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

2003

ANNUAL REPORT

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Acknowledgments

This report is a summary of pest management-related studies conducted on fruit and vegetable crops in 2003 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, consultants and the crop protection industry in western North Carolina is also presented. Certain aspects of work supported by the NC Cooperative Extension Service IPM Program, NC Agricultural Research Service, Southern Region IPM Program, and USDA RAMP are also presented.

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2003 Weather Data - Mountain Horticultural Crops Research Station, Fletcher, NC.

March

	Temp (oF)		Rain
Day	**High**	**Low**	**(in.)**
1	60	35	
2	60	35	0.06
3	60	25	
4	53	22	
5	58	30	0.03
6	73	42	1.18
7	65	35	0.02
8	49	24	
9	67	25	
10	68	26	
11	55	25	
12	65	25	
13	74	30	
14	79	38	
15	57	38	
16	56	40	0.76
17	61	39	
18	61	48	0.23
19	58	48	0.15
20	56	42	1.61
21	51	43	0.15
22	72	44	
23	65	35	
24	66	30	
25	71	29	
26	75	37	
27	73	43	
28	65	46	
29	67	48	
30	67	27	0.63
31	41	23	
			4.82

April

	Temp (oF)		Rain
Day	**High**	**Low**	**(in.)**
1	47	21	
2	73	31	
3	80	31	
4	80	38	
5	74	48	0.34
6	75	35	0.02
7	69	32	1.1
8	51	39	0.05
9	47	35	0.41
10	48	36	0.26
11	43	28	1.43
12	62	30	
13	70	30	
14	74	28	
15	76	36	
16	80	39	
17	77	44	
18	73	38	1.08
19	54	43	
20	67	44	
21	72	44	
22	73	43	0.41
23	60	38	
24	68	29	
25	70	34	0.03
26	59	46	0.11
27	70	43	
28	78	40	
29	79	45	
30	83	45	
			5.24

May

	Temp (oF)		Rain
Day	**High**	**Low**	**(in.)**
1	82	50	0.3
2	81	51	0.6
3	80	45	0.87
4	75	42	0.06
5	74	41	0.14
6	62	48	2.59
7	68	51	1.41
8	72	48	0.44
9	87	51	
10	90	53	
11	86	52	
12	81	47	
13	73	50	
14	74	47	
15	74	50	0.14
16	75	52	0.11
17	82	45	0.1
18	66	49	0.4
19	59	48	0.49
20	62	48	
21	71	51	0.03
22	67	54	0.97
23	64	51	0.65
24	74	55	1.22
25	74	45	0.02
26	76	45	0.11
27	76	44	
28	72	42	
29	75	50	0.1
30	71	47	0.06
31	76	48	
			10.82

June

	Temp (oF)		Rain
Day	**High**	**Low**	**(in.)**
1	82	48	
2	71	40	
3	75	45	0.18
4	73	55	0.35
5	83	49	0.03
6	75	45	
7	78	50	1.05
8	80	50	0.91
9	83	50	0.46
10	80	47	
11	84	52	
12	86	57	0.23
13	82	60	0.07
14	84	58	
15	85	58	0.02
16	84	58	0.78
17	81	59	0.62
18	76	60	
19	72	58	0.48
20	81	58	
21	78	50	
22	75	47	0.06
23	81	46	
24	84	49	
25	89	53	
26	90	56	
27	89	57	
28	83	59	0.20
29	76	55	0.03
30	87	55	1.64
			7.11

2003 Weather Data - Mountain Horticultural Crops Research Station, Fletcher, NC.

July				August				September				October			
	Temp (oF)		Rain		Temp (oF)		Rain		Temp (oF)		Rain		Temp (oF)		Rain
Day	High	Low	(in.)	Day	High	Low	(in.)	Day	High	Low	(in.)	Day	High	Low	(in.)
1	80	59	0.35	1	84	62	0.21	1	85	61	0.65	1	68	32	
2	68	58	2.45	2	84	59	0.85	2	85	58		2	65	39	
3	73	55	0.14	3	87	60	0.03	3	86	58		3	60	27	
4	84	55	0.02	4	82	60	0.55	4	85	62	0.01	4	60	29	
5	89	60		5	85	56	1.37	5	80	55	0.1	5	72	29	
6	88	55	0.91	6	85	57	0.06	6	83	56		6	70	48	0.02
7	84	54	0.03	7	85	58	0.02	7	76	55		7	69	42	0.02
8	83	60		8	80	59	0.75	8	76	52	0.11	8	73	44	
9	90	60		9	83	59	0.02	9	78	51		9	66	50	0.42
10	87	61	0.31	10	84	59		10	78	52		10	66	53	0.25
11	83	57	0.71	11	82	57	0.02	11	78	48		11	68	52	0.15
12	84	52		12	83	56		12	80	45		12	73	44	0.02
13	85	52		13	82	57	0.09	13	80	48		13	74	43	
14	81	51	0.33	14	85	59		14	85	47		14	77	47	
15	82	56	0.02	15	89	64	0.12	15	80	53	0.22	15	73	44	0.11
16	81	59	0.27	16	89	64	0.14	16	82	51		16	63	28	
17	89	60	0.22	17	87	59		17	80	44		17	70	28	
18	88	57	0.19	18	88	57		18	78	43		18	68	30	
19	89	52	0.02	19	88	55		19	77	47		19	68	29	
20	85	50		20	85	58		20	82	47		20	74	29	
21	90	59	2.65	21	88	60	0.07	21	84	45		21	75	33	
22	87	57	0.32	22	88	60		22	80	46	0.05	22	80	37	
23	83	58		23	75	60		23	66	50	2.2	23	66	30	
24	80	50		24	78	58		24	70	42		24	62	28	
25	80	51		25	78	58		25	75	43		25	65	28	
26	85	54		26	87	58		26	82	47		26	68	28	
27	86	54		27	93	59		27	78	48		27	60	51	1.5
28	88	54		28	92	61		28	81	47	0.10	28	63	32	0.03
29	89	59		29	88	60		29	70	34		29	54	33	0.06
30	85	63	1.13	30	89	62	0.18	30	61	31		30	65	29	
31	80	62	1.05	31	86	62	0.97					31	77	33	
			11.12				5.45				3.44				2.58

Tomato Insecticide Trial

A study was conducted at the Mountain Horticultural Crops Research Station (Fletcher, NC) to evaluate various insecticides and insecticide programs for control of the insect complex attacking tomatoes in western North Carolina.

Materials and Methods

Six-week-old 'Mountain Supreme' transplants were set on 17 June. Plants were set 18 in. apart within 20-ft rows, and rows were on 10-ft centers. Single-row plots were arranged in a randomized complete block design with four replications. Insecticide treatments were applied on 24 July; 1, 11, 20, and 29 August; and 5 and 12 September, with a tractor-mounted boom sprayer delivering 50-125 GPA (gallonage increased as plants grew) through 7 hollow cone nozzles per row (three nozzles on each side and one overhead). With the exception of insect control, standard practices for staked tomato production in western North Carolina were followed.

Potato aphid (PA) populations were monitored on 13 and 27 August and 9 September by observing 10 leaves (3rd most recently expanded leaf) per plot and recording the number of leaves infested with ≥1 apterous aphid. Thrips populations were sampled on 28 July and 14 August by collecting 10 flowers per treatment, placing them in a vial of ethanol, and counting the number of thrips in each