/leaf and 31 mites/leaflet. The abundant rainfall likely contributed to wash-off of materials and short residual activity. As expected, those treatments that received a pyrethroid (treatments 1-4) had significantly lower aphid populations than the Grandevo treatments, which did not differ from the control (Table 2). TSSM populations began to increase in early June, and Athena and Gladiator treatments consistently had the lowest mite populations (Table 3). The weekly applications of TriTek suppressed mite populations below the control on most sample dates and had significantly lower cumulative mite-days than the control. Neither the Biomite nor the Grandevo treatments significantly reduced mite densities below the control, although densities were slightly lower than the control. Lepidopteran pests (predominately tomato fruitworm) caused 15.5% damage to non-treated tomatoes, and the rotational treatments of Radiant, Coragen and Karate were most effective in suppressing damage. Stink bug and thrips damage was low and quite variable, and there were no differences among treatments.

Table 1. Insecticide treatment programs applied ‘Red Defender’ tomatoes. Mills River, NC. 2013.

TRT	Insecticide	Rate/Acre	GPA[1]	Application dates
1	Brigade 2EC	6.4 fl oz	50-100	6/28, 7/16, 7/30, 8/6, 8/14, 8/21
	Athena EW	10 fl oz		7/9, 7/23
2	Mustang Max 0.83EC	4 fl oz	50-100	6/28, 7/9, 7/30, 8/6, 8/14, 8/21
	Gladiator EW	19 fl oz		7/16, 7/23
3	Radiant 1 SC	6 fl oz	50-100	6/28, 7/30, 8/21
	Coragen 1.67SC	4 fl oz		7/16, 8/6
	Karate 2.08CS	1.6 fl oz		7/9, 7/23, 8/14
	Biomite	2.0 pts		7/16, 7/23, 7/30, 8/6, 8/14, 8/21
4	Radiant 1 SC	6 fl oz	50-100	6/28, 7/30, 8/21
	Coragen 1.67SC	4 fl oz		7/16, 8/6
	Karate 2.08CS	1.6 fl oz		7/9, 7/23, 8/14
	TriTek	1.0%		7/9, 7/16, 7/23, 7/30, 8/6, 8/14, 8/21
5	Grandevo DF2	2 lb	25	6/28, 7/9, 7/16, 7/23, 7/30, 8/6, 8/14, 8/21
6	Grandevo DF2	2 lb	50	6/28, 7/9, 7/16, 7/23, 7/30, 8/6, 8/14, 8/21
7	Grandevo DF2	2 lb	100	6/28, 7/9, 7/16, 7/23, 7/30, 8/6, 8/14, 8/21
8	Grandevo DF2	2 lb	100	6/28, 7/9, 7/16, 7/19, 7/23, 7/26, 7/30, 8/2, 8/6, 8/14, 8/21
9	Non-treated Control	—	—	—

[1] For all treatments except 5 and 6, applications were applied at 50 and 75 GPA on 28 June and 9 July, respectively, and 100 GPA thereafter. Treatments 5 and 6 applications were made at 25 and 50 GPA on all dates.

Table 2. Mean potato aphid populations on tomatoes treated with different insecticide programs. Mills River, NC. 2013.

			Aphids per leaf						Cumul.
TRT	Insecticide	GPA	6/25	8/1	8/8	8/15	8/23	8/29	Aphid-days
1	Brigade 2EC Athena EW	50-100	0.0a	0.0a	0.0a	0.0a	1.3a	0.5a	10.3a
2	Mustang Max 0.83EC Gladiator EW	50-100	0.0a	0.0a	0.0a	1.0ab	1.5a	0.8a	20.3a
3	Radiant 1 SC Coragen 1.67SC Karate 2.08CS Biomite	50-100	0.0a	0.0a	0.0a	0.5ab	0.8a	0.0a	9.0a
4	Radiant 1 SC Coragen 1.67SC Karate 2.08CS TriTek	50-100	0.0a	0.0a	0.3ab	0.0a	2.0a	0.0a	15.8a
5	Grandevo DF2	25	1.3a	2.5a	2.8c	5.3abc	1.0a	8.0abc	111.5b
6	Grandevo DF2	50	2.5a	3.3a	3.3c	6.0bc	0.5a	12.0bc	138.8b
7	Grandevo DF2	50-100	1.5a	14.0a	2.3bc	7.8c	0.3a	15.5c	225.4b
8	Grandevo DF2	50-100	1.0a	1.0a	2.8c	8.3c	0.5a	4.3ab	107.9b
9	Non-treated Control	—	2.5a	5.0a	3.5c	3.8abc	0.8a	2.5ab	109.1b

Means within 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. 2013.

			Mites per leaflet								Cumul.
TRT	Insecticide	GPA	6/27	7/11	7/18	7/25	8/1	8/8	8/15	8/23	mite-d
1	Brigade 2EC Athena EW	50-100	0.1a	0.0a	1.3a	1.0a	1.0a	3.7a	3.9a	0.7a	85.2a
2	Mustang Max EC Gladiator EW	50-100	0.3a	3.2bc	2.5a	8.6ab	4.1a	7.8a	10.9ab	1.3a	289.3ab
3	Radiant 1 SC Coragen 1.67SC Karate 2.08CS Biomite	50-100	0.3a	2.3bc	3.9ab	11.6bc	18.6b	33.4b	26.8c	4.7a	734.6c
4	Radiant 1 SC Coragen 1.67SC Karate 2.08CS TriTek	50-100	1.1a	3.2bc	1.9a	10.5ab	5.0a	14.3a	15.1bc	1.6a	390.0b
5	Grandevo DF2	25	0.6a	1.8ab	8.1bc	18.6bc	21.9bc	31.8b	26.7c	0.9a	792.9c
6	Grandevo DF2	50	0.2a	2.3bc	9.7c	12.3bc	23.9bc	41.8b	23.0bc	0.7a	817.6c
7	Grandevo DF2	100	0.7a	5.1bc	10.7c	21.9c	27.3bc	39.2b	26.5bc	0.4a	958.5c
8	Grandevo DF2	100	0.6a	3.7bc	8.5c	15.0bc	30.6c	44.6b	21.4bc	0.7a	900.9c
9	Control	—	1.7a	5.0c	11.7c	27.0c	31.1c	34.3b	24.6bc	0.4a	984.4c

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

Table 4. Mean percentage damage caused by lepidopteran (LEP) pests, stink bugs (SB) and thrips (THP) to ‘Red Defender’ tomatoes treated with various insecticide programs. Mills River, NC. 2013.

			% Damage		
TRT	Insecticide	GPA[1]	LEP	SB	THP
1	Brigade 2EC Athena EW	50-100	4.3abc	0.0a	6.1a
2	Mustang Max 0.83EC Gladiator EW	50-100	9.7cd	0.5a	4.2a
3	Radiant 1 SC Coragen 1.67SC Karate 2.08CS Biomite	50-100	2.7ab	0.4a	6.4a
4	Radiant 1 SC Coragen 1.67SC Karate 2.08CS TriTek	50-100	1.9a	1.7a	1.2a
5	Grandevo DF2	25	12.9d	2.3a	7.1a
6	Grandevo DF2	50	12.5d	0.6a	3.4a
7	Grandevo DF2	100	9.4bcd	5.3a	6.9a
8	Grandevo DF2	100	10.1cd	2.2a	1.9a
9	Non-treated Control	—	15.5d	2.5a	2.0a

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

EVALUATION OF DRIP APPLICATIONS OF CYAZYPYR AND IMIDACLOPRID ON TOMATOES, 2013

TOMATO, *Lycopersicon esculentum* Mill. 'Red Defender'

Flower thrips (FT): *Frankliniella tritici* (Fitch) and *F. occidentalis* (Pergande)
Tobacco thrips (TT): *Frankliniella fusca* (Hinds)
Potato aphid (PA): *Macrosiphum euphorbiae* (Thomas)
Twospotted spider mite (TSSM): Tetranychus urticae (Koch)
Tomato fruitworm (TFW): *Helicoverpa zea* (Boddie)
Armyworms (AW): *Spodoptera* spp.
Stink bugs (SB): *Euschistus servus* (Say), *Acrosternum hilare* (Say), *Halyomorpha halys* (Stål)

This study was conducted at the Mountain Horticultural Crops Research Station in Mills River, NC. The objective was to compare the efficacy of cyazypyr and imidacloprid applied at planting and through a drip irrigation system for insect control and prevention of TSWV. Six-week-old 'Red Defender' tomato transplants were set on 21 May on black plastic mulch with drip irrigation. Plots consisted of two 20-foot long rows on 5-foot centers, with treatment rows separated by 10 feet of bare ground and replicates separated by 15 feet. Plants were spaced 1.5 feet within rows, and treatments were replicated four times and arranged in a RCBD. At-planting insecticide treatments were made by pouring 16 oz of insecticide solution at the base of each plant after transplanting to simulate a transplant solution application. Drip applications were made by injecting insecticide solutions into plots through the drip irrigation system with a CO_2 injection system. In addition to soil insecticide applications, two applications of Radiant (6 oz/acre) were applied on 17 and 26 June for thrips control. Foliar applications were made with a CO_2-powered backpack sprayer delivering 50 gallons per acre through 2 nozzles per row (two drop nozzles on each side of the row). Materials, application methods, and application dates are listed in the tables. Tomatoes were staked and strung as needed and sprayed with a standard fungicide and herbicide program.

Early in the season, FT were sampled by beating 10 plants per plot over a 8 ½ x 10 inch white sampling board and counting the number of insects observed. When plants developed flowers, sampling switched to 10 flowers per plot, which were removed and placed in a vial of 50% ETOH, after which the dislodged FT were counted under a stereomicroscope. PA were sampled by observing 10 recent, fully-expanded leaves per plot and recording the total number of leaves infested with apterous aphids. TSSM were counted on 10 terminal leaflets per plot. Season total insect-days were calculated by multiplying the average count between sample dates by the time between samples (days) and summing values from all sample dates. Mature fruit were harvested from the eight middle plants of each plot on 31 Jul and 12 Aug and graded for size (Jumbo >3.5", XL 3-3.5", L 2.5-3", and M 2-2.5"), weight, and insect damage. All data were subjected to two-way ANOVA and means were separated by LSD ($P = 0.05$).

Due to an extremely wet season, insect populations were very low in this trial. There was less than 1 FT per plant during beat sampling and less than 2 FT per flower in any treatment at any time during the season (Tables 1 and 2). There was also high variability among replications and no significant differences in FT or IFB were observed, with the exception of the beat samples on 5 Jun, when the AdmirePro-Coragen, AdmirePro-only, and cyazypry-AdmirePro treatments had significantly fewer FT than the control. PA populations reached a peak density in the control of only 17.5% infested leaves, and the only date on which treatment differences were significant was 15 August, when the cyazypyr at planting only treatment had significantly higher numbers than the Admire treatments. TSSM populations never exceeded 1.5 mites per leaf at any time and there were no significant differences observed. The experiment was harvested only two times (31 July and 12 August) by the time that a severe late blight infestation reduced overall plant quality to a low level. Percent marketability of fruit from the sum of both harvests ranged from 81.5% in the control to 93.7% in the AdmirePro-cyazypyr treatment, but there were no significant differences. Insect damage was consistently highest in the control, with 5.5%, 2.5%, and 10.5% lepidopterous, stink bug, and thrips damage, respectively. High variability among replications masked any statistically significant differences. No TSWV infections were observed in any plot, likely due to abundant rainfall and low thrips populations.

Table 1. FT and IFB populations sampled by beating Red Defender tomato plants treated with various insecticides. Mills River, NC. 2013.

Treatment	Rate	App. method	App. timing	FT per 10 plants 30-May	5-Jun	11-Jun	17-Jun
Admire Pro 4.6SC Cyazypyr 20SC	10.5 oz 10 oz	Transplant water Drip	At planting (5/21) 2-wk, 4-wk (6/4, 6/18)	0.0a	1.5abc	2.5a	0.8a
Admire Pro 4.6SC Coragen 1.67SC	10.5 oz 5.0 oz	Transplant water Drip	At planting (5/21) 3-wk, 5-wk (6/11, 6/25)	0.3a	1.0ab	2.5a	0.0a
Admire Pro 4.6SC	10.5 oz	Transplant water	At planting (5/21)	0.0a	0.3a	1.5a	0.3a
Cyazypyr 20SC	13.5 oz	Transplant water	At planting (5/21)	0.3a	2.3bc	3.3a	0.5a
Cyazypyr 20SC Admire Pro 4.6SC	13.5 oz 10.5 oz	Transplant water Drip	At planting (5/21) 2-wk (6/4)	0.5a	1.0ab	1.5a	0.5a
Control	-	-	-	0.0a	3.3c	4.8a	0.3a

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

Table 2. FT populations sampled in flowers of Red Defender tomato plants treated with various insecticides. Mills River, NC. 2013.

				FT per 10 flowers									
Treatment	Rate	App. method	App. timing	17-Jun	27-Jun	3-Jul	11-Jul	17-Jul	25-Jul	1-Aug	8-Aug	15-Aug	CTD
Admire Pro 4.6SC Cyazypyr 20SC	10.5 oz 10 oz	Transplant water Drip	At planting (5/21) 2-wk, 4-wk (6/4, 6/18)	1.3a	6.8a	1.5a	1.0a	1.5a	0.3a	1.3a	0.3a	0.0a	100.6a
Admire Pro 4.6SC Coragen 1.67SC	10.5 oz 5.0 oz	Transplant water Drip	At planting (5/21) 3-wk, 5-wk (6/11, 6/25)	1.3a	19.3a	6.8a	3.5a	2.0a	0.3a	1.5a	0.5a	0.3a	262.8a
Admire Pro 4.6SC	10.5 oz	Transplant water	At planting (5/21)	2.5a	10.5a	5.0a	4.5a	6.0a	0.5a	0.8a	0.3a	0.3a	216.6a
Cyazypyr 20SC	13.5 oz	Transplant water	At planting (5/21)	2.8a	18.3a	2.0a	4.0a	3.5a	2.8a	0.3a	0.8a	0.0a	253.9a
Cyazypyr 20SC Admire Pro 4.6SC	13.5 oz 10.5 oz	Transplant water Drip	At planting (5/21) 2-wk (6/4)	3.3a	5.0a	2.8a	3.0a	3.5a	0.8a	1.3a	0.8a	0.0a	140.6a
Control	-	-	-	3.3a	10.5a	10.0a	7.3a	5.8a	0.8a	2.5a	0.8a	0.0a	289.6a

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

Table 3. PA populations of Red Defender tomato plants treated with various insecticides. Mills River, NC. 2013.

				% PA-infested leaves							
Treatment	Rate	App. method	App. timing	27-Jun	11-Jul	17-Jul	25-Jul	1-Aug	8-Aug	15-Aug	CAD
Admire Pro 4.6SC Cyazypyr 20SC	10.5 oz 10 oz	Transplant water Drip	At planting (5/21) 2-wk, 4-wk (6/4, 6/18)	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	2.5a	0.9a
Admire Pro 4.6SC Coragen 1.67SC	10.5 oz 5.0 oz	Transplant water Drip	At planting (5/21) 3-wk, 5-wk (6/11, 6/25)	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	12.5ab	4.4a
Admire Pro 4.6SC	10.5 oz	Transplant water	At planting (5/21)	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a
Cyazypyr 20SC	13.5 oz	Transplant water	At planting (5/21)	0.0a	0.0a	0.0a	2.5a	2.5a	0.0a	30.0b	13.8a
Cyazypyr 20SC Admire Pro 4.6SC	13.5 oz 10.5 oz	Transplant water Drip	At planting (5/21) 2-wk (6/4)	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	5.0a	1.8a
Control	-	-	-	0.0a	2.5a	25.0a	17.5a	10.0a	10.0a	15.0ab	50.3a

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

Table 4. TSSM populations of Red Defender tomato plants treated with various insecticides. Mills River, NC. 2013.

				TSSM per 10 leaflets					
Treatment	Rate	App. method	App. timing	17-Jul	25-Jul	1-Aug	8-Aug	15-Aug	CMD
Admire Pro 4.6SC Cyazypyr 20SC	10.5 oz 10 oz	Transplant water Drip	At planting (5/21) 2-wk, 4-wk (6/4, 6/18)	0.0a	0.0a	1.5a	2.7a	12.5a	735.9a
Admire Pro 4.6SC Coragen 1.67SC	10.5 oz 5.0 oz	Transplant water Drip	At planting (5/21) 3-wk, 5-wk (6/11, 6/25)	0.0a	0.1a	0.8a	2.2a	10.1a	565.3a
Admire Pro 4.6SC	10.5 oz	Transplant water	At planting (5/21)	0.0a	0.6a	3.4a	5.8a	14.3a	1180.4a
Cyazypyr 20SC	13.5 oz	Transplant water	At planting (5/21)	0.0a	2.3a	2.5a	3.8a	13.6a	1071.0a
Cyazypyr 20SC Admire Pro 4.6SC	13.5 oz 10.5 oz	Transplant water Drip	At planting (5/21) 2-wk (6/4)	0.0a	0.0a	0.7a	2.7a	7.5a	493.5a
Control	-	-	-	0.3a	0.0a	1.4a	1.6a	7.9a	525.0a

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

Table 5. Season total fruit (by weight) harvested from Red Defender tomato plants treated with various insecticides. Mills River, NC. 2013.

					Marketable					Non-Marketable			
Treatment	Rate	App. method	App. timing	Total Yield (lbs)	% Jumbo	% Extra Large	% Large	% Medium	% Total Marketable	% Leps	% SB	% Thrips	% Under-sized
Admire Pro 4.6SC Cyazypyr 20SC	10.5 oz 10 oz	Trans. water Drip	At planting (5/21) 2-wk, 4-wk (6/4, 6/18)	34.0a	8.6a	54.8a	29.9a	0.3a	93.7a	0.5a	0.0a	5.7a	0.1a
Admire Pro 4.6SC Coragen 1.67SC	10.5 oz 5.0 oz	Trans. water Drip	At planting (5/21) 3-wk, 5-wk (6/11, 6/25)	43.7a	22.3b	50.0a	18.9a	0.4a	91.6a	2.1a	0.3a	5.9a	0.1a
Admire Pro 4.6SC	10.5 oz	Trans. water	At planting (5/21)	36.8a	11.4a	43.7a	31.2a	1.5a	87.8a	3.5a	0.2a	8.4a	0.1a
Cyazypyr 20SC	13.5 oz	Trans. water	At planting (5/21)	34.8a	12.0a	51.6a	25.2a	0.5a	89.3a	3.0a	0.3a	7.3a	0.0a
Cyazypyr 20SC Admire Pro 4.6SC	13.5 oz 10.5 oz	Trans. water Drip	At planting (5/21) 2-wk (6/4)	38.5a	7.8a	61.3a	22.4a	0.8a	92.4a	1.8a	0.4a	5.4a	0.0a
Control	-	-	-	33.2a	15.3ab	44.0a	21.8a	0.5a	81.5a	5.5a	2.5a	10.5a	0.0a

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

CUCUMBER INSECTICIDE TRIAL – 2013

CUCUMBER, *Cucumis sativus* ‘Dasher II’

Cucumber beetle (CB): *Diabotica undecimpunctata howardi* (Barber) and *Acalymma vittatum* (Fabricius)
Potato aphid (PA): *Macrosiphum euphorbiae* (Thomas)
Miscellaneous lepidopterans (LEP)

This study was conducted at the Mountain Horticultural Crops Research Station in Mills River, NC. ‘Dasher II’ cucumber seeds were direct-seeded on 28 May into black plastic mulch with drip irrigation. Plots consisted of single 25-ft long rows on 10-ft centers and rows were separated by 10 feet of bare ground. Plants were spaced 12 inches apart within rows, and treatments were replicated four times and arranged in a RCBD. Insecticide treatments were applied with a CO_2 backpack sprayer using 2 to 6 nozzles/row (1 to 3 nozzles/side, both sides of row sprayed) as plants grew. Treatments, rates, and application timing are listed in the tables. Cucumbers were staked and strung as needed and sprayed with a standard fungicide program.

Cucumber beetles were monitored on three of the most recently expanded leaves on 10 plants per plot, and beetle damage was monitored by recording the number of beetle-damaged leaves out of 10 per plot. Aphids were monitored by recording the number of apterous aphids on 10 leaves per plot. Mature fruit were harvested from the center 15 feet of row of each plot on 16, 18, 25, and 29 Jul and 1, 6, 8, and 13 Aug. For the purposes of analysis, harvests were combined into Early (16 and 18 Jul), Middle (25 and 29 Jul and 1 Aug), and Late (6, 8, and 13 Aug) harvests. Fruit were graded for 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 feeding by adult cucumber beetles. All data were subjected to two-way ANOVA and means were separated by LSD (P=0.05).

Cucumber beetle populations were low in this trial and only exceeded 1 per leaf on 27 June; however, there were significantly higher season total beetles in the control (22.8 per 10 plants) than in either the low-rate IKI-3106SL or the Sevin/Asana/Perm-Up treatments (11.8 and 4.3 per 10 plants, respectively) (Table 1). The control also had a consistently higher percentage of damaged leaves throughout the season, with a season total of 64.0%, compared to the treated plots, which ranged from 40.5 to 49.0%. There were no aphids observed in any of the plots during the season.

Although season total fruit yield ranged from 76.9 lbs in the control to 120.4 lbs in the high-rate IKI-3106SL treatment, none of the differences were significant due to the high variability among replications (Table 2). All of the treated plots produced significantly higher amounts of marketable fruit than the control, and all treatments significantly reduced the amount of heavily scarred fruit below the control. The amount of fruit with lepidopteran entries was extremely low throughout the trial and there were no significant differences among any of the plots.

Table 1. Season total cucumber beetles and beetle feeding damage on leaves of 'Dasher II' cucumber plants, Mills River, NC. 2013.

Treatment	Rate/A	Application Dates	Cucumber beetles per 10 plants	Percent damaged leaves
IKI-3106 SL	11.0 fl oz	14, 26 Jun 9, 16, 23, 30 Jul	11.8ab	41.0a
IKI-3106 SL	16.4 fl oz	14, 26 Jun 9, 16, 23, 30 Jul	15.3bc	49.0a
Sevin XLR	1 qt	14 Jun	4.3a	40.5a
Asana XL	6 fl oz	26 Jun, 9, 16 Jul		
Perm-Up	6 fl oz	23, 30 Jul		
Control	-	-	22.8c	64.0b

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

Table 2. Season total harvest damage on 'Dasher II' cucumbers, Mills River, NC. 2013.

				Marketable			Non-marketable		
Treatment	Rate/A	Application Dates	Total yield (lbs)	% clean fruit	% w/ slight scarring	% total market-able	% w/ heavy scarring	% w/ lep entries	% w/ other damage
IKI-3106 SL	11.0 fl oz	14, 26 Jun 9, 16, 23, 30 Jul	117.7a	62.2a	27.2a	89.4b	8.3a	0.0a	2.3a
IKI-3106 SL	16.4 fl oz	14, 26 Jun 9, 16, 23, 30 Jul	120.4a	51.3a	39.0b	90.3b	6.0a	0.1a	3.6a
Sevin XLR	1 qt	14 Jun	97.0a	64.1a	21.8a	85.9b	11.4a	0.0a	2.7a
Asana XL	6.0 fl oz	26 Jun, 9, 16 Jul							
Perm-Up	6.0 fl oz	23, 30 Jul							
Control	-	-	76.9a	51.5a	24.7a	76.1a	20.0b	0.3a	3.6a

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

TOMATO NEONICOTINOID SOIL INSECTICIDE TRIAL – 2013

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

Thrips (FT): *Frankliniella tritici* (Fitch) and *Frankliniella occidentalis* (Pergande)
Potato aphid (PA): *Macrosiphum euphorbiae* (Thomas)
Twospotted spider mite (TSSM): *Tetranychus urticae* (Koch)
Tomato fruitworm (LEP): *Helicoverpa zea* (Boddie)
Armyworms (LEP): *Spodoptera* spp.
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 May 24 on black plastic mulch with drip irrigation. Plots consisted of two 25-ft long rows on 5-ft centers. Plants were spaced 1.5 ft within rows, and treatments were replicated four times and arranged in a RCBD. Insecticide treatments were injected into drip irrigation lines via a CO_2 injector on 19 June and 9 July (materials and rates are listed in the tables), and tomatoes were staked and strung as needed and sprayed with a standard fungicide program.

FT populations were monitored by collecting 10 flowers per plot, placing them in a vial of 50% ETOH, and counting dislodged thrips under a stereomicroscope. PA were sampled by observing 10 recent, fully-expanded leaves per plot and recording the total number of leaves infested with apterous aphids. TSSM were counted on 10 terminal leaflets per plot. Season total insect-days were calculated by multiplying the average count between sample dates by the time between samples (days) and summing values from all sample dates. On 9 and 20 August and 5 September, mature fruit were harvested from the eight middle plants of each plot and graded for damage by lepidopterans, stink bugs, and thrips. All data were subjected to two-way ANOVA and means were separated by LSD (p=0.05).

Due to record rainfall, insect activity was extremely low in this trial. FT populations exceeded 1 thrips/flower only once in one plot, PA never exceeded 3 aphids/10 leaves, and TSSM remained below 1 mite/leaflet. There were no significant differences observed either on individual sample dates or when cumulative insect-days were calculated (Table 1). Over the course of three harvests, only one significant difference was observed, when the control plots had more FT damage (15.9%) compared to the treated plots (3.3-7.3%) on 8 August. Season total LEP damage ranged from 0.6 to 2.5% across treatments, SB damage from 5.7 to 9.0%, and FT damage from 4.5 to 8.1%, but none of these differences were statistically significant.

Table 1: Populations of FT, PA, and TSSM and fruit damage by LEP, SB, and FT on ‘Florida 47’ tomatoes treated with various insecticides through the drip irrigation system. Waynesville, NC. 2013

Treatment*	Rate / A	Applic. date	Cumulative insect days			Season total fruit at harvest	% damaged fruit at harvest (season total)		
			FT / 10 flowers	PA / 10 leaves	TSSM / 10 leaflets		LEP	SB	FT
Admire Pro 4.6SC	10.5 fl oz	9 Jul	73.4a	2.3a	7.8a	154.8a	1.3a	6.7a	4.6a
Platinum 75SG	3.67 oz	9 Jul	104.1a	3.1a	0.0a	139.5a	1.3a	5.8a	4.5a
Scorpion 35SL	10.5 fl oz	9 Jul	71.6a	5.1a	29.8a	146.5a	1.1a	9.0a	5.5a
Belay 2.13SC	12 fl oz	9 Jul	77.3a	2.3a	13.0a	147.8a	0.6a	8.8a	5.0a
Venom 70SG	6 oz	9 Jul	78.6a	7.0a	0.0a	179.3a	2.5a	7.0a	4.5a
Control	-	-	50.0a	16.5a	7.0a	162.5a	1.2a	5.7a	8.1a

*All treatments (including control) were treated with Coragen (4 fl oz/A) through the drip irrigation system on 19 June.

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

Effect of Biologically Based Pesticides on Various Life Stages of Twospotted Spider Mite

The twospotted spider mite (TSSM) is a common pest of tomatoes and cucurbit crops in North Carolina. TSSM is a difficult pest to control because of its rapid development rate during the warm summer months, the absence of effective natural enemies in vegetable cropping systems, and the development of resistance to commonly used acaricides. This laboratory study was conducted to evaluate several biologically based products that could be used to help suppress TSSM populations and thereby reduce reliance on synthetic acaricides.

Materials and Methods:

Chemicals. Five different products and a non-treated control were tested. Chemical treatments included: three rates of MBI203 DF2 (Grandeva, Marrone Bio Innovations, Davis, CA) at equivalent rates of 1, 2 and 3 lbs/acre, MBI206 EP (Marrone Bio Innovations) at equivalent rates of 1 and 2 gal/acre; GOS (Georgia Organic Solutions, Blakely, GA) Neem 7-Way at 1% solution plus 0.25% GOS Emulsifier (80% d-Limonene, 20% surfactant); TriTek (Brandt Consolidated, Springfield, IL) at 1% solution; and Acramite 50WP (Chemtura Corp., Middlebury, CT) at the equivalent rate of 0.08 lb (0.04 lb AI) per acre. The Acramite rate was equivalent to only about 10% of recommended field rates, but the 200 ppm rate was about 2X greater than the 95% LC_{95} value for adults at 48 h. All treatments were diluted in distilled water (pH 5.2) with Latron B1956 adjuvant added at 0.01% (2 drops per liter). For both of the MBI treatments and Acramite, rates were based on applying products in 50 gallons water/acre. Controls were dipped in distilled water + Latron B1956.

Bioassay Methods. The effect of various pesticides on TSSM toxicity and fecundity was assessed via direct contact and residual exposure bioassays. For contact exposure, mites were transferred with a camel hair brush onto a 2.0 cm diameter bean leaf disc placed on moist cotton in a 5.5 cm diameter petri dish, and then test materials were topically applied to leaf discs with an artist air brush (Paasche model H-set airbrush, Chicago, IL) in 50 µl aliquots. For residual contact exposure, leaf discs were dipped into test solutions and then placed on paper towels for 1 hr to dry, after which they were placed on moist cotton in a 5.5 cm diameter petri dish and mites placed on discs. For both bioassay methods, leaf discs were placed on moist cotton in petri dish bottoms that were covered with tops that had a 2-cm diameter screened hole, and all discs with mites were incubated in a growth chamber at 25°C, ~60% RH, and 16:8 L:D.

Adult bioassays. For adult bioassays, 10 adult females were placed on each leaf disc and mortality was recorded at 24 and 48 h. The number of eggs laid was also recorded, and expressed as number of eggs per female per day. For each treatment, a replicate consisted of 5 leaf discs (=50 mites) and each treatment was replicated three times.

Deuto- and protonymph bioassays. Because of the similar appearance of deutonymphs and protonymphs, they were not differentiated for these bioassays. For each replicate, 10 deutonymphs and/or protonymphs were placed on each of five leaf discs, and each treatment was replicated three times. Mortality was recorded after 24, 48 and 72 h.

Larval bioassays. Due to the small size of TSSM larvae, it was impractical to transfer larval stage individuals with a camel hair brush. Hence, to expose larvae, five adult females were placed on leaf discs for a 4 to 6 h oviposition period and then removed. For contact exposure, eggs were incubated for 4 d at 25°C – time interval for eggs to hatch – at which time the number of larvae on each disc was counted, and then treated with treatment solutions using the airbrush. For residual bioassays, leaf discs were dipped into test solutions, allowed to air dry ~1 h, and then five adult females were placed on discs for a 4 to 6 h oviposition period. A replicates consisted of five leaf discs, and each treatment was replicated three times. Larval numbers were counted at 4 days when eggs hatched (pre-treatment number), and mortality was recorded at 24, 48, 72 and 96 h after treatment.

Egg bioassays. To establish cohorts of eggs, adult females were placed on leaf discs for 4 to 6 h oviposition periods as described above. For contact activity bioassays, eggs were treated with test solutions via the artist air brush to 24 hr-old eggs. For residual activity bioassays, ovipositing adults were placed on leaf discs for a 4 to 6 h oviposition, 24 h after they were dipped into test solutions. A replicate consisted of five discs, and each treatment was replicated three times. Leaf discs were checked at 4, 5, 6 and 7 days later and the percentage of eggs hatching was recorded.

Statistics. Data were subjected to a 9 x 2 factorial analysis to test for differences among pesticide treatments and contact versus residual exposure. A paired t-test was used to test for differences among exposure methods, while LSD was used to test for differences among pesticide treatments. All percentage data was transformed using acrsin $\sqrt{x}$ to normalize variance, while numerical data were transformed using $\sqrt{x}$.

Results:

ANOVA statistics for the effects of chemical, exposure method, and interaction of chemical x exposure are shown in Table 1. Chemical effects were significant for all bioassays, while exposure method was significantly only for ovicidal tests, 24 mortality counts of larvae, and 24-h mortality of dueto/protonymphs. Interaction effects were significant for most bioassays.

Adult mortality and fecundity. Acramite was the only chemical that resulted in mortality at 24 h after exposure (Table 2). At 48 h, mortality in all three rates of MBI 203 and the neem treatment were also significantly higher than the control. A significant chemical x exposure interaction was the result of Acramite being significantly more toxic via contact (92.7±5.4% mortality) versus residual (62.7±7.7% mortality) at the 48-h exposure.

With the exception of MBI 206, all chemical treatments significantly reduced fecundity below that of the control, which averaged 7.6 and 5.6 eggs/female/day at 24 and 48 hr after exposure to chemicals (Table 2). Exposure method had no effect on fecundity. Based on the total number of eggs produced per cohort, all treatments except the low rate of MBI 203 significantly reduced fecundity below the control. Fecundity was lowest in the Acramite treatment, which had almost 90% fewer eggs than the control, followed by the MBI 203 treatments, and neem and TriTek.

<u>Larval mortality</u>. The only instance in which exposure method was a significant effect was at 24 h, when residual exposure (30.8±5.9) had significantly higher mortality than contact exposure mortality (23.8±5.3). Also, mortality in the 2 gal rate of MBI 206 and neem treatments were higher in the residual versus contact exposure (Table 3). In addition to Acramite, which caused high mortality of larvae at 24 h, neem oil and TriTek both resulted in about 60% mortality by 96 h post treatment, and MBI 203 averaged about 50% across all three treatments.

<u>Deutonymphs and protonymphs</u>. Chemical and exposure x chemical interaction effects were significant for bioassays at 24, 48 and 72 h post exposure, while exposure was significant only at 24 h. Mortality across all treatments was higher via contact (19.1±4.6% versus 13.4±2.7%). With the exception of BMI 203, most chemical treatments were less toxic to deuto/protonymphs compared to larvae, and mortality increased with longer periods of exposure to the chemical – at 72 hr all treatments except contact exposure to TriTek had significantly higher mortality than the control (Table 4). Acramite was most toxic, and toxicity was greater via contact compared to residual exposure.

<u>Ovicidal effects</u>. Neem oil, TriTek and Acramite were the only chemicals to exhibit ovicidal activity, and this activity was apparent by contact, not residual exposure (Table 5). Greater activity via contact exposure for these products accounted for the significant chemical x exposure interaction.

Table 1. ANOVA statistics for experiments comparing the effects of nine chemical treatments applied by two exposure methods on twospotted spider mite.

Category	Factor	F	P
24-h adult mortality	Chemical	20.95	<0.001
	Exposure	0.06	0.806
	Chemical x exposure	1.09	0.395
48-h adult mortality	Chemical	14.46	<0.001
	Exposure	0.01	0.613
	Chemical x exposure	2.52	0.028
24-h deuto/protonymph mortality	Chemical	22.87	<0.001
	Exposure	4.74	0.0362
	Chemical x exposure	2.56	0.0254
48-h deuto/protonymph mortality	Chemical	26.54	<0.001
	Exposure	0.04	0.848
	Chemical x exposure	4.81	<0.001
72-h deuto/protonymph mortality	Chemical	50.185	<0.001
	Exposure	0.08	0.0779
	Chemical x exposure	9.32	<0.001
24-h larval mortality	Chemical	77.9	<0.001
	Exposure	10.41	<0.003
	Chemical x exposure	2.21	<0.001
48-h larval mortality	Chemical	5.31	<0.001
	Exposure	3.13	<0.08
	Chemical x exposure	4.10	<0.002
72-h larval mortality	Chemical	37.10	<0.001
	Exposure	0.12	0.914
	Chemical x exposure	3.42	0.005
96-h larval mortality	Chemical	34.42	<0.001
	Exposure	3.81	0.193
	Chemical x exposure	4.19	<0.001
Eggs/female at 24 h	Chemical	33.67	<0.001
	Exposure	0.001	0.059
	Chemical x exposure	2.47	0.001
Eggs/female at 48 h	Chemical	13.82	<0.001
	Exposure	3.29	0.078
	Chemical x exposure	1.17	0.344
Total eggs/female	Chemical	28.60	<0.001
	Exposure	0.94	0.37
	Chemical x exposure	1.88	0.095
5-DAT Ovicidal	Chemical	11.24	<0.001
	Exposure	53.78	<0.001
	Chemical x exposure	6.18	<0.001
6-DAT Ovicidal	Chemical	10.67	<0.001
	Exposure	32.71	<0.001
	Chemical x exposure	6.99	<0.001
7-DAT Ovicidal	Chemical	7.81	<0.001
	Exposure	48.31	<0.001
	Chemical x exposure	4.65	<0.001

For all ANOVA's, df for Chemical, exposure, and chemical x exposure effects were 3, 36; 1, 36; and 8, 36, respectively.

Table 2. Percentage mortality of twospotted spider mite adult females following contact and residual exposure to various acaricides.

Material	Amt/ Liter	Equivalent per acre	% Mortality		Eggs/female		Total eggs per cohort
			24-h	48-h	24-h	48-h	
MBI 203 DF2	2.4 gm	1 lb	12.0 ± 1.2a	41.0 ± 5.6cd	3.1 ± 0.3bc	1.3 ± 0.3a	214.2 ± 30.3b
MBI 203 DF2	4.8 gm	2 lb	16.0 ± 1.2a	36.3 ± 6.1c	2.6 ± 0.4b	1.2 ± 0.3a	183.3 ± 33.7b
MBI 203 DF2	7.2 gm	3 lb	16.3 ± 2.8a	50.7± 9.8d	2.2 ± 0.4ab	0.7 ± 0.3a	142.8 ± 30.6b
MBI 206 EP	20 ml	1 gal	9.3 ± 2.8a	23.3 ± 3.0ab	7.1 ± 0.3e	4.4 ± 0.4c	553.3 ± 31.1de
MBI 206 EP	40 ml	2 gal	7.7 ± 1.9a	19.7 ± 3.9ab	6.9 ± 0.5e	3.5 ± 1.0bc	508.7 ± 63.4d
GOS Neem	1%	1%	16.3 ± 4.1a	30.0 ± 6.7bc	4.1 ± 1.0cd	2.7 ± 0.6b	328.0 ± 73.8c
TriTek	1%	1%	10.3 ± 1.9a	22.3 ± 1.8ab	4.5 ± 0.2d	3.3 ± 0.5bc	372.8 ± 21.1c
Acramite 50WP	0.2	0.08 lb	60.0 ± 8.5b	*77.7 ± 7.9e	1.3 ± 0.2a	0.5 ± 0.2a	74.3 ± 10.8a
Control	-	-	6.7 ± 1.1a	12.0 ± 1.8a	7.9 ± 0.4e	5.6 ± 0.5d	654.7 ± 26.7e

Means within the same column followed by the same letter are not significantly different by LSD (P = 0.05). * indicates that means from different exposure method (contact versus residual) within the same chemical treatment are significantly different by *t*-test (P < 0.05).

Table 3. Twospotted spider mite larval mortality following contact and residual exposure to various acaricides.

			24 h		48 h		72 h		96 h	
Material	Amt/ Liter	Equiv. Per Acre	Contact	Residual	Contact	Residual	Contact	Residual	Contact	Residual
MBI 203	2.4 gm	1 lb	8.6 ± 1.5ab	11.4 ± 2.6a	16.6 ± 2.0ab	27.3 ± 7.7bc	26.5 ± 4.8b	35.1 ± 7.8bc	33.4 ± 5.6b	45.9 ± 9.9bcd
MBI 203	4.8 gm	2 lb	22.7 ± 2.3cd	11.4 ± 3.1a	28.3 ± 2.4bc	29.8 ± 8.bc	31.6 ± 3.0bc	50.3 ± 4.2d	42.6 ± 2.5b	58.7 ± 5.9de
MBI 203	7.2 gm	3 lb	35.0 ± 5.8d	34.9 ± 1.6b	39.1 ± 4.3c	27.8 ± 2.6bc	42.3 ± 3.7bc	34.9 ± 2.2bc	*56.8 ± 5.1c	41.4 ± 1.8bc
MBI 206	20 ml	1 gal	8.6 ± 1.5ab	4.8 ± 2.4a	16.3 ± 3.0ab	6.1 ± 3.5a	33.7 ± 9.0bc	9.1 ± 3.8a	*45.7 ± 7.9bc	15.5 ± 6.5a
MBI 206	40 ml	2 gal	*4.9 ± 0.4a	11.5 ± 1.2a	23.7 ± 9.8bc	13.7 ± 2.0ab	47.8 ± 15.6c	26.1 ± 1.4b	66.4 ± 10.6d	34.9 ± 7.1b
GOS Neem	1%	1%	*20.8 ± 2.1bc	63.8 ± 3.8c	*30.1 ± 2.0bc	65.0 ± 5.0d	*45.6 ± 4.4c	66.2 ± 6.2e	61.5 ± 7.6cd	72.9 ± 2.9e
TriTek	1%	1%	16.9 ± 3.3abc	43.1 ± 15.3b	23.0 ± 1.7b	44.3 ± 14.3c	42.7 ± 2.3bc	47.7 ± 11.0cd	63.4 ± 6.2d	55.8 ± 4.3cd
Acramite 50W	0.2	0.08 lb	95.3 ±2.4e	95.3 ± 2.5d	98.6 ± 0.6d	100.0 ± 0.0e	100 ± 0d	100 ± 0f	100.0 ± 0.0e	100.0 ± 0.0f
Control	-	-	2.0 ± 0.5a	5.1 ± 2.6a	2.5 ± 0.3a	5.1 ± 2.6a	4.2 ± 0.8a	7.6 ± 2.6a	8.7 ± 0.9a	11.0 ± 3.5a

Means within the same column followed by the same letter are not significantly different by LSD (P = 0.05). * indicates that means from different exposure method (contact versus residual) within the same chemical treatment are significantly different by *t*-test (P < 0.05).

Table 4. Percentage mortality of twospotted spider mite deutoronymphs + protonymphs following contact and residual exposure to various acaricides.

			24 h		48 h		72 h	
Material	Amt/ Liter	Equiv. Per Acre	Contact	Residual	Contact	Residual	Contact	Residual
MBI 203 DF2	2.4 gm	1 lb	6.7 ± 4.1 a	10.0 ± 0.0 ab	*12.7 ± 5.5 abc	33.3 ± 7.0 b	*28.0 ± 4.0 cd	48.0 ± 5.3 c
MBI 203 DF2	4.8 gm	2 lb	10.0 ± 2.0a	11.3 ± 1.8 ab	21.3 ± 1.8 bc	32.0 ± 6.4 b	36.0 ± 2.0 d	46.7 ± 7.4 c
MBI 203 DF2	7.2 gm	3 lb	14.7 ± 3.3 a	16.0 ± 3.1 b	24.7 ± 4.4 c	36.0 ± 3.1 b	*34.0 ± 1.2 d	53.3 ± 0.7 c
MBI 206 EP	20 ml	1 gal	9.3 ± 0.7 a	5.3 ± 1.8 a	12.7 ± 2.4 abc	10.0 ± 3.1 a	14.7 ± 2.4 ab	19.3 ± 1.8 b
MBI 206 EP	40 ml	2 gal	16.0 ± 8.1 a	6.0 ± 2.3 a	17.3 ± 2.4 abc	11.3 ± 1.8 a	22.0 ± 4.2 bc	16.7 ± 1.3 b
GOS Neem	1%	1%	16.7 ± 8.2 a	8.7 ± 4.1 ab	23.3 ± 9.3 bc	12.7 ± 4.4 a	34.0 ± 4.6 d	24.0 ± 5.3 b
TriTek	1%	1%	6.0 ± 3.1 a	8.0 ± 4.0 ab	10.0 ± 3.1 ab	15.3 ± 4.4 a	18.7 ± 0.7 ab	22.7 ± 5.9 b
Acramite 50WP	0.2	0.08 lb	*73.3 ± 8.1 b	42.0 ± 11.1 c	*82.0 ± 6.1 d	50.7 ± 8.7 b	*92.0 ± 2.0 e	57.3 ± 6.4 c
Control	-	-	4.0 ± 1.2 a	4.7 ± 1.8 a	8.0 ± 1.2 a	6.7 ± 2.7 a	12.7 ± 2.9 a	8.7 ± 1.8 a

Means within the same column followed by the same letter are not significantely different by LSD (P = 0.05). * indicates that means from different exposure method (contact versus residual) within the same chemical treatment are significantly different by *t*-test (P < 0.05).

Table 5. Percentage of twospotted spider mite eggs hatching on bean leaf discs on various days after treatment of acaricides via contact and residual exposure.

Material	Amt/ Liter	Equiv. Per Acre	5 DAT		6 DAT		7 DAT	
			Contact	Residual	Contact	Residual	Contact	Residual
MBI 203	2.4 gm	1 lb	*78.7 ± 7.6 c	93.8 ± 4.0 b	*78.7 ± 7.6 c	95.5 ± 4.5 ab	*78.7 ± 7.6 cd	97.0 ± 3.0 ab
MBI 203	4.8 gm	2 lb	89.4 ± 2.6 c	96.8 ± 3.2 b	*92.2 ± 1.7 d	98.9 ± 1.1 b	*93.7 ± 0.6 d	98.9 ± 1.1 b
MBI 203	7.2 gm	3 lb	*85.6 ± 1.8 c	92.5 ± 2.2 b	87.2 ± 1.0 d	93.5 ± 1.5 ab	87.2 ± 1.0 d	94.7 ± 2.7 ab
MBI 206	20 ml	1 gal	*87.7 ± 1.8 c	92.4 ± 2.0 b	89.7 ± 1.2 d	92.4 ± 2.0 ab	90.4 ± 0.5 d	94.4 ± 3.1 ab
MBI 206	40 ml	2 gal	78.7 ± 12.0 c	92.4 ± 2.1 b	78.7 ± 12.0 c	93.0 ± 2.7 ab	78.7 ± 12.0 cd	93.0 ± 2.7 ab
GOS Neem	1%	1%	52.6 ± 3.1 b	67.7 ± 14.4 a	*60.4 ± 1.3 bc	84.3 ± 9.7 a	*61.8 ± 0.8 bc	86.1 ± 8.0 a
TriTek	1%	1%	*32.0 ± 9.2 ab	89.3 ± 5.6 b	*40.4 ± 10.7 b	89.3 ± 5.6 ab	*43.7 ± 13.3 b	89.3 ± 5.6 ab
Acramite 50WP	0.2	0.08 lb	*15.5 ± 6.4 a	87.9 ± 6.4 b	*16.3 ± 5.9 a	89.0 ± 5.6 ab	*17.2 ± 5.5 a	89.0 ± 5.6 ab
Control	-	-	79.1 ± 11.4 c	94.5 ± 2.0 b	79.1 ± 11.4 cd	94.5 ± 2.0 ab	79.1 ± 11.4 d	94.5 ± 2.0 ab

Means within the same column followed by the same letter are not signification different by LSD (P = 0l05). * indicates that means from different exposure method (contact versus residual) within the same chemical treatment are significantly different by *t*-test ($P < 0.05$).

Comparison of Chemigation versus Foliar Insecticide Application for Vegetable Insect Management – 2013 On Farm Tests

Over the past decade, traditional insecticides and application methods have been subject to increasing scrutiny. Certain older pesticides have been associated with negative impacts on human health (including farmworker safety) and the environment. In addition, the use of conventional foliar spraying systems for applying insecticides is inefficient in terms of the small amount of active ingredient reaching the target site, and the potential for environmental contamination associated with spray drift. However, in recent years there has been a wide array of reduced-risk insecticides registered on vegetables that have a friendly human health and environmental profile, and which also provide excellent levels of insect control. The fact that many of these move systemically within the plant allows for alternative application methods that can help to mitigate issues associated with foliar spraying.

Chemigation is the practice of applying pesticides to crops using irrigation systems. The use of drip irrigation for applying systemic insecticides to soil for uptake by crops is a potentially powerful tool that offers several advantages over foliar spraying, including:

- Reduced exposure of farmworkers to pesticides, because the chemical is in the plant's vascular system rather than on the leaf surface;
- Longer residual activity of systemic insecticides (weeks versus days);
- Greater flexibility in that applications can be made in weather conditions that preclude foliar application (i.e., excessive rain or wind);
- Reduced potential for non-target effects, including environmental sites, due to the absence of spray drift;
- Reduced potential for contamination of sensitive water resources, because insecticides do not accumulate on the soil surface and erode into streams during rain events.

Despite the potential benefits of chemigation for insect management, it has not been thoroughly evaluated to fully understand its benefits and shortcomings under a diversity of conditions in North Carolina. The objective of this study was to compare the level of insect management and profitability resulting from insecticides applied via drip irrigation and conventional foliar spraying in different NC vegetable production areas.

Methods and Materials

<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 Counties, and two locations in the Mills River area of Henderson County. At each site, two tomato fields ranging in size from 3 to 7 acres were used as non-replicated treatments – one was designated the chemigation treatment and the other the conventional treatment. At the

Rowan County location, the study was also conducted in peppers, which consisted of two fields each approximately 3 acres. Also, one tomato field (Hen-J) was planted in grape tomatoes, while all other tomato fields were planted in large round tomatoes.

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. 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. Supplemental foliar insecticide applications were made to chemigation treatments only if scouting programs indicated that a pest population was exceeding damage thresholds. 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 systems 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,

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

Data Collection: Each study site was visited at approximately 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 five random sites per treatment by recording the number of twospotted spider mites and immature whiteflies on 10 leaflets, and 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. Finally, 50 fruit were examined for damage by insects – lepidopteran and stink bugs – at each monitoring site (i.e., 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 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.

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 profits. The value of fruit was based on average USDA Agricultural Marketing Service price reports during the harvest periods of these studies, and was 62¢ and 50¢ per lb for tomatoes and peppers, respectively, and $1.45/lb for cherry tomatoes. 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

Pesticide Use and Impacts: Averaged across all locations, there was a reduction of approximately 56% in total insecticide inputs in chemigation vs. conventional foliar spray treatments – 1.11 vs. 2.42 lbs active ingredient per acre (Fig. 1). This reduction occurred at all locations, and ranged from a reduction of 44.4% at Madison to 65.8% at Hend-D. The two most commonly used insecticides in chemigation treatments were neonicotinoids (66.7%) and diamides (10.8%), while in the conventional spray treatments the organophosphate dimethoate (40.9%) and carbamate Lannate (14.5%) accounted for the highest insecticide inputs.

In terms of the number of foliar insecticide applications, the chemigation and conventional treatments averaged 0.5 and 10.3 applications per crop, respectively (Fig. 2). Those insecticides accounting for the majority of applications to conventional treatments were pyrethroids (29.1%), organophosphates (24.3%), diamides (16.2%) and carbamates (12.9%). A single foliar application was made to the chemigation treatment at three of the six sites. Two of these applications (one dimethoate and one Coragen) were the result of miscommunication between the grower and project leader, and one Assail application was made late in the season for whiteflies at the grower’s discretion. In addition, a miticide was required in both the chemigation and conventional treatments at three of the five tomato sites.

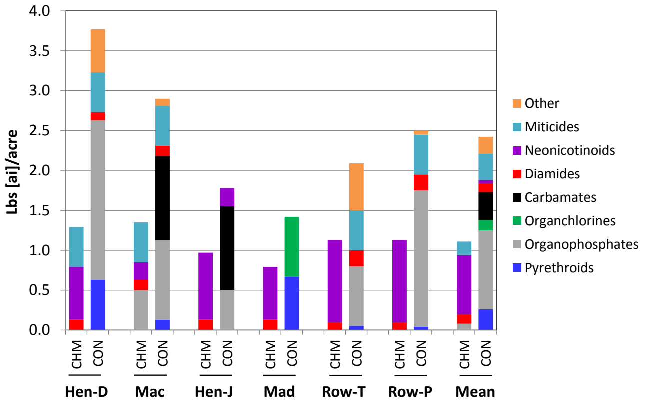

Fig. 1. Amount of insecticides applied to tomatoes and peppers (Row-P) via chemigation (CHM) and conventional foliar sprays (CON).

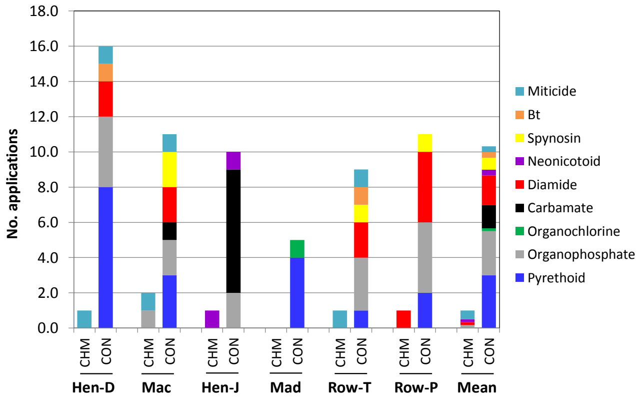

Fig. 2. Number of foliar insecticide and miticide applications made to chemigation (CHM) and conventional spray (CON) treatments in tomatoes and peppers (Row-P).

Although the cost of insecticides applied to the chemigation treatment were lower than those in the conventional treatments at four of the six study sites, the cost averaged across all sites was slightly higher in the chemigation vs. conventional treatments - $155.89 vs. $142.38 per acre (Fig 3). These values were not statistically different. At the two sites where the cost of the conventional was lower, one relied almost exclusively on Lannate, while the other made a total of only five foliar insecticide applications, four of which were pyrethroids.

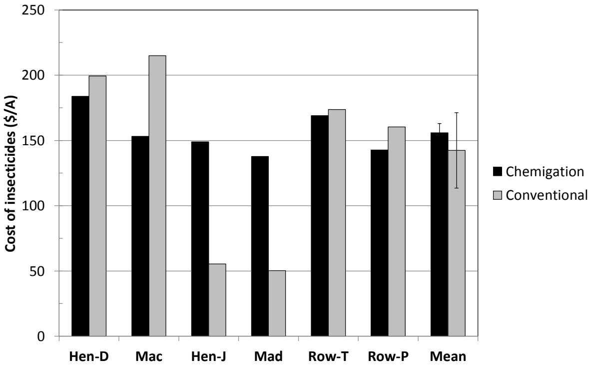

Fig. 3. Cost of insecticides used in chemigation and conventional treatments.

The two analyses conducted as surrogate measures of risk to farmworkers and the environment demonstrated two clear benefits of chemigation vs conventional foliar spraying. Averaged across all locations, fields were inaccessible to farmworkers for a total of 1.4 and 10.3 days in the chemigation and conventional treatments, respectively (Fig. 4). This was the result of fewer foliar applications and greater reliance on reduced-risk insecticides with shorter REI's in the chemigation vs. conventional treatments. In addition, the overall lower pesticide inputs and greater reliance on reduced-risk insecticides – i.e., those with lower EIQ values – resulted in consistently lower EIQ ratings in chemigation versus conventional treatments (Fig. 5).

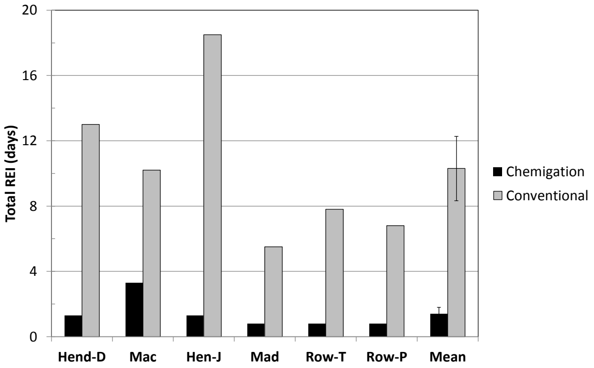

Fig. 4. Number of days crops were inaccessible due to insecticide re-entry interval restrictions when using chemigation vs. conventional spray programs.

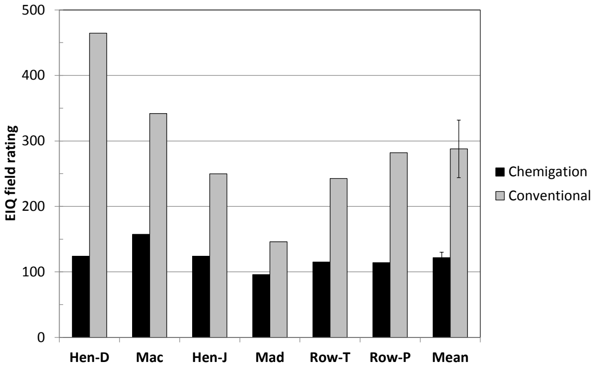

Fig. 5. Environmental impact Quotient (EIQ) field rating of insecticides applied to chemigation (CHM) and conventional (CON) foliar spray treatments.

Insect Control and Profitability: A primary reason for conducting these studies at multiple locations was to ensure an evaluation against a diverse pest complex in vegetable production areas representative of North Carolina. Unfortunately, overall pest pressure was low 2013, primarily due to record rainfall throughout the state.

Only three different indirect arthropod pests were detected at one or more study sites – flower thrips, twospotted spider mites and whiteflies. There was no clear indication that any of these pests were differentially affected by the two insecticide programs. Thrips infesting tomato flowers were relatively high in three of the five tomato fields (Fig. 6). While thrips numbers were generally lower in chemigation vs. conventional treatments, overall means across all sites were not statistically different. Thrips and their key predator insidious flower bug (IFB) were both higher in the chemigation treatment at pepper site. The acaricide Acramite (bifenazate) was applied to both treatments at three tomato sties (Hend-D, Macon and Rowan-T) for control of twospotted spider mite. The Madison site was the only one where mite populations were clearly higher in the chemigation vs. control treatment (Fig 7). Finally whitefly populations were relatively high at only one site (Hend-D), and averaged across all locations were slightly higher, but not statistically different in the chemigation treatment (Fig. 8). This whitely population in the chemigation treatment was surprising, because neonicotinoids (Admire and Venom) and Coragen applied via drip irrigation have previously shown to provide excellent whitefly control. It should be noted, however, that whiteflies did not increase to high numbers until mid-to-late September, or approximately 10 to 12 weeks after the last Coragen and Venom applications.

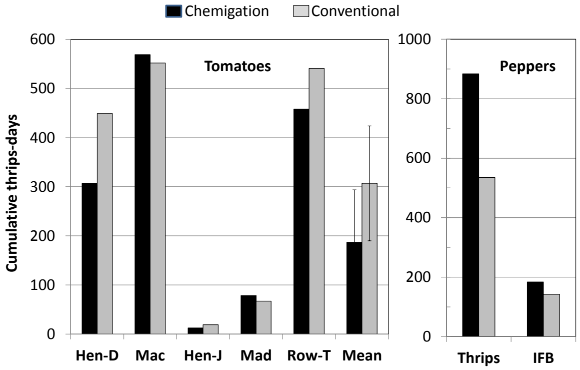

Fig. 6. Season cumulative thrips-days in tomato and pepper flowers treated with insecticides via chemigation and conventional foliar sprays.

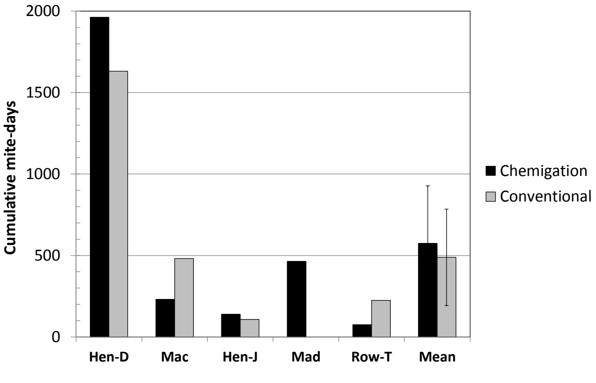

Fig. 7. Season cumulative mite-days for twospotted spider mite on tomatoes treated with insecticides via chemigation and conventional foliar sprays.

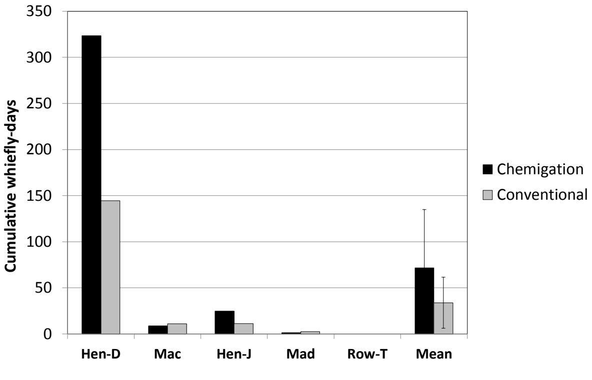

Fig. 8. Season cumulative whitefly-days on tomatoes treated with insecticides via chemigation and conventional foliar sprays.

Direct damage cause by lepidopteran larvae and stink bugs was low, averaging less than 1% across all locations (Fig. 9). While the chemigation and conventional insecticide programs surely contributed to this low damage, low pest populations also played a role. Nonetheless, when averaged across all locations, the percentage insect-damaged fruit was lower in the chemigation (0.36%) vs. conventional treatments (0.63%). This lower level of damage was due to lower stink bug damage in the chemigation treatments – 0.1 vs. 0.35%.

Results of the partial budget analyses showed that there were no differences in net profits generated from crops grown using chemigation vs. conventional foliar applications. These results are not surprising in view the small differences in insecticide costs and the extremely low levels of insect damage in 2013. When averaged across all locations, net profits generated from chemigation and conventional treatments averaged $11,969 and $11,942 per acre.

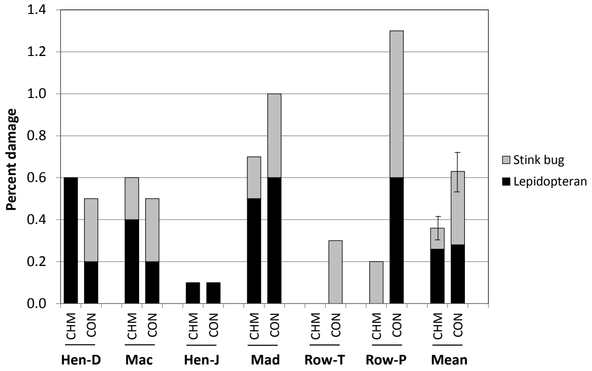

Fig. 9. Insect damaged fruit in chemigation (CHM) and conventional (CON) treatments at five tomato and one pepper (Row-P) locations.

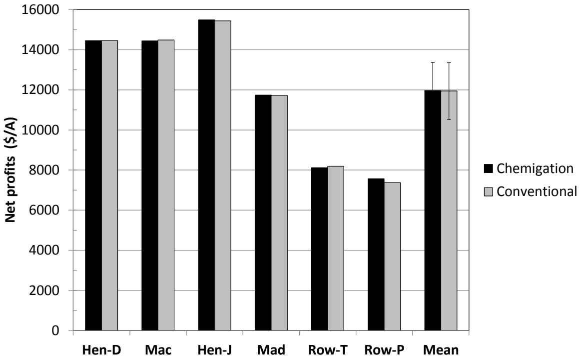

Fig. 10. Net profits resulting from tomatoes and peppers (Row-P) grown using chemigation versus conventional foliar sprays for insect management.

Conclusions

One of the goals of this project was to identify potential shortcomings of chemigation for insect management in fruiting vegetables in NC. Unfortunately, the overall low levels of insect pressure in 2013 did not sufficiently stress the management systems to expose potential weak points, particularly for direct insect pests such as lepidopteran pests (tomato fruitworm, armyworms and corn borer) and stink bugs. Nonetheless, it was apparent that twospotted spider mite is one pest that will continue to require foliar applications of acaricides for control. The abrupt increase in whitefly populations in the chemigation treatment at one location was surprising, but the need for supplemental control of whiteflies late in the season in western NC is questionable.

To date there has been no evidence that the insecticides used in the chemigation programs of this study directly affect yields, and hence profitability resulting from treatments was based principally on the level of insect control, which affected marketable yields and gross profits, and the cost of insect management programs. While there was no difference in profitability between chemigation and conventional foliar spray programs, there were several benefits of chemigation that were clearly evident in these studies. First, the overall reduced insecticide inputs and greater reliance on reduced-risk insecticides in chemigation vs. conventional treatments resulted in a significant reduction in active ingredients applied, reduced potential for exposure of farmworkers to pesticides, and reduction in environmental risks based on EIQ ratings. Repeating these studies in 2014 under higher insect pressure will hopefully provide greater clarity on the attributes of chemigation as an insect management strategy in NC.

Acknowledgments

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2013 PEACH INSECTICIDE TRIAL

PEACH, *Prunus persica* (L.) 'Contender'

Oriental fruit moth (OFM): *Grapholita molesta* (Busck)
Plum Curculio (PC): *Conotrachelus nenuphar* (Herbst)
Catfacing Insects (CF): *Lygus lineolaris* (Palisot de Beauvois) and *Euschistus servus* (Say)
Brown Marmorated Stink Bug (BMSB): *Halyomorpha halys* (Stål)
San Jose Scale (SJS): *Quadraspidiotus perniciosus* (Comstock)

The trial was conducted in a five-year-old block of 'Contender' peaches at the Mountain Horticultural Crops Research Station in Mills River, NC. Trees were planted 15 ft apart in rows on 20 ft centers. Plots consisted of single trees with a non-sprayed tree separating treatment trees within rows, and a non-sprayed row separating treatment rows. All insecticide applications were made with a tractor-mounted air blast sprayer delivering 125 GPA. Four insecticide treatments and a non-treated control were arranged in a RCBD with four replications. Insecticide treatments consisted of four applications each of Endigo 2.71ZC (6 fl oz/A), Actara 25WG (5.5 oz/A), Voliam Flexi 40WDG (7 oz/A) and an industry standard. The Endigo, Actara, and Voliam Flexi treatments were applied on 25 April (petal fall) and 14 May, 25 June and 19 July. Each of the above treatments were also sprayed with Perm-Up 3.2EC (8 fl oz/A) on 28 May and 11 June. The industry standard consisted of two applications of Imidan 70WP (3 lb/A) on 25 April and 14 May, followed by four applications of Perm-Up 3.2EC (8 fl oz/A) on 28 May, 11 and 25 June, and 19 July. Oriental fruit moth shoot damage (flagging) was assessed on 6 June and 8 July, and 50 fruit per treatment were evaluated for insect damage on 6 June and at harvest on 5 August. In addition to inspecting fruit for external damage symptoms, at harvest each fruit was cut to detect internal feeding damage caused by BMSB.

Overall insect pressure was relatively low in this trial, due largely to unusually high rainfall during May, June and July (36.8 inches fell in this three month span). The abundant and frequent rainfall appeared to reduce the overall efficacy of insecticide treatments, although differences between treatments and the control were detected for certain insects. There was very little OFM shoot damage prior to harvest, and only 10.5% of non-treated fruit had larval entries at harvest (Table 1). OFM damage ranged from 1.5 to 2.5% in insecticide treatments, all of which were significantly lower than the control. Second generation plum curculio damage, which occurred in mid to late July, caused 13% damage in the control, and insecticide treatments reduced that to 5 to 6.5%. This was the first year that BMSB was present in peaches at the MHCRS, and 9% of non-treated fruit exhibited internal feeding damage; insecticide treatments appeared equally effective and reduced damage to ≤3%. Finally, approximately 10% of non-treated fruit were infested with San Jose scale, but damage was highly aggregated within the block and no differences were detected among treatments

Table 1. Mean oriental fruit moth shoot damage (flagging), and fruit damage caused by plum curculio (PC), catfacing insects (CF), OFM, internal stink bug damage (SB), and San Jose scale (SJS). Mills River, NC 2013.

		OFM Flagging		Percent fruit damage						
				6 June		5 August				
Treatment	Rate/A	6/6	7/8	PC	CF	PC	CF	OFM	BMSB	SJS
Endigo 2.71ZC PermUp 3.2EC	6.0 fl oz 8.0 fl oz	0a	0.5a	2.0a	0a	5.0a	0a	2.5a	3.5a	3.0a
Actara 25WG PermUp 3.2EC	5.5 oz 8.0 fl oz	0a	0a	1.5a	0a	5.5a	0.5a	2.0a	3.0a	2.0a
Voliam Flexi 40WDG PermUp 3.2 EC	7.0 oz 8.0 fl oz	0a	0a	2.5a	0a	5.5a	2.5a	1.5a	2.5a	13.0a
Imidan 70WP PermUp 3.2EC	3.0 lb 8 fl oz	0a	0a	1.5a	0a	6.5a	1.0a	1.5a	1.5a	6.0a
Control		0.3a	1.3a	2.0a	0a	13.0b	2.0a	10.5b	9.0b	10.5a

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

EVALUATION OF CYAZYPYR FOR PLUM CURCULIO CONTROL ON APPLE, 2013

APPLE: *Malus domestica* Borkhauser 'Golden Delicious' and 'Red Delicious'

Plum Curculio: *Conotrachelus nenuphar* (Herbst)

The purpose of this study was to determine the efficacy of cyazypyr for control of plum curculio (PC). The experiment was conducted in two locations on the Mountain Horticultural Crops Research Station in Mills River, NC. One location was a block of 34-year-old 'Golden Delicious' apples which turned out to have poor fruit set. Therefore, a second location, consisting of 7-year-old 'Delicious' trees adjacent to the 'Golden' trees, was also used. 'Golden' trees were spaced 10 feet apart within rows and 25 feet between rows. Plots consisted of two adjacent trees and were sprayed at 109 GPA. 'Delicious' trees were spaced 10 feet apart with 20 feet between rows. Plots consisted of five adjacent trees and were sprayed at 80 GPA. All plots were randomized in a RCBD. Materials, rates, and timing are listed in the tables. In addition to insecticide applications, all trees were sprayed with the same standard fungicide and herbicide program. On 19 Jun, 100 apples (or as many apples as were present) from each sample plot in the 'Golden' block were examined and the number with any PC damage were recorded. On 25 Jun, 50 apples from each sample plot in the 'Red' block were examined. All data were subjected to two-way ANOVA and means were separated by LSD ($P = 0.05$).

PC population pressure is historically high in both blocks, and accordingly the 'Golden Delicious' fruit samples had extensive PC damage in every treatment (Table 1). The control plots had the most damage (49.3%), while insecticide treatments ranged from 30.3% to 46.0%. However, there were no significant differences among any of the plots. 'Delicious' control plots had even higher damage levels at 53.5%, and considerably lower levels in the treated plots, which ranged from 17.5% to 25.0%. There were no significant differences among treated plots, but all were significantly lower than the control. When both 'Golden' and 'Red' blocks were combined, control damage averaged 51.4%, significantly higher than all treated plots except for the 10-day cyazypyr, which was just barely outside the margin of being statistically different.

Table 1. PC damage on ‘Golden Delicious’ and ‘Red Delicious’ apples treated with various insecticides and spray schedules. Mills River, NC. 2013.

			% PC-damaged fruit		
Treatment	Rate/A	App. Timing[1]	‘Golden Delicious’ (19-Jun)	‘Red Delicious’ (25-Jun)	Average of ‘Golden Delicious’ and ‘Red Delicious’
Cyazypyr 10SE	13.6 oz	PF, 7-d interval	30.3a	25.0a	27.6a
Cyazypyr 10SE	13.6 oz	PF, 10-d interval	46.0a	19.5a	32.8ab
Cyazypyr 10SE	13.6 oz	PF, 14-d interval	45.0a	17.5a	31.3a
Avaunt	5 oz	PF, 14-d interval	35.5a	24.5a	30.0a
Imidan	3 lb	PF, 14-d interval	36.8a	24.5a	30.7a
Control	-	-	49.3a	53.5b	51.4b

[1] All treatment plots were sprayed at Petal Fall on 5/8. Plots on a 7-day schedule were sprayed again on 5/15, 5/22, 5/29, and 6/8. Plots on a 10-day schedule were sprayed on 5/18, 5/29, and 6/8, and plots on a 14-day schedule were sprayed on 5/22 and 6/8.

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

APPLE MITICIDE TRIAL – 2013

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 35 yr-old block of 'Delicious' apples at the Mountain Horticultural Crops Research Station in 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 at 2-wk intervals with Rimon 0.83EC (20 oz/A) and Lannate LV (3 pts/A) on 14 and 29 May, 14 and 28 June, and 16 July. No other insecticides were applied, but a season-long standard fungicide program was used. All miticide treatments were applied on two dates. On 21 May (2nd cover spray), two Agri-Mek 0.7SC (3 oz/A) treatments were applied, one with a horticultural oil (0.25% BioCover UL) and one with a non-ionic penetrating surfactant (0.25% LI-700). The timing of these treatments was based on a typical preventive application early in the season when leaf tissue is most amenable to translaminar movement. Curative applications of three different miticides (Acramite 50WO at 1 lb/A, Nealta 1.67SC at 13.5 oz/A, and Omega 4SC at 13.8 oz/A) were made on 18 July when ERM motile populations averaged approximately 2 mites per leaf. Mite populations remain unusually active late into the season, and a second application of all treatments was made on 23 August, when mite populations in the control averaged about 14 mites per leaf. 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 any 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

European red mite populations were extremely late in occurrence in 2013. In North Carolina, mites typically begin to appear in apples in late May to early June, and curative applications of miticides, when needed, are generally made in late June to early July. Populations normally decline to very low levels by late July to early August. In 2013, ERM did not surpass one mite per leaf until mid July, and numbers remained >20 per leaf through mid September. This highly unusual phenology may have been related to high rainfall in 2013. From May through August, a total of 45.95 inches of rain fell at the MHCRS, and during June and July (28.44 inches) rain fell on 42 of 61 days.

Mite populations were highly variable, and consequently there were few significant differences among treatments until later in the season. Total motile mites (adults + immatures), adults, immatures and egg densities appear in Tables 1-4, respectively. Based on season cumulative mite days, Agri-Meck + BioCover UL oil and Acramite were most effective in suppressing populations, while Agri-Mek + LI-700, Omega and Nealta were intermediate between the two most effective treatments and the control. Seasonal cumulative mite days in Fig. 1 illustrates seasonal population trends in the different treatments. Populations of the predatory mite *Neoseiulus fallacis* were very low and had minimal impact on ERM. Low predatory mite densities were probably due to applications of Lannate.

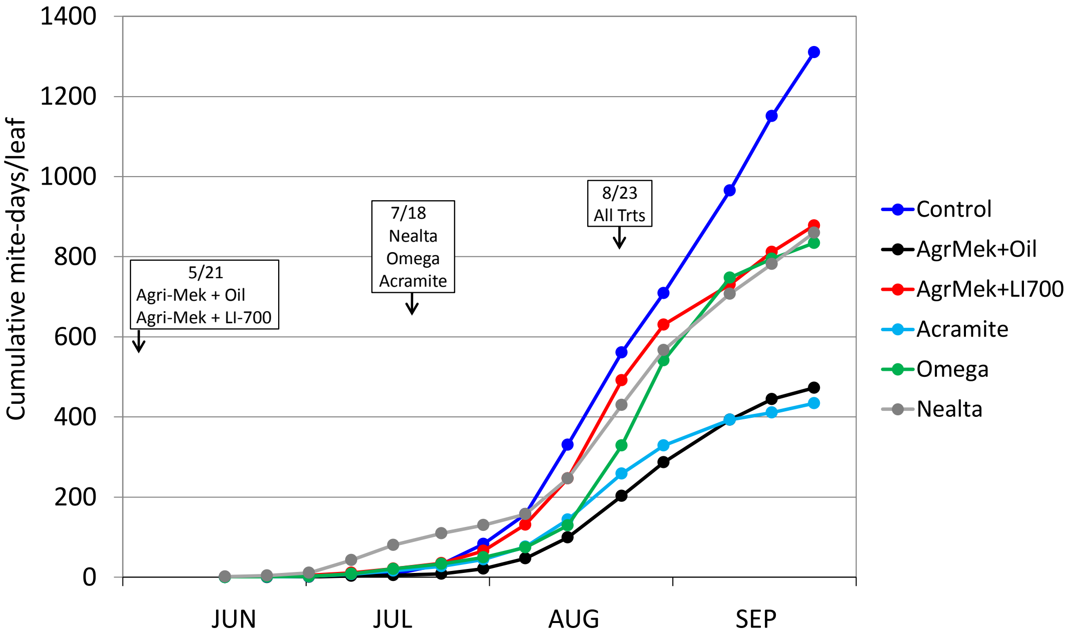

Fig. 1. Cumulative mite days on apples treated with various miticides. Mills River, NC. 2013.

Table 1. Mean European red mite motiles (adults + immatures) on ‘Delicious’ apples treated with various miticides on 21 May (both Agri-Mek treatments), 18 July (Nealta, Acramite and Omega treatments), and 23 August (all treatments). Mills River, NC. 2013.

		Motiles per leaf														
Treatment	Rate/A	6/17	6/24	7/1	7/8	7/15	7/23	7/30	8/6	8/13	8/22	8/29	9/9	9/16	9/23	CMD
Agri-Mek 0.7SC + Hort Oil	3 fl oz 0.25%	0.0	0.0	0.2	0.5	0.1	0.9	2.7	4.8	10.1	13.0	10.9	8.5	6.3ab	1.8a	472.7a
Agr-Mek 0.7SC + LI-700	3 fl oz 0.25%	0.3	0.0	0.8	1.1	1.8	1.6	7.3	11.4	21.4	33.0	6.7	11.8	11.2abc	7.7b	877.8ab
Acramite 50WP	1 lb	0.0	0.1	0.3	1.4	1.0	1.6	3.3	5.7	13.8	11.7	8.3	3.5	1.6a	5.1ab	434.0a
Omega	13.8 oz	0.0	0.3	0.1	1.6	2.0	1.0	3.8	3.2	12.6	31.7	29.0	8.6	4.9ab	6.3ab	834.2ab
Nealta	13.5 oz	0.3	0.4	1.6	7.5	3.3	3.9	2.0	5.8	19.6	21.2	17.8	7.8	13.6bc	8.5b	858.5ab
Control	—	0.1	0.0	0.2	0.6	0.2	6.1	8.4a	13.0	36.5	14.8	24.7	18.7	27.1c	10.6b	1310.1b

Means within the same column followed by different letter are not significantly different by LSD (P = 0.05). Columns with no numbers indicate ANOVA was not significant.

Table 2. Mean European red adult densities on 'Delicious' apples treated with various miticides on 21 May (both Agri-Meck treatments), 18 July (Nealta, Acramite and Omega treatments), and 23 August (all treatments). Mills River, NC. 2013

		Adults per leaf														
Treatment	Rate/A	6/17	6/24	7/1	7/8	7/15	7/23	7/30	8/6	8/13	8/22	8/29	9/9	9/16	9/23	CMD
Agri-Mek 0.7SC + Hort Oil	3 fl oz 0.25%	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.9	1.1	3.7	2.4a	1.7a	1.1a	0.5a	93.7a
Agri-Mek 0.7SC + LI-700	3 fl oz 0.25%	0.1	0.0	0.1	0.2	0.9	0.3	1.0	2.6	2.1	6.7	2.1a	3.3ab	2.7a	1.2a	178.1abc
Acramite 50WP	1 lb	0.0	0.1	0.1	0.3	0.5	0.1	0.9	1.4	2.3	4.5	2.1a	0.5a	0.3a	0.8a	106.5ab
Omega 4SC	13.8 oz	0.0	0.1	0.1	0.3	1.0	0.0	1.3	1.3	1.3	5.6	5.2ab	1.6a	1.1a	1.0a	155.6abc
Nealta	13.5 oz	0.1	0.2	0.5	1.2	1.6	0.3	0.5	2.3	2.2	6.9	3.3a	1.6a	3.0a	0.6a	187.0bc
Control	—	0.0	0.0	0.0	0.1	0.1	1.5	1.5	2.7	4.0	5.0	8.7b	6.9b	12.5b	3.1b	351.6c

Means within the same column followed by different letter are not significantly different by LSD (P = 0.05). Columns with no numbers indicate ANOVA was not significant.

Table 3. Mean European red immature densities on ‘Delicious’ apples treated with various miticides on 21 May (both Agri-Meck treatments), 18 July (Nealta, Acramite and Omega treatments), and 23 August (all treatments). Mills River, NC. 2013

		Immatures per leaf														
Treatment	Rate/A	6/17	6/24	7/1	7/8	7/15	7/23	7/30	8/6	8/13	8/22	8/29	9/9	9/16	9/23	CMD
Agri-Mek 0.7SC + Hort Oil	3 fl oz 0.25%	0.0	0.0	0.2	0.4	0.0	0.8	2.4	4.0	9.0	9.3	8.5	6.8	5.1a	1.3	379.0
Agri-Mek 0.7SC + LI-700	3 fl oz 0.25%	0.2	0.0	0.6	0.9	1.0	1.3	6.3	8.8	19.4	26.3	4.6	8.5	8.5a	6.5	698.9
Acramite 50WP	1.0 lb	0.0	0.0	0.2	1.1	0.5	1.5	2.4	4.3	11.6	7.2	6.2	3.0	1.4a	4.2	327.4
Omega 4SC	13.8 oz	0.0	0.2	0.0	1.3	1.1	1.0	2.6	1.9	11.3	26.1	23.8	7.0	3.8a	5.4	678.5
Nealta	13.5 oz	0.3	0.2	1.2	6.3	1.7	3.6	1.5	3.5	17.4	14.4	14.6	6.2	10.6a	8.0	671.6
Control	—	0.1	0.0	0.2	0.6	0.1	4.7	6.9	10.3	32.5	9.8	19.0	11.9	22.2b	7.6	958.4

Means within the same column followed by different letter are not significantly different by LSD (P = 0.05). Columns with no numbers indicate ANOVA was not significant.

Table 4. Mean European red eggs on 'Delicious' apples treated with various miticides on 21 May (both Agri-Meck treatments), 18 July (Nealta, Acramite and Omega treatments), and 23 August (all treatments). Mills River, NC. 2013

		Eggs per leaf													
Treatment	Rate/A	6/17	6/24	7/1	7/8	7/15	7/23	7/30	8/6	8/13	8/22	8/29	9/9	9/16	9/23
Agri-Mek 0.7SC + Hort Oil	3 fl oz 0.25%	0.0	0.4	0.3	0.3	1.8	1.9	1.9	11.9	11.0	18.8	22.4	17.8a	10.2a	10.5
Agri-Mek 0.7SC + LI-700	3 fl oz 0.25%	0.1	0.0	1.3	0.5	3.6	3.6	6.5	34.9	17.9	42.3	28.5a	26.5ab	20.9b	27.9
Acramite 50WP	1.0 lb	0.0	0.1	0.9	1.6	4.5	7.7	3.3	18.5	25.4	15.2	25.2a	11.4a	4.8a	19.8
Omega 4SC	13.8 oz	0.0	0.2	0.6	1.7	4.1	6.9	5.4	13.5	20.7	31.4	52.8ab	24.8ab	8.9a	31.0
Nealta	13.5 oz	0.2	1.9	6.1	6.1	11.3	11.1	8.6	29.7	44.9	24.7	52.4ab	26.1ab	27.7b	25.9
Control	—	0.0	1.2	0.2	0.4	1.2	9.6	13.8	27.2	29.5	15.3	82.9b	51.0b	55.1c	31.9

Means within the same column followed by different letter are not significantly different by LSD (P = 0.05). Columns with no numbers indicate ANOVA was not significant.

Table 5. Mean *Neoseiulus fallacis* densities on ‘Delicious’ apples treated with various miticides on 21 May (both Agri-Meck treatments), 18 July (Nealta, Acramite and Omega treatments), and 23 August (all treatments). Mills River, NC. 2013

		Neoseiulus fallacis per leaf														
Treatment	Rate/A	6/17	6/24	7/1	7/8	7/15	7/23	7/30	8/6	8/13	8/22	8/29	9/9	9/16	9/23	CMD
Agri-Mek 0.7SC + Hort Oil	3 fl oz 0.25%	0.0	0.0	0.2	0.2	0.4	0.3	0.1	0.3	0.0	0.4	0.1	0.4	0.5	0.4	21.8
Agri-Mek 0.7SC + LI-700	3 fl oz 0.25%	0.1	0.1	0.2	0.1	0.4	0.1	0.1	0.3	0.1	0.3	0.1	0.5	0.7	0.6	24.6
Acramite 50WP	1.0 lb	0.1	0.0	0.1	0.5	0.2	0.2	0.2	0.3	0.2	0.6	0.2	0.4	0.5	0.4	26.1
Omega 4SC	13.8 oz	0.0	0.0	0.1	0.2	0.1	0.1	0.0	0.1	0.1	0.4	0.3	0.4	0.3	1.1	19.7
Nealta	13.5 oz	0.0	0.1	0.2	0.3	0.2	0.2	0.0	0.2	0.3	0.7	0.3	0.5	0.4	0.7	27.1
Control	—	0.1	0.1	0.1	0.1	0.3	0.2	0.2	0.5	0.4	0.3	0.3	0.7	1.6	1.0	39.4

Means within the same column followed by different letter are not significantly different by LSD (P = 0.05). Columns with no numbers indicate ANOVA was not significant.

EFFECTS OF CYAZYPYR APPLICATIONS ON PEACH FRUIT SIZE, 2013

PEACH, *Prunus persica* ‘Coral Star’ and ‘All Star’

This study was conducted to examine potential fruit size-enhancing capability of cyazypyr (Exirel) on peaches. The trial was conducted in a 1.5-acre mature block of peach trees in Fruitland, NC. Trees were spaced 12 feet apart with 20 feet between rows (198 trees/acre), and plots consisted of 15-tree blocks (5 trees x 3 rows) with each treatment replicated four times in a RCBD. All trees in replicates I and II were ‘Coral Star’ and those in replicates III and IV were ‘All Star.’ Materials, rates, and timing are listed in the tables, and all applications were made with an airblast sprayer delivering approximately 125 GPA. Due to an applicator error, the study deviated from the original protocol in that there was 1) no Pink Stage only application of cyazypyr and 2) a Petal Fall + Shuck Split treatment was added. Also, >1” of rain fell within 30 minutes of completing Petal Fall applications on 17 April, so treatments were reapplied on 18 April. Except for insecticides applied at pink, petal fall and shuck split, which constituted the treatment applications, all plots were treated with the same insecticide and fungicide program the remainder of the season. After standard fruit thinning across the whole block, fruit on two different branches on two different trees in each test plot were further thinned to a uniform density such that no fruit were <6 inches apart. These limbs served as fruit sample sites the remainder of the year. The diameters of 20 and 25 fruit per limb were measured with calipers on 2 Jul and again at harvest on 2 Aug, respectively. At harvest, fruit were harvested and weighed. All data were subjected to two-way ANOVA and means were separated by LSD ($P = 0.05$).

At the mid-season assessment, fruit diameter was significantly greater in the Shuck Split treatment (Trt 3) and Control (Trt 5) than the Pink/Petal Fall treatment (Trt 1); there was no difference among the remaining treatments. At harvest on 2 August, both fruit diameter and weight were highly variable and there were no differences among treatments.

Table 1. Size and weight of fruit from ‘Coral Star’ and ‘All Star’ peaches treated with cyazypyr at different times. Fruitland, NC. 2013.

			Fruit diameter (cm)		Total weight (gm/fruit)
Treatment[1]	Rate/A	App. Timing[2]	2-Jul	2-Aug	2-Aug
1. Cyazypyr 10SE + Silwet L77 Delegate + Silwet L77	13.5 oz + 0.25% 6.0 oz + 0.25%	Pink, Petal Fall Shuck Split	4.03a	6.95a	222.0a
2. Cyazypyr 10SE + Silwet L77 Delegate + Silwet L77	13.5 oz + 0.25% 6.0 oz + 0.25%	Petal Fall Pink, Shuck Split	4.24ab	7.04a	217.7a
3. Cyazypyr 10SE + Silwet L77[3] Delegate + Silwet L77	13.5 oz + 0.25% 6.0 oz + 0.25%	Shuck Split Pink, Petal Fall	4.58b	7.30a	237.4a
4. Cyazypyr 10SE + Silwet L77 Delegate + Silwet L77	13.5 oz + 0.25% 6.0 oz + 0.25%	Petal, Shuck Split Pink	4.19ab	7.14a	229.7a
5. Delegate + Silwet L77	6.0 oz + 0.25%	Pink, Petal Fall, Shuck Split	4.59b	6.95a	223.8a

[1] Treatment 1 in the original protocol was a single Exirel application at Pink. Due to applicator error, Exirel was applied again at Petal Fall in this treatment, which was the same as treatment 3 in the protocol. Consequently, treatment 3 was altered to include Exirel at Petal Fall and Shuck Split.

[2] Pink = 4/6, Petal Fall = 4/18, Shuck Split = 4/26. Petal fall applications on 4/18 were a reapplication, as 1 inch of rain fell within 30 minutes of applications made on 4/17.

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

Effects of Early Season Cyazypyr Applications on Apple Insect Control and Fruit Size

APPLE: *Malus domestica* Borkhauser 'Granny Smith'

Plum curculio (PC): *Conotrachelus nenuphar* (Herbst)
Plant bugs (PB): *Lygus lineolaris* (Palisot de Beauvois)
Codling moth (CM): *Cydia pomonella* (L.)
Oriental fruit moth (OFM): *Grapholita molesta* (Busck)
Comstock mealybug (CMB): *Pseudococcus comstockie* (Kuwana)
Stink bugs (SB): *Euschistus servus* (Say), *Acrosternum hilare* (Say)

The purpose of this study was to examine insect control efficacy and potential fruit size-enhancing capability of cyzazypyr on apples. The trial was conducted in a 2.3-acre block of approximately 15-yr-old 'Granny Smith' apple trees in in Dana, NC. Trees were spaced 10 x 20 ft (218 trees per acre) and were approximately 15 ft tall with an estimated tree-row-volume of 220 GPA. Plots consisted of 30 trees (3 rows x 10 trees) with each treatment replicated four times in a RCBD. Materials, rates, and timing are listed in the tables, and all applications were made with an airblast sprayer delivering 101 GPA. Except for the pink, petal fall, and 1st cover sprays that constituted the trial, all treatments were sprayed with identical insecticides: Oil + Lorsban at green tip, Altacor at 3rd cover, Imidacloprid in June and July, and Delegate in late August. To determine insect damage, 100 fruit from each plot were examined on 18 June (midseason) and 20 September (harvest) for damage by internal-feeding lepidopterans (CM and OFM), PC, and PB. At harvest on 20 September, 100 fruit per plot (50 fruit each from the center two trees per plot) were harvested and examined externally for insect damage, and then cut to detect internal damage. Treatment effects on fruit size were initially examined after initial fruit set (20 June) by recording the number of fruit per 100 flower clusters on two sample limbs per tree on each of four trees per plot. On 25 July the number of fruit per spur was calculated by counting the number of fruit on 20 randomly selected spurs on each of four trees per plot. Immediately prior to commercial harvest (18 Sept.), 100 fruit per plot (a random sample of 12 fruit per tree from four trees per plot) were harvested and each fruit was measured for length and diameter and the number of seeds per fruit was also counted. All data were subjected to two-way ANOVA and means separated by LSD (P = 0.05).

Insect damage was low in this trial, and there were no significant differences among treatments in the level of damage caused by specific insects on 18 June (Table 1). Plum curculio was the leading cause of damage, with damage across all treatments averaging 5.6% on 18 June, but only 2.2% at harvest on 20 September. Total insect damage was significant different among treatments, with cyazypyr applied at pink and petal fall generally having more damage than cyazypyr applied at petal fall and first cover. No treatment effects were detected for any fruit size parameter measured (Table 2).

Table 1. Percent insect damage on ‘Granny Smith’ apple trees treated with various spray schedules. Dana, NC. 2013.

			Mid-Season (18-Jun)			Harvest (20-Sep)					
Treatment	Rate/A	App. Timing[1]	% Internal Lep	% PC	% PB	% Internal Lep	% PC	% PB	% CMB	% SB	Total % damage
1. Cyazypyr 10SE + Induce	16.9 oz 0.5%	Pink, Petal Fall	0.0a	5.3a	0.3a	0.0a	5.3b	1.0a	1.3a	2.5a	10.0b
2. Cyazypyr 10SE + Fontelis 1.67SC + Induce	16.9 oz 20.0 oz 0.5%	Pink, Petal Fall Pink, Petal Fall	0.0a	5.3a	0.8a	0.0a	1.8a	3.0b	0.5a	0.5a	5.8ab
3. Cyazypyr 10SE + Induce	16.9 oz 0.5%	Petal Fall, 1st Cover	0.0a	3.8a	0.8a	0.3a	0.0a	1.3a	1.0a	1.3a	3.8a
4. Cyazypyr 10SE + Fontelis 1.67SC + Induce	16.9 oz 20.0 oz 0.5%	Petal Fall, 1st Cover Petal Fall, 1st Cover	0.0a	7.5a	0.8a	0.0a	1.0a	0.3a	0.3a	0.8a	1.8a
5. Actara 25WDG + Avaunt 30WDG + Delegate 25WDG	4.5 oz 6.0 oz 5.0 oz	Pink Petal Fall 1st Cover	0.0a	6.3a	0.8a	0.0a	2.0a	0.8a	0.8a	1.0a	4.3a

[1] Pink = 15-Apr, Petal Fall = 9-May, 1st Cover = 23-May.

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

Table 2. Fruit size and yield on 'Granny Smith' apple trees treated with various spray schedules. Dana, NC. 2013.

			Fruit Set		Harvest		
Treatment	Rate/A	App. Timing[1]	Fruit/100 clusters	Fruit/spur	Seeds/fruit	Fruit Length/Diam. ratio	Fruit Diam. (mm)
1. Cyazypyr 10SE + Induce	16.9 oz 0.5%	Pink, Petal Fall	13.9a	2.10a	6.73a	0.91a	75.2a
2. Cyazypyr 10SE + Fontelis 1.67SC + Induce	16.9 oz 20.0 oz 0.5%	Pink, Petal Fall Pink, Petal Fall	14.0a	2.09a	6.83a	0.91a	75.5a
3. Cyazypyr 10SE + Induce	16.9 oz 0.5%	Petal Fall, 1st Cover	12.6a	1.84a	6.81a	0.92a	76.3a
4. Cyazypyr 10SE + Fontelis 1.67SC + Induce	16.9 oz 20.0 oz 0.5%	Petal Fall, 1st Cover Petal Fall, 1st Cover	16.3a	1.80a	7.04a	0.92a	76.4a
5. Actara 25WDG + Avaunt 30WDG + Delegate 25WDG	4.5 oz 6.0 oz 5.0 oz	Pink Petal Fall 1st Cover	15.0a	1.80a	6.69a	0.91a	75.9a

[1] Pink = 15-Apr, Petal Fall = 9-May, 1st Cover = 23-May.

Means in the same column followed by the same letter are not significantly different by LSD (*P* = 0.0)

Interpreting Codling Moth and Oriental Fruit Moth Pheromone Trap Captures with Different Lures

Mating disruption for codling moth and oriental fruit moth (OFM) is a common management practice used by approximately 40% of North Carolina apple growers. Isomate CM/OFM TT is the most commonly used pheromone dispensing product and considered the industry standard, although previous studies in NC have demonstrated that CideTrak CM-OFM is equally effective. Both products have a recommended application rate of 200 dispensers per acre, have a similar pheromone load, and provide season-long activity with a single application. Annual use of mating disruption can eliminate on average 2.5 insecticide sprays for codling moth and OFM compared to orchards not using mating disruption. While this reduction in insecticide cost does not off-set the cost of mating disruption, it is considered an important insecticide resistance management tool because it helps to maintain this pest complex at very low levels without the use of insecticides.

In recent years pheromone companies have devoted efforts to improve the cost of mating disruption by reducing application costs with various low-density dispenser systems, and by reducing the total amount of pheromone deployed with more targeted pheromone release systems or more effective pheromone products. Hence, one objective of this study was to evaluate two different low-density dispensing systems for mating disruption of codling moth and OFM in southeastern apple systems. Isomate Mist is an aerosol canister-release system that is deployed at one unit per acre and emits pheromone during periods of codling moth flight activity. CideTrak Meso is a dispenser that is deployed at 30 dispensers per acre and reduces the total amount of pheromone used (on an area basis) by enhancing the “activity” of codling moth pheromone with the addition of a pear ester kairomone (referred to as DA).

Because of the passive nature of control associated with mating disruption, monitoring moth activity to provide advanced warning of damaging populations is a key component of mating disruption programs. Currently, recommendations are to use delta-style pheromone traps (e.g., Pherocon VI) baited with Trece long-life lures (CM-L2 and OFM-L2). An enhanced codling moth lure that contains codling moth pheromone and a pear ester kairomone has been shown in various studies to increase captures of males and also to attract females. Comparison of CM-L2 vs. CM-DA Combo in NC in 2010 and 2011 showed that CM-DA Combo lures captured about 3X more moths than CM-L2 during the first generation, but there was no difference in trap captures during the second generation. Furthermore, the increase in trap captures with CM-DA Combo lures was due primarily to increased captures of males rather than female capture. This trial included a comparison of several experimental lures deployed with acetic acid as a lure enhancement (Knight and Light 2012, Environ. Entomol. 41: 407-414).

Materials and Methods

Isomate CM-OFM TT and Isomate Mist CM-OFM Trial. This single site, non-replicated trial was conducted in an approximately 45-acre mixed-variety apple orchard in Fruitland, NC. Treatments included a 32-acre block treated with Isomate Mist CM-OFM at a density of one per acre, an approximately 5-acre block treated with Isomate CM-OFM TT at 200 dispensers per acre, and a 7-acre non-treated control. All dispensers were erected on 11 April, and Mist dispensers were removed on 26 September.

Mist dispensers consisted of aerosol canisters filled with 69.45% inerts, 18.05% of the single component codling moth pheromone (codlemone), and 12.5% of the 3-component blend OFM pheromone. Canisters were programmed to release puffs at 15-minute intervals from 5PM to 12 midnight, but did not operate at temperatures below 50°F. On average, the canisters released 1.295 gm per day (~46 mg per puff), or 0.23 gm of codlemone and 0.16 gm of OFM pheromone. Canisters were in the orchard for 168 days, which resulted in a total release of 38.64 and 26.88 gm of codling moth and OFM pheromone.

Isomate CM-OFM TT dispensers each contained 318 mg of codling moth pheromone (3-component blend) and 103.3 mg of OFM pheromone (3-component blend). At 200 dispensers per acre, total codling moth and OFM pheromone deployed was 63.6 and 20.7 gm per acre, respectively. All treatments received the same insecticide program which consisted of a Lorsban + oil at ½" green, Actara at petal fall, Delegate in late June (3rd cover), and Assail in late July.

Efficacy of mating disruption treatments was assessed with moth captures in pheromone traps and fruit damage assessments in early July and at harvest in September. In each mating disruption treatment, a comparison was made of two different lures each for codling moth and OFM. Codling moth lures consisted of the standard CM-L2 lure that contained 3.5 mg of the single component codling moth pheromone, and the CMDA combo lure (containing approximately 3 mg each of codling moth pheromone and the pear ester kairomone) plus a separate acetic acid lure (Pherocon AA). Oriental fruit moth lures compared were the standard OFM-L2 and CMDA/OFM (Trece experimental lure TRE 0937) plus a Pherocon AA lure. All trapping stations used Delta style traps (Pherocon VI) placed in the upper canopy. In the Isomate TT and control treatments one trap of each type were used, while 3 codling moth and 2 OFM traps of each type were used in the 32-acre Mist block. All traps were checked weekly and liners were replaced as necessary to maintain a clear surface. All CMDA, AA and OFM-L2 lures were replaced at 8 wk intervals, while CMDA/OFM and CM-L2 lures were replaced at 12-wk intervals. Damage assessments were obtained by examining 50 fruit per tree from each of 10 trees per treatment on 12 July, and 100 fruit from each of 5 (control and Isomate TT treatments) or 12 (Isomate Mist) trees at harvest on 10 September. Fruit harvested in September were all cut to detect internal damage.

CideTrak CM-OFM and CideTrak Meso CM+OFM+DA Trial. A trial that compared two different Trece pheromone dispensers for mating disruption was conducted in three separate orchards in Henderson County (Fruitland, Edneyville and Dana). At each location there were two 5-acre mating disruption treatments (Cide-Trak CM-OFM and CideTrak Meso CM+OFM+DA) and a 5 to 8 acre non-treated control. Dispensers were hung at the Fruitland and Edneyville locations on 3 May and the Dana site on 7 May, which coincided with petal fall. CideTrak CM-OFM dispensers (TRE 0936/13) contained 230 and 100 mg of the three-component blends each of codling moth and OFM pheromone, and were applied at 200 per acre for a total deployment rate of 46 and 20 gm pheromone per acre, respectively. CideTrak Meso CM+OFM+DA dispensers (TRE 0915/13) each contained 750, 500 and 500 mg of codling moth, OFM and DA, respectively. They were deployed at 30 dispensers per acre for a total deployment rate of 22.5, 15 and 15 gm per acre of codling moth pheromone, OFM pheromone, and DA, respectively. Although insecticide use varied among study sites, within a study site the insecticide program was the same across all three treatments.

Efficacy of mating disruption treatments were assessed with pheromone traps and fruit damage assessments as described above. However, rather than comparing CM-DA Combo + AA versus CM-L2, the CM-DA Combo + AA was compared to CM-DA without AA. Hence, within each treatment there were four traps; one each baited with CMDA + AA and CM-L2 to monitor codling moth, and one each of CMDA/OFM + AA and OFM-L2 to monitor OFM. Mid-season damage assessments were taken on 12 July by observing 100 fruit from each of 10 locations per treatment and recording the number with internal lepidopteran damage. Damage at harvest was estimated by harvesting 50 fruit per tree from each of 5 trees per treatment and recording the number damaged by various insects. Fruit were harvested in the Dana, Edneyville and Fruitland orchards on 9, 10 and 12 September, respectively.

Results

Isomate TT – Mist Trial. Codling moth populations in the Isomate TT/Mist trial were very low, with a season total of only two moths captured in traps baited with the CM-L2 lure and CMDA+AA (Fig. 1). The highest trap captures were with the CMDA+AA and CMDA/OFM+AA lures in the Isomate Mist treatment, and all moths were caught during the flight period of the overwintering generation. Oriental fruit moth trap captures were of moderate density in the control treatment, with a season total capture of 92 moths/trap with the CM-L2 lure (Fig. 2) in the non-disrupted control. The enhanced attractiveness of the CMDA/OFM+AA lure compared to the CM-L2 lure was illustrated by a total capture of almost 6X more moths in traps baited with CMDA/OFM+AA. Seasonal cumulative trap captures in the various treatments with the OFM-L2 lure and CMDA/OFM+AA lures are shown in Fig. 3 and 4, respectively. Zero OFM captures in pheromone traps baited with the OFM-L2 lure when placed in mating disruption orchards is typical. Hence, it is noteworthy that the CMDA/OFM+AA baited traps captured a total of 26 and 72 moths/trap in the Isomate TT and Mist treatments, respectively. The increased trap captures later in the season (about 140 days after deployment) could represent increasing OFM populations, which is typical in August and September, or a decline in the release of pheromone from pheromone dispensers. While release of OFM pheromone from Isomate TT dispensers was likely very low at this time, Mist dispensers were still emitting the same amount of pheromone compared to early in the season. This occurrence, along with increased captures in non-disrupted blocks in September, suggests that the late-season increase was associated with high OFM densities, which were not otherwise detected with the OFM-L2 lure. At harvest, 2% of control fruit had entries by internal-feeding lepidopterans, while only 0.4 and 0.5% damage was detected in the Isomate TT and Mist treatments, respectively (Fig. 5). Although only one live OFM larva was collected at harvest, all damage resembled that of OFM. No damage was detected in the July assessment.

CideTrak – Meso Trial. Similar to the previous trial, codling moth populations were low in this study, with an average of only 13.3, 6.0, and 16.7 total moths/trap captured with CMDA+AA, CMDA/OFM+AA, and CMDA lures, respectively, in non-disrupted plots (Fig. 6.). Seasonal cumulative captures (Fig. 7) illustrate that trap capture was most intense during flight of the overwintering generation (May to early July). Based on moth capture in traps baited with CM-L2 lures in non-disrupted blocks, OFM populations were of low to moderate intensity with a season total of only 72 moths/trap; capture in traps baited with CMDA/OFM+AA was 337 moths/trap, or about 4.5X higher than that in the CM-L2 traps (Fig. 8). Seasonal cumulative trap captures were again zero or near zero with CM-L2 lures in both mating disruption treatments (Fig. 9), but the CMDA/OFM+AA lures again detected an increase in OFM numbers during September (Fig. 10) – season total OFM capture in the CideTrak and Meso treatments were 4.2 and 19.7 moths/trap, respectively. Across all locations, internal lepidopteran damage was detected in only one plot, the non-disrupted control at the Edneyville location, with only 0.8% internal lepidopteran damage.

Conclusions

Low codling moth populations were attributed to a low overwintering population of codling moth due to a widespread freeze and small crop load in 2012, and record rainfall in 2013 that suppressed populations – total rainfall in Henderson County from May through August was 52.2 inches. The two different types of low-density pheromone dispensers evaluated in these trials, Isomate Mist canisters and CideTrak Meso dispensers, both resulted in slightly higher OFM trap captures than their respective low-density dispenser treatments (i.e., Isomate CM-OFM TT and CideTrak CM-OFM), but appeared to provide similar levels of control to that of Isomate TT and CideTrak dispensers. The higher pheromone trap captures in the low-density dispenser treatments were both associated with late-season OFM populations that were detected only with the highly sensitive CMDA/OFM+AA lures. Late-season OFM trap captures in all mating disruption blocks were zero or near zero with the standard CM-L2 lures. Unfortunately, codling moth populations were too low to differentiate treatment effects.

Low codling moth populations made it difficult to thoroughly evaluate the various codling moth lures, but when averaged across all locations, the addition of acetic acid lures with CMDA and CMDA/OFM caught more moths than either CMDA alone or the standard CM-L2 lure in blocks treated with mating disruption dispensers (Fig. 11). This trend was not apparent in non-disrupted blocks, although captures in traps baited with CM-L2 lures were consistently lower than all other lures. Traps baited with CMDA/OFM+AA caught considerably more OFM than the standard OFM-L2 lure in both mating disruption and non-disrupted orchards (Fig. 12). While the enhanced lures clearly increased the detection of low density codling moth and OFM populations, additional studies will be necessary to interpret the meaning of trap captures and develop revised threshold levels to dictate the need for supplemental insecticide applications in mating disruption orchards. An additional objective should be to determine if the same trapping density is required for enhanced versus standard lures. Finally, the CMDA/OFM+AA lures may serve as a potential dual trapping system for codling moth and OFM, as traps baited with these lures were attractive to both species.

Acknowledgments

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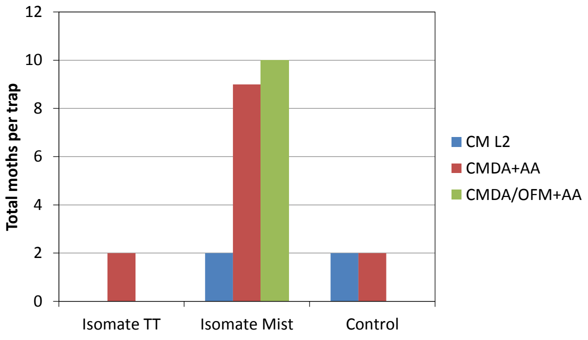


Fig. 1. Season total codling moth captures in traps baited with different lures and placed in mating disrupted and non-disrupted blocks of apples. Fruitland, NC. 2013.

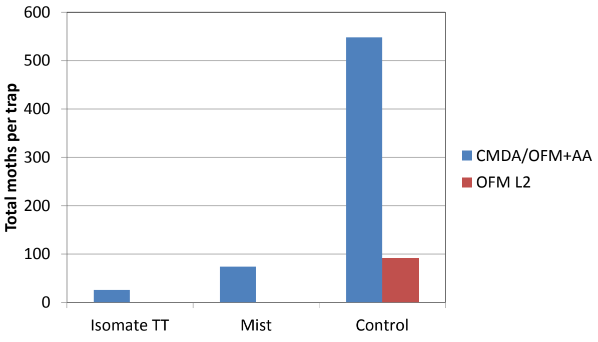


Fig. 2. Season total oriental moth captures in traps baited with different lures and placed in mating disrupted and non-disrupted blocks of apples. Fruitland, NC. 2013.

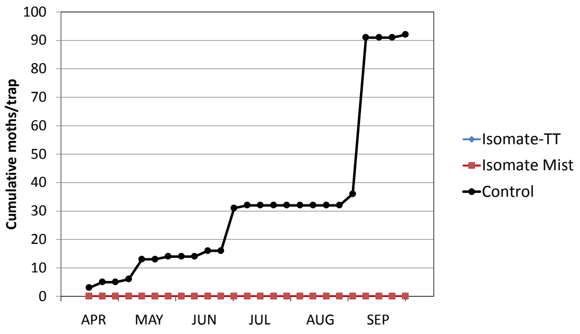


Fig. 3. Season cumulative oriental fruit moth captures (OFM-L2 lure) in blocks of apples treated with different mating disruption dispensers. Fruitland, NC. 2013.

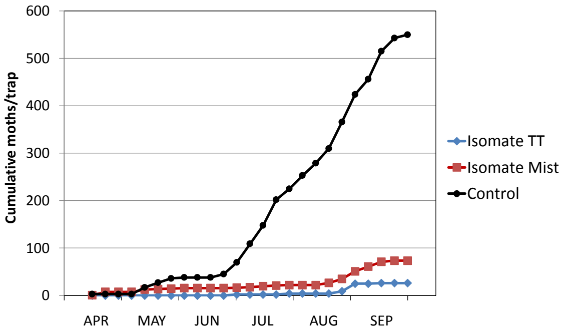


Fig. 4. Season cumulative oriental fruit moth captures (CMDA/OFM+AA lure) in blocks of apples treated with different mating disruption dispensers. Fruitland, NC. 2013.

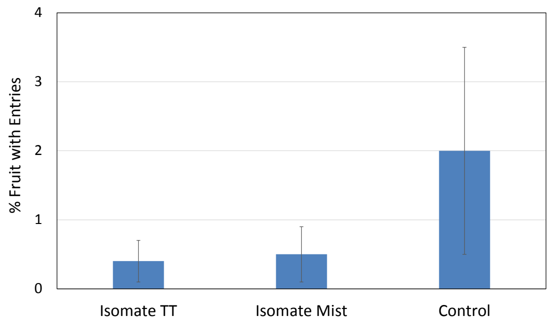


Fig 5. Mean percentage (±SEM) of apples in mating disrupted and non-disrupted blocks damaged by internal-feeding lepidopteran larvae. Fruitland, NC. 2013.

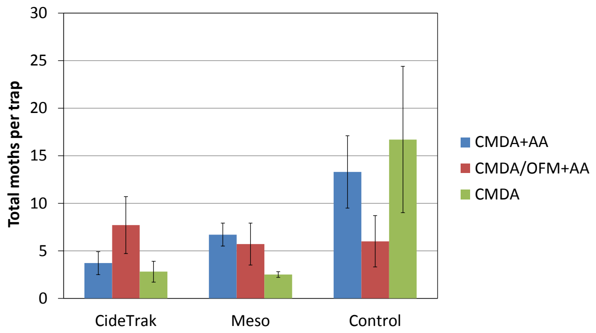


Fig. 6. Season total codling moth captures in traps baited with different lures in mating disrupted and non-disrupted blocks of apples. Henderson County, NC. 2013.

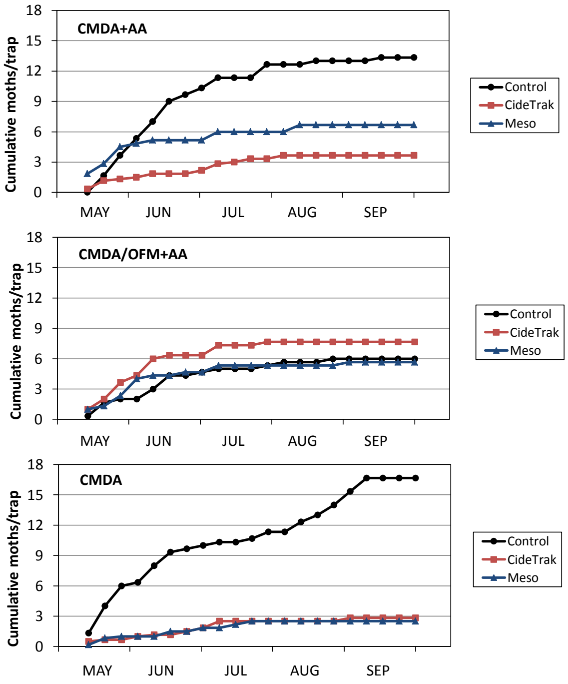


Fig. 7. Cumulative codling moth pheromone trap captures in mating disrupted and non-disrupted blocks of apples., with three Different lure types – CMDA+AA, CMDA/OFM+AA,and CMDA. Henderson County, NC. 2013.

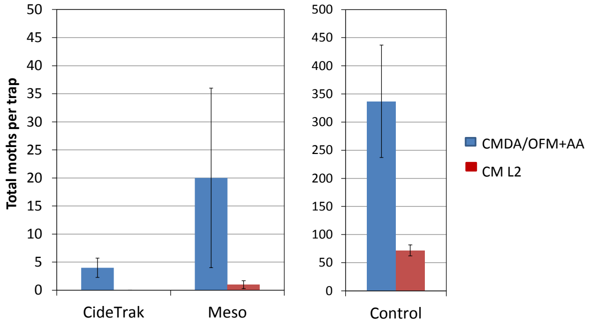


Fig. 8. Season total oriental fruit moth captures in traps baited with different lures in mating disrupted and non-disrupted blocks of apples. Henderson, NC. 2013.

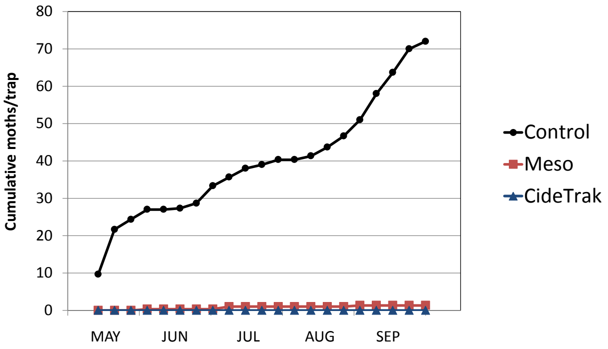


Fig. 9. Mean cumulative oriental fruit moth pheromone trap captures (CM-L2 lures) in mating disrupted and non-disrupted blocks of apples. Henderson County, NC. 2013.

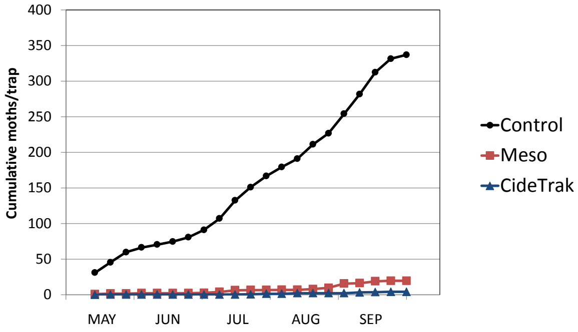


Fig. 10. Mean cumulative oriental fruit moth pheromone trap captures (CMDA/OFM+AA lures) in mating disrupted and non-disrupted blocks of apples. Henderson County, NC. 2013.

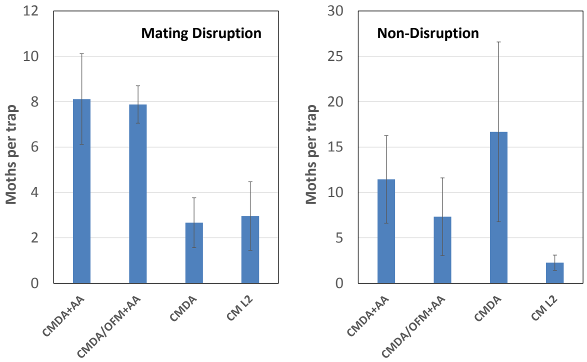


Fig. 11. Mean season total codling moth captures across all mating disruption and non-disrupted blocks in traps baited with different lures. Henderson County, NC. 2013.

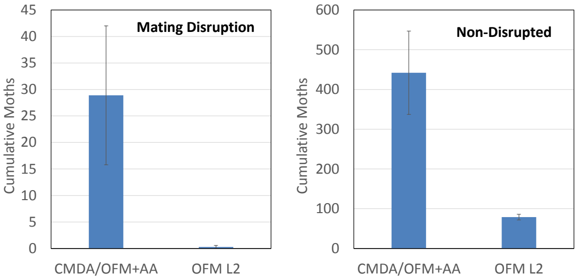
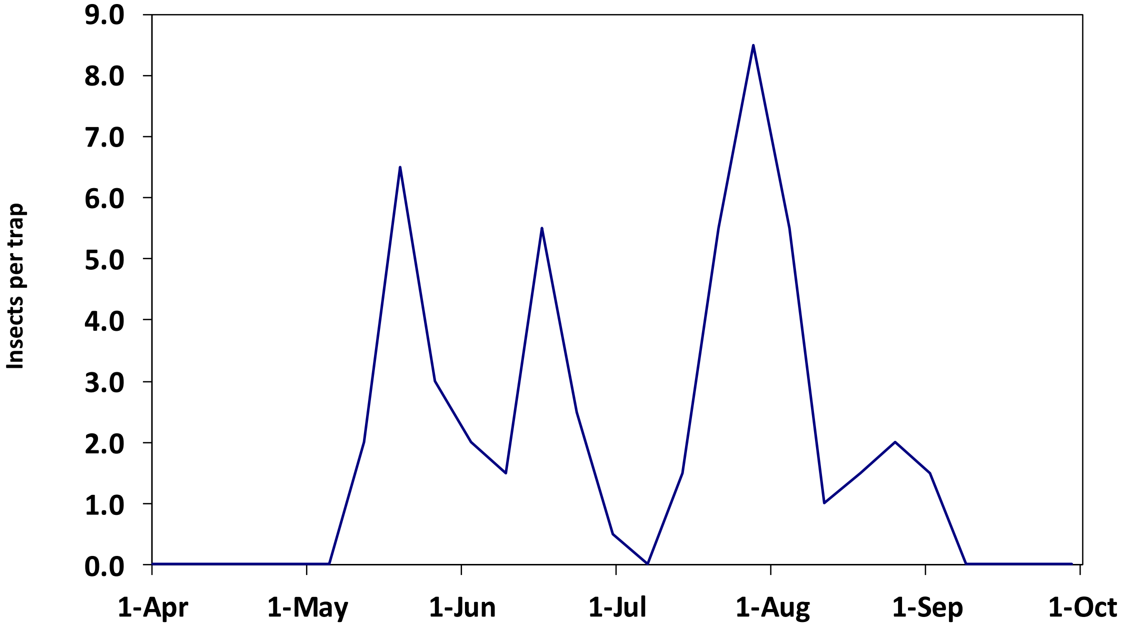
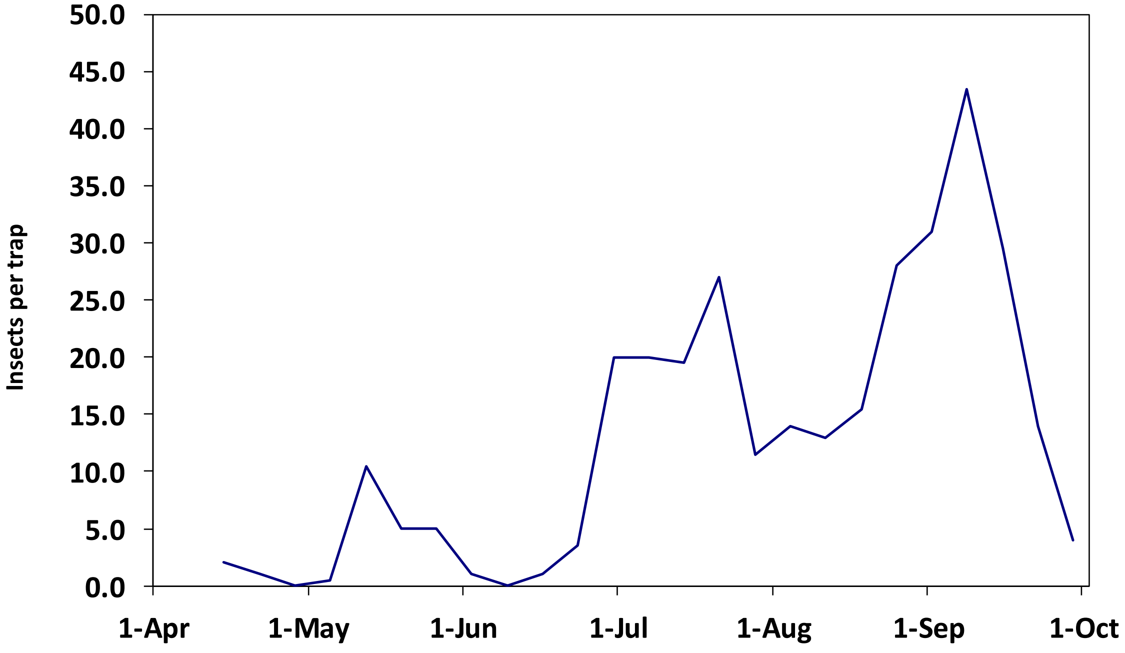


Fig. 12. Mean season total codling moth captures across all mating disruption and non-disrupted blocks in traps baited with different lures. Henderson County, NC. 2013.

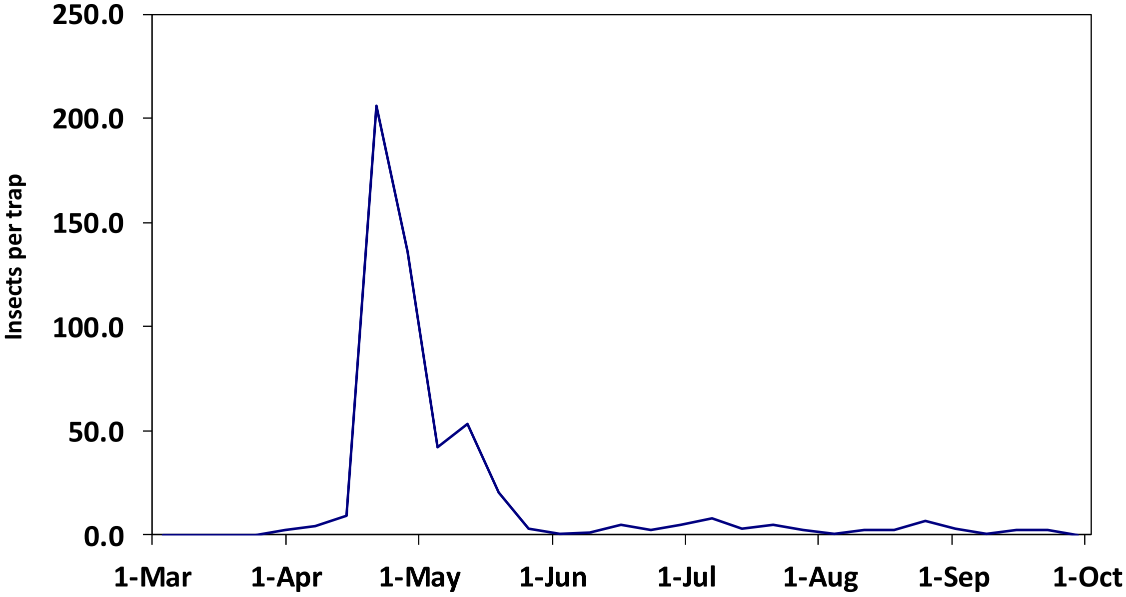
Codling Moth Trap Captures, MHCRS
Mills River, Henderson County, NC, 2013



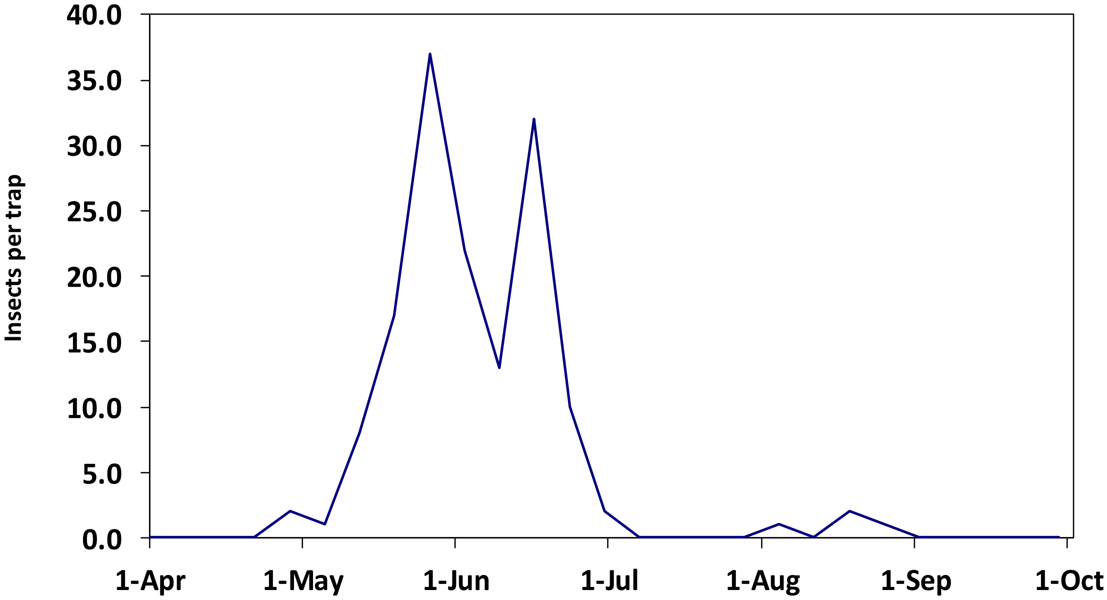
Oriental Fruit Moth Trap Captures
Fruitland, Henderson County, NC, 2013



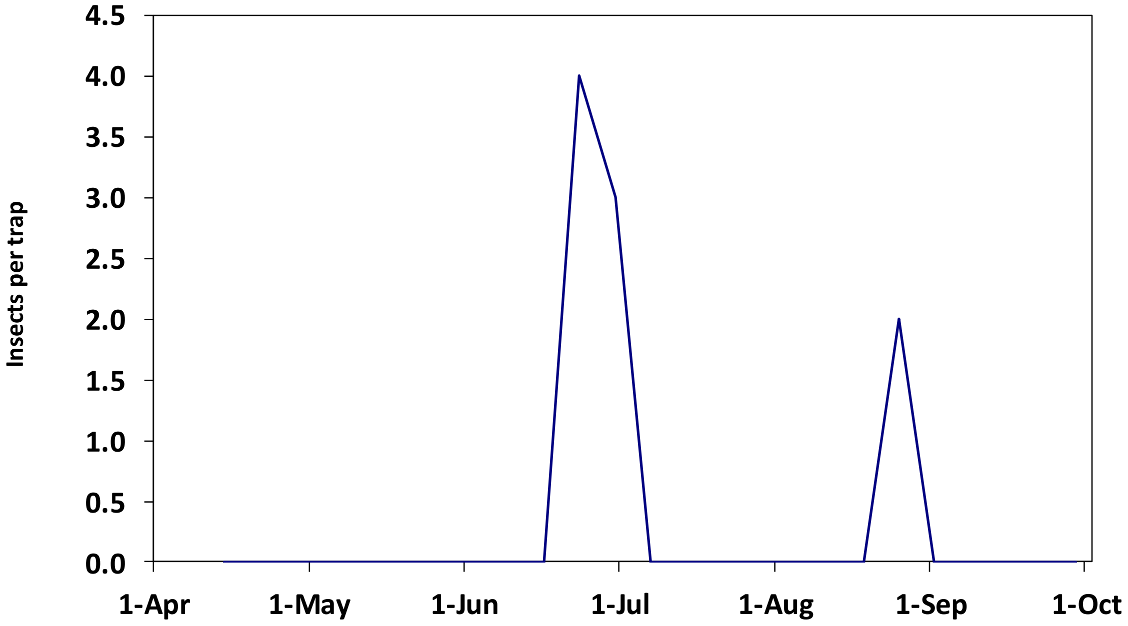
Oriental Fruit Moth Trap Captures, MHCRS
Mills River, Henderson County, NC, 2013



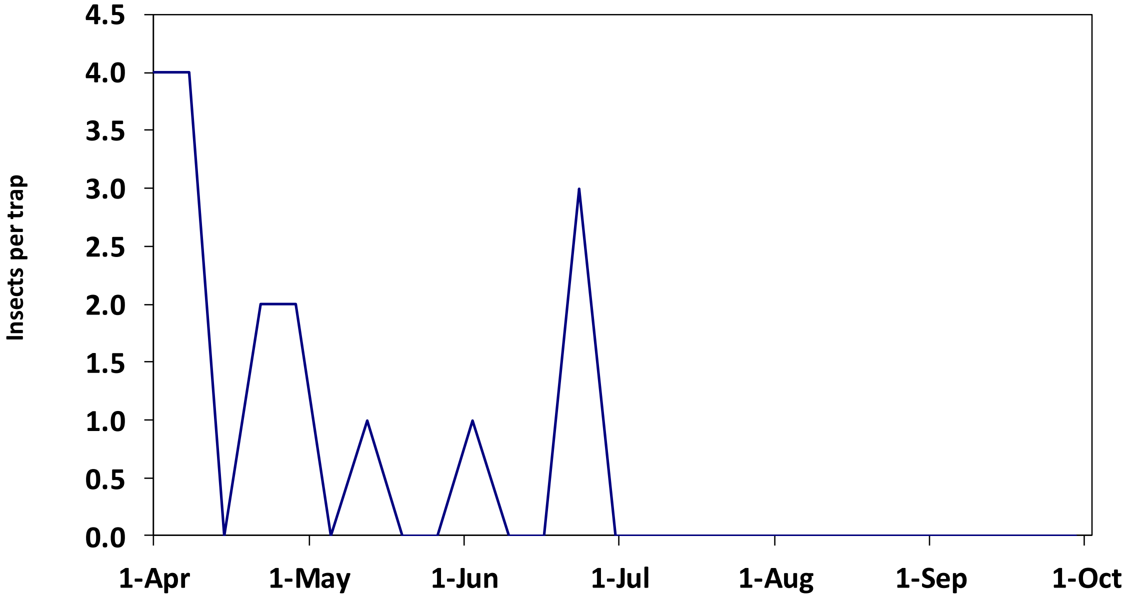
Tufted Apple Bud Moth Trap Captures, MHCRS
Mills River, Henderson County, NC, 2013

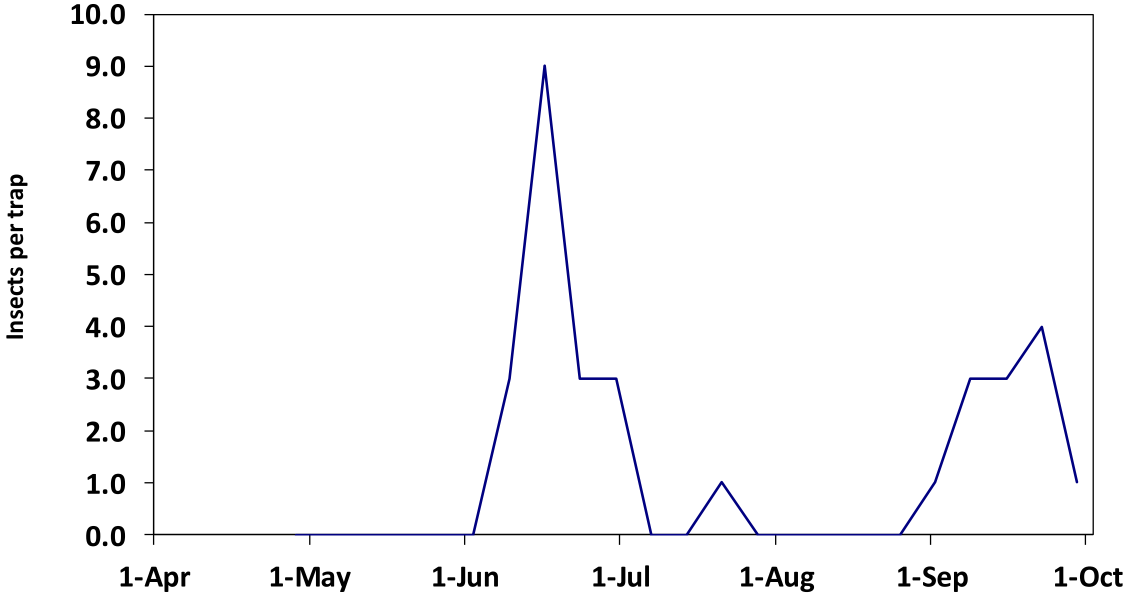


Redbanded Leafroller Trap Captures
Edneyville, Henderson County, NC, 2013

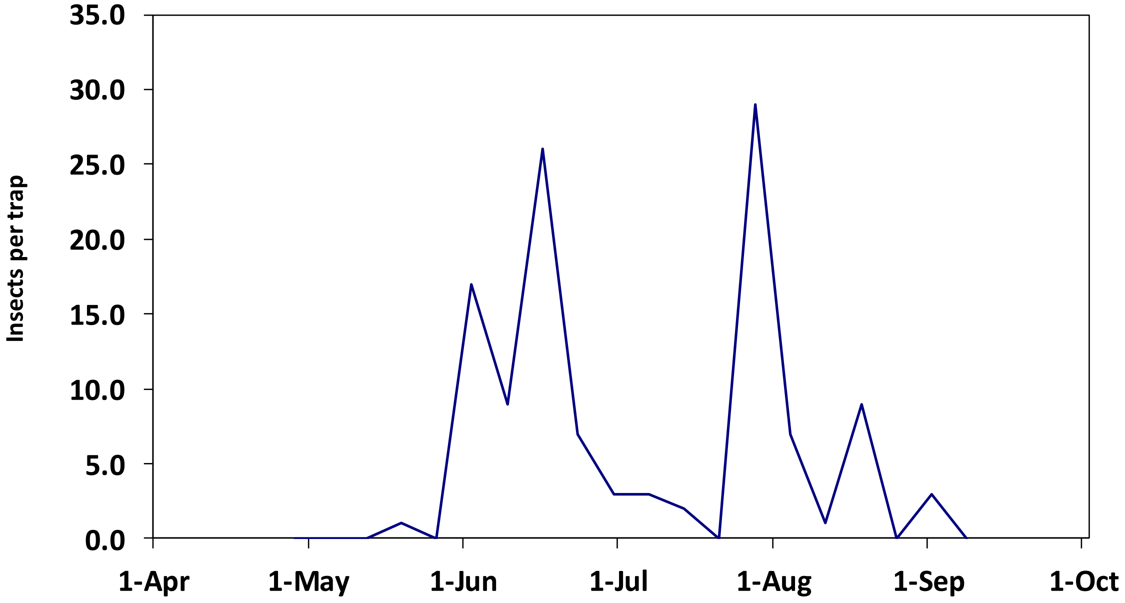


Redbanded Leafroller Trap Captures, MHCRS
Mills River, Henderson County, NC, 2013

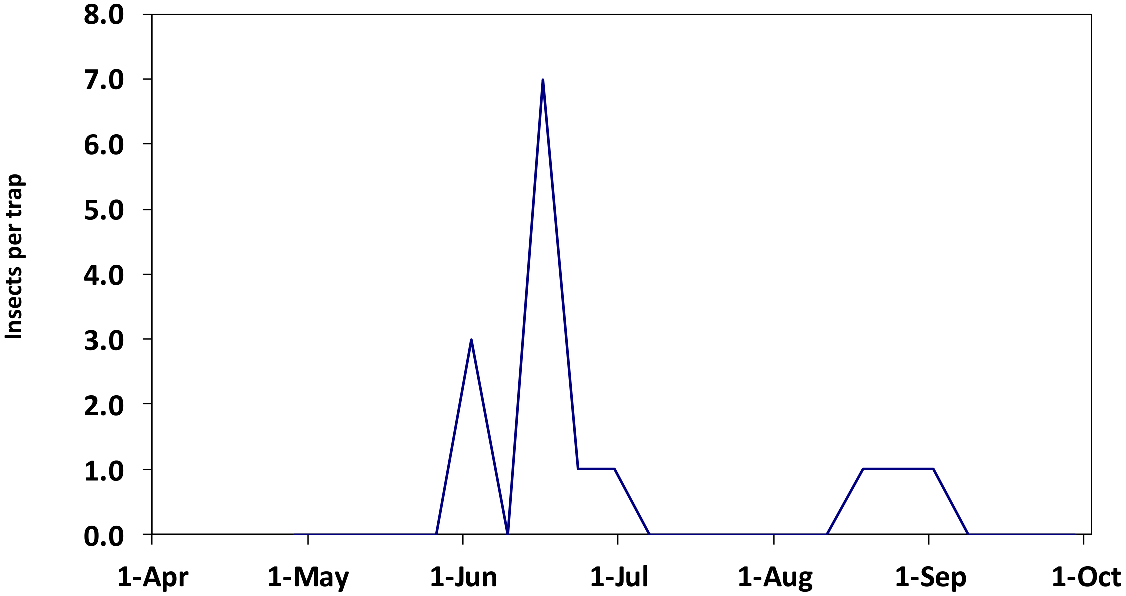




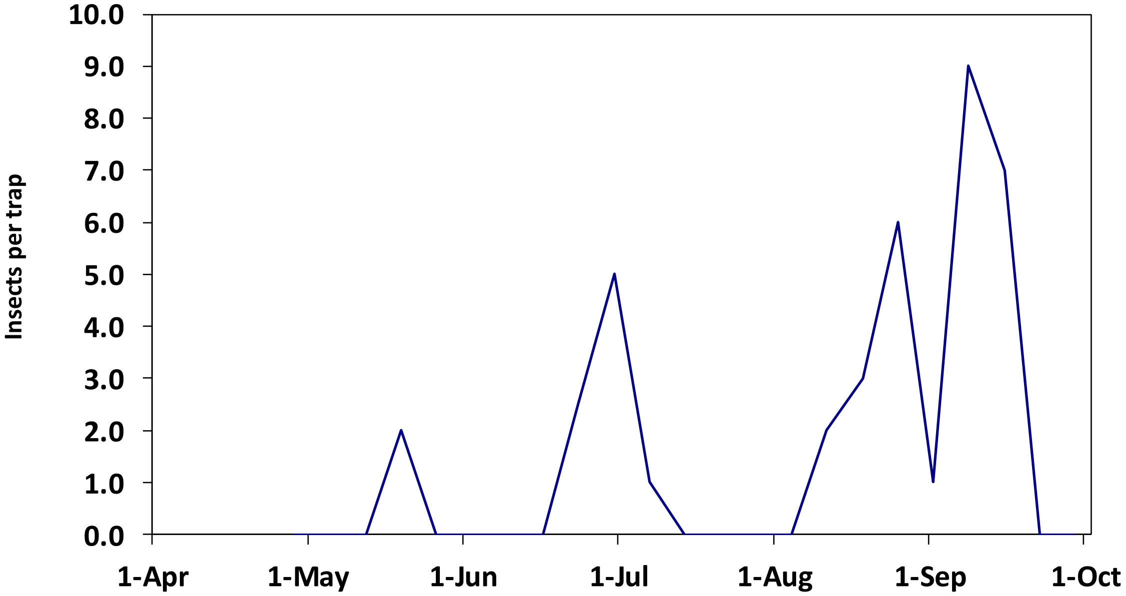
Obliquebanded Leafroller Trap Captures
Edneyville, Henderson County, NC, 2013



Obliquebanded Leafroller Trap Captures
Mill Spring, Polk County, NC, 2013

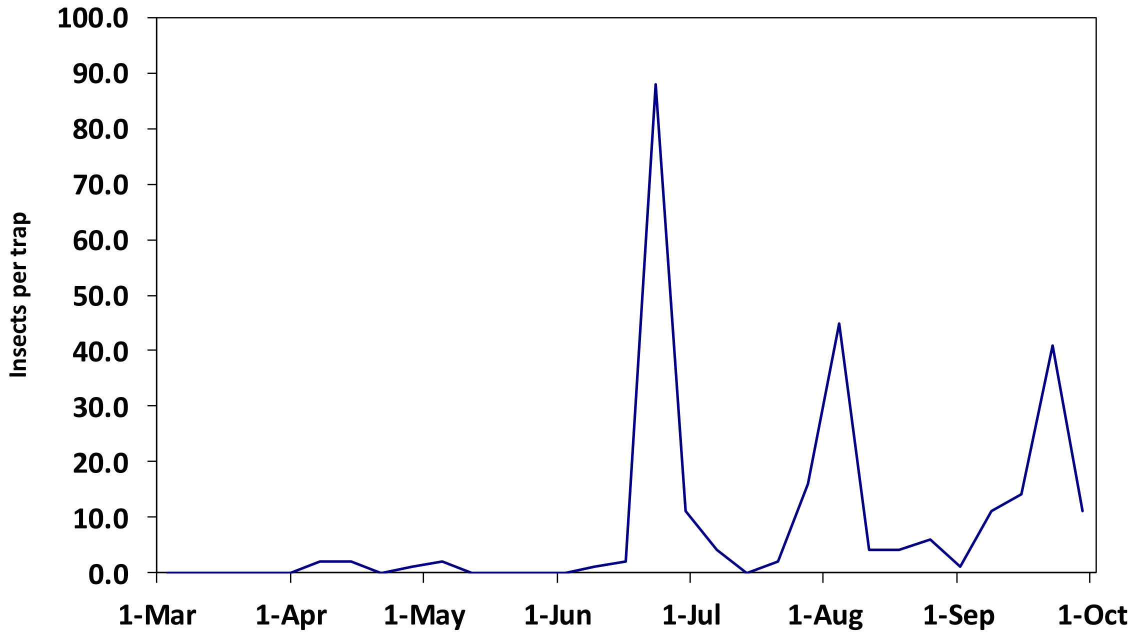


Obliquebanded Leafroller Trap Captures, MHCRS
Mills River, Henderson County, NC, 2013

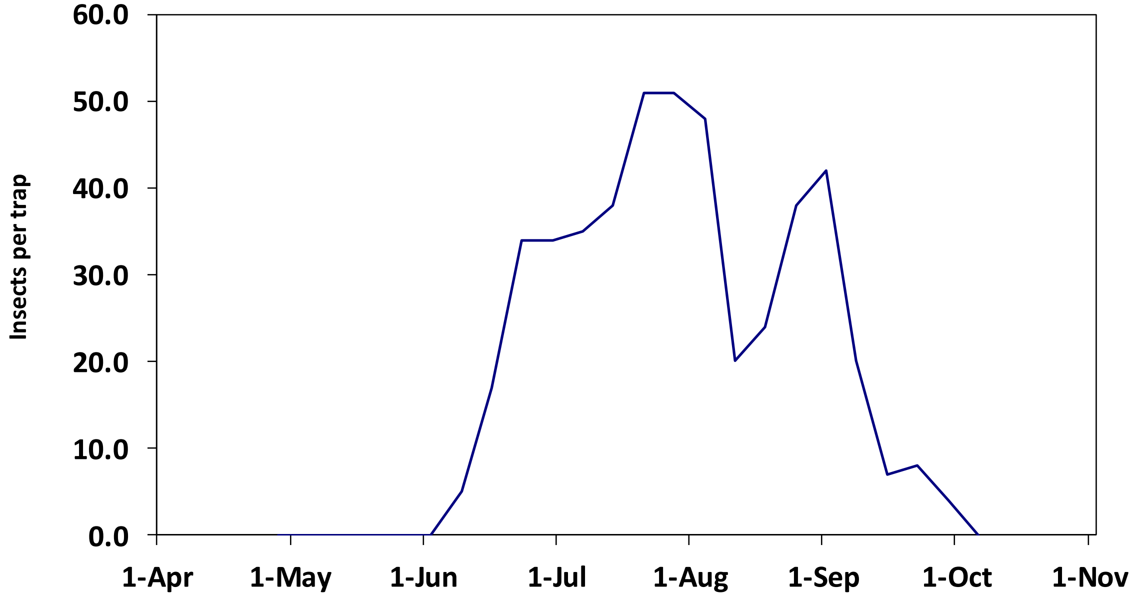


Lesser Appleworm Trap Captures, MHCRS
Mills River, Henderson County, NC, 2013

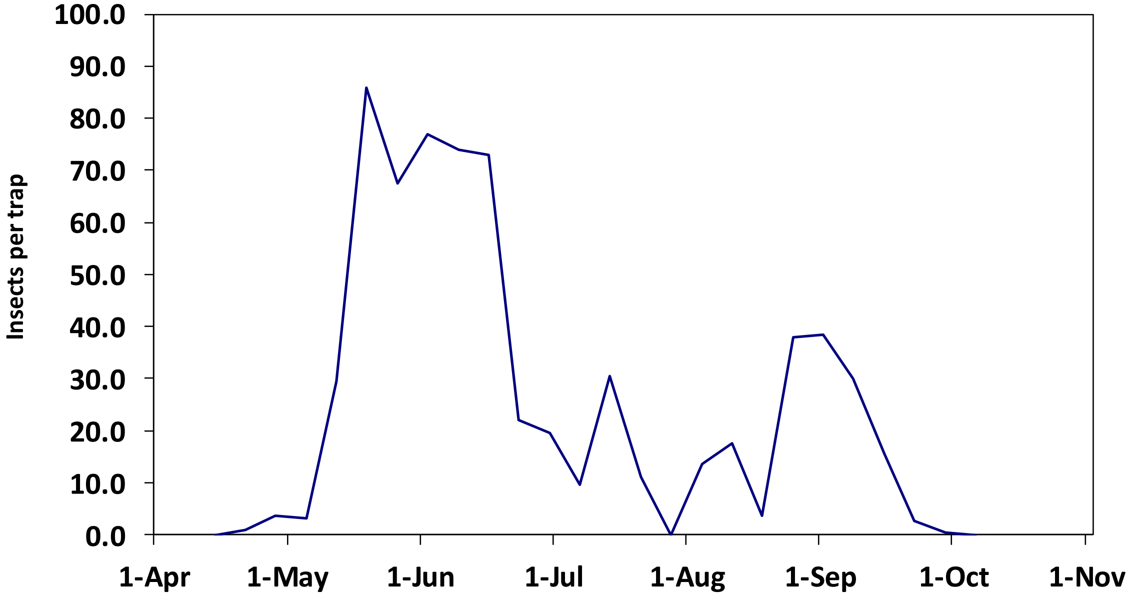
Spotted Tentiform Leafminer Trap Captures, MHCRS
Mills River, Henderson County, NC, 2013



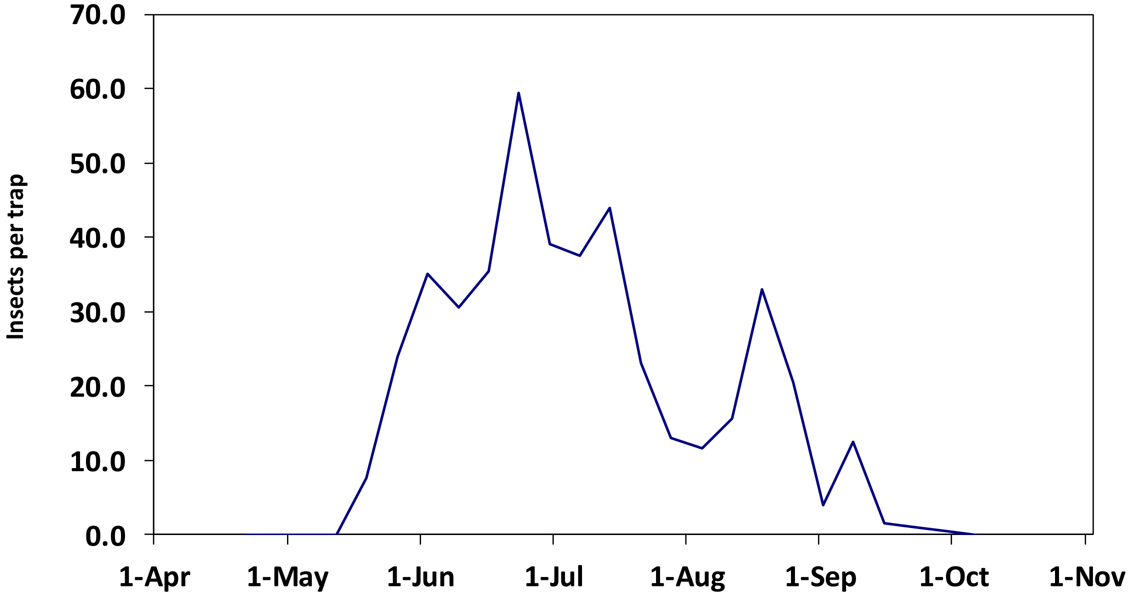
Peachtree Borer Trap Captures, MHCRS
Mills River, Henderson County, NC, 2013



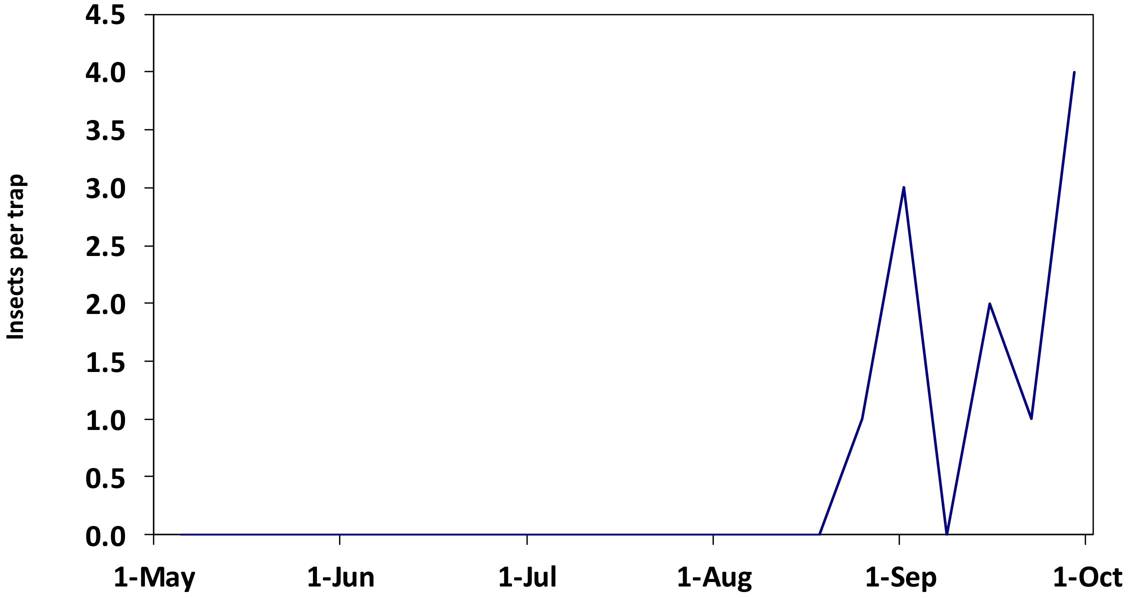
Lesser Peachtree Borer Trap Captures, MHCRS
Mills River, Henderson County, NC, 2013



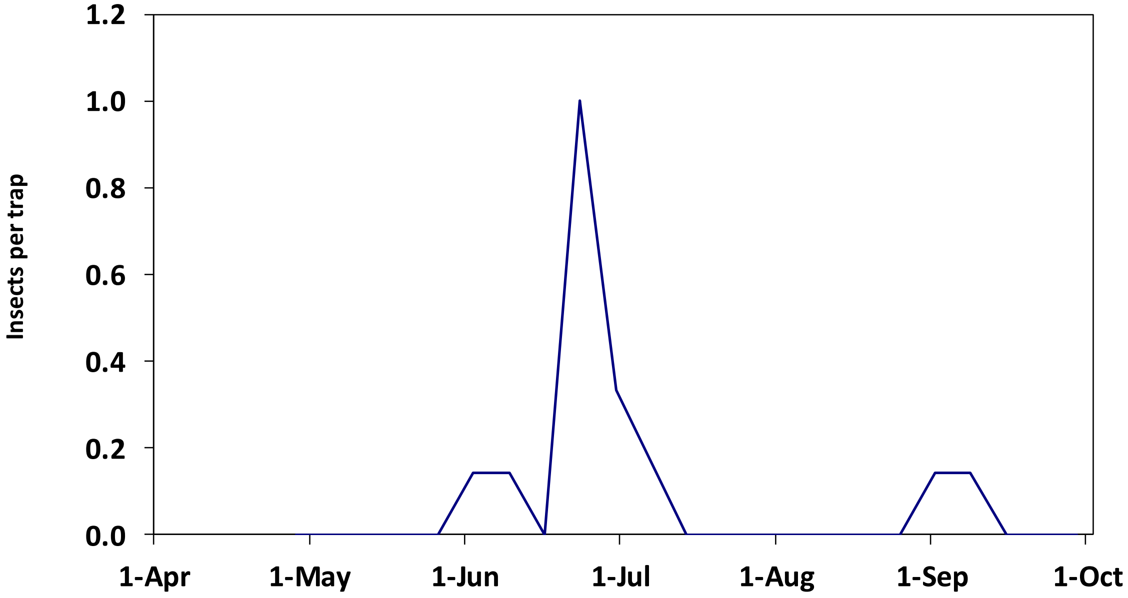
Dogwood Borer Trap Captures, MHCRS
Mills River, Henderson County, NC, 2013

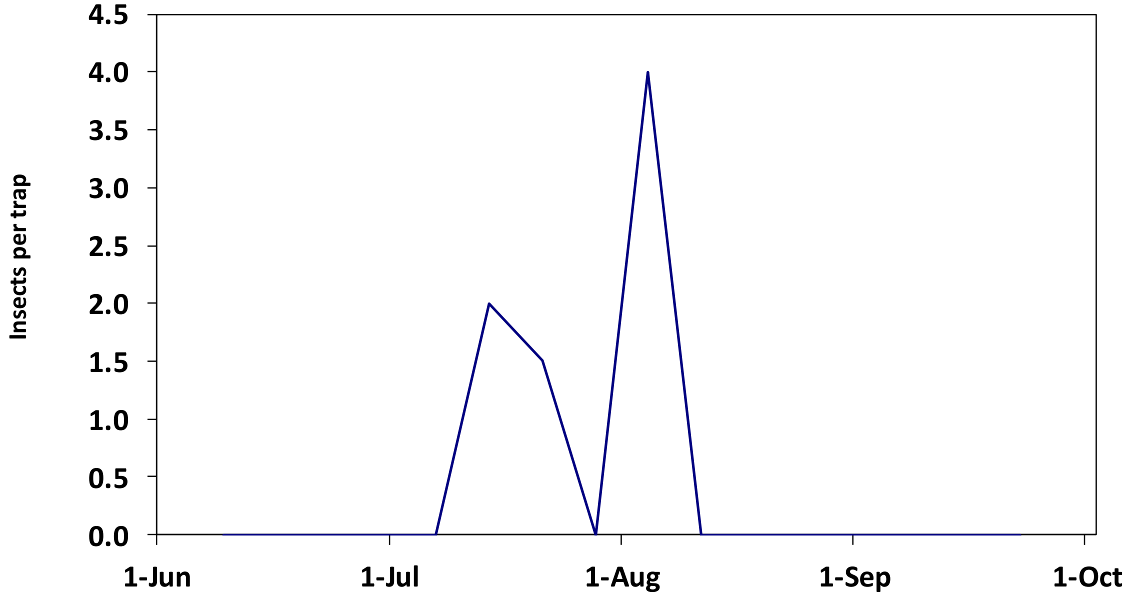


Apple Maggot Trap Captures
Fruitland, Henderson County, NC, 2013

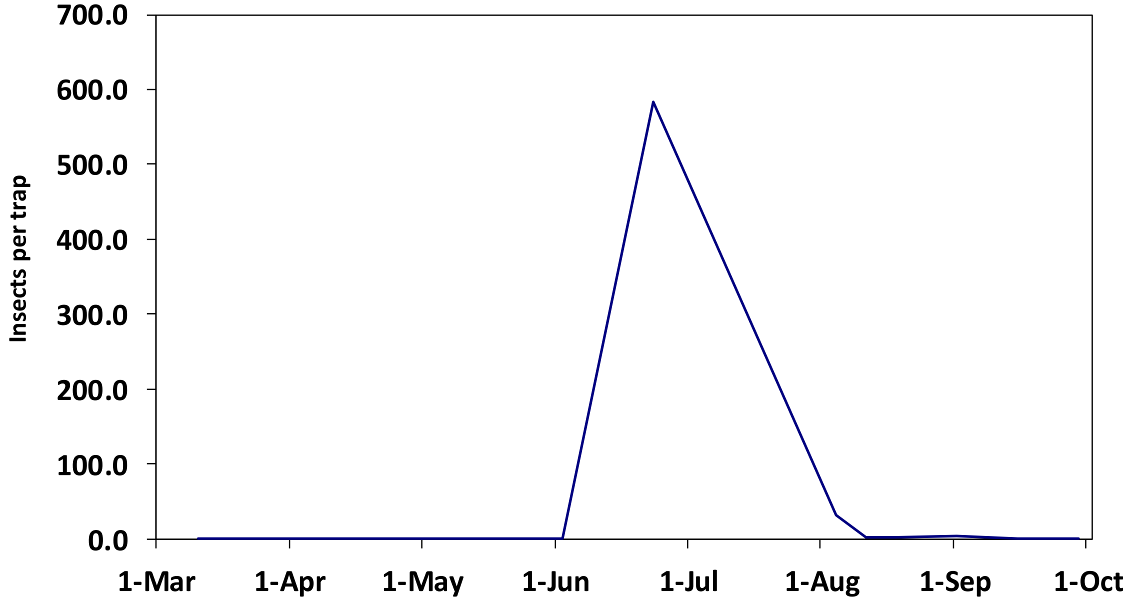


Sharpshooter Trap Captures, MHCRS
Mills River, Henderson County, NC, 2013

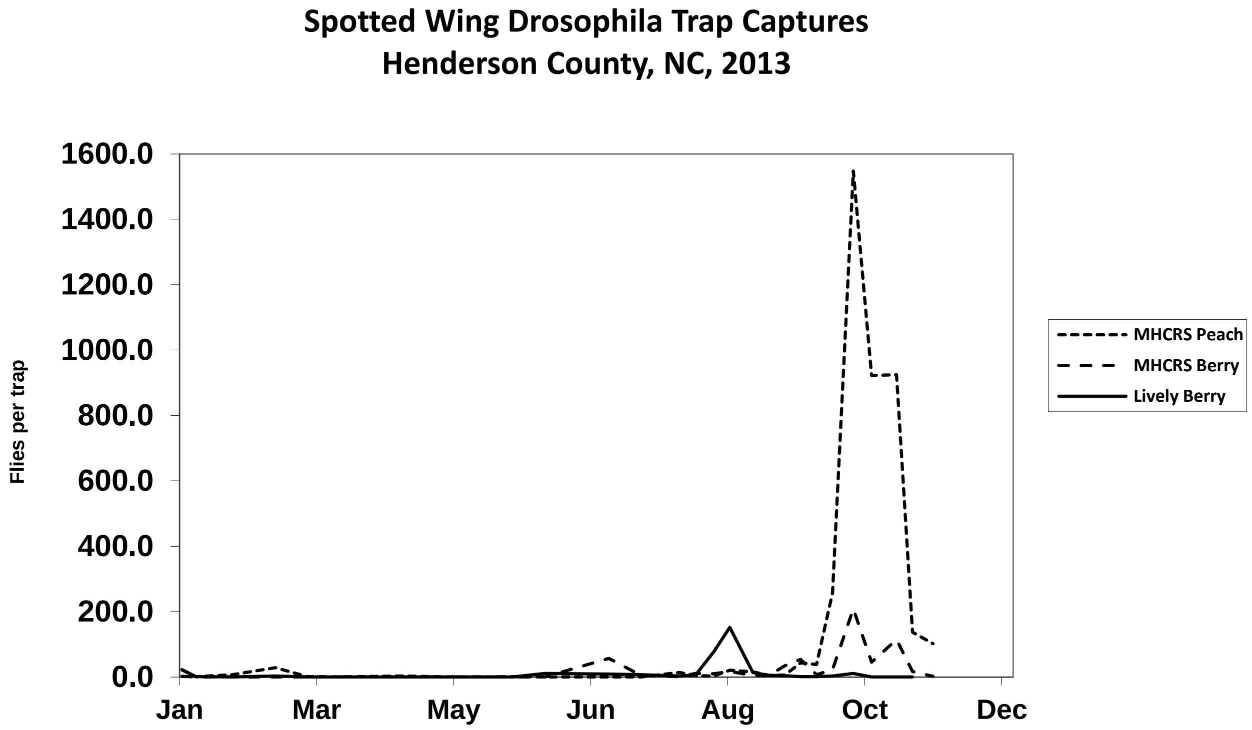


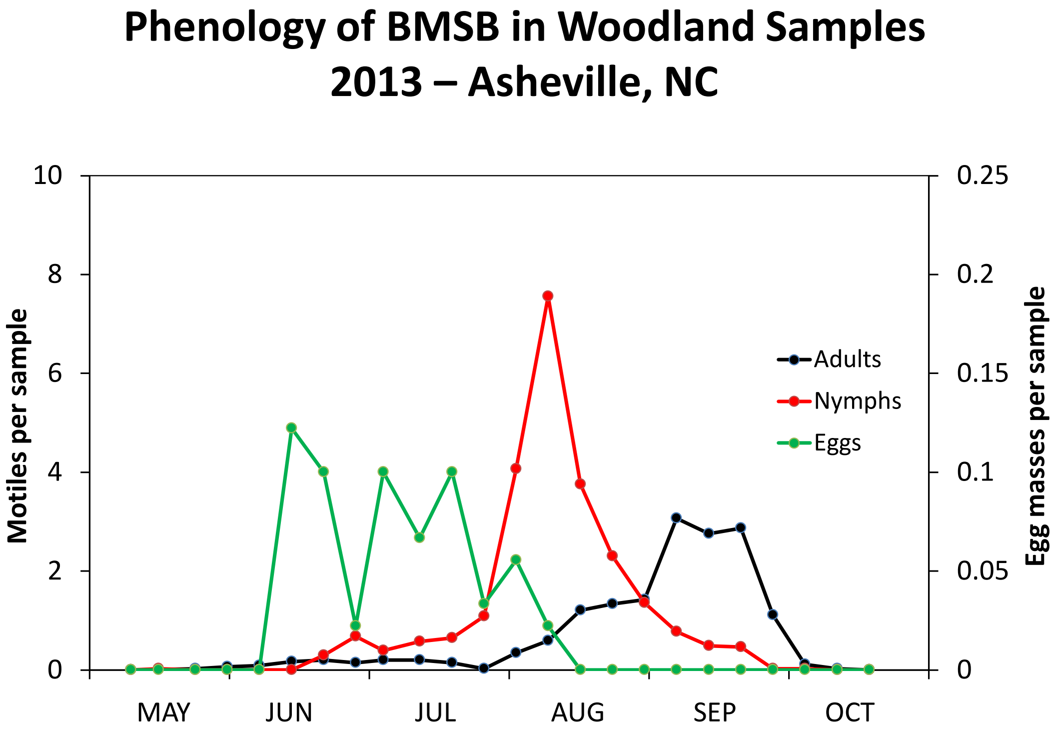


Tomato Fruitworm Trap Captures, MHCRS
Mills River, Henderson County, NC, 2013



Thrips Trap Captures, MHCRS
Mills River, Henderson County, NC, 2013


Spotted Wing Drosophila Trap Captures
Henderson County, NC, 2013
Flies per trap
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
Jan
Mar
May
Jun
Aug
Oct
Dec
MHCRS Peach
MHCRS Berry
Lively Berry


Phenology of BMSB in Woodland Samples
2013 – Asheville, NC
Motiles per sample
10
8
6
4
2
0
Egg masses per sample
0.25
0.2
0.15
0.1
0.05
0
MAY
JUN
JUL
AUG
SEP
OCT
Adults
Nymphs
Eggs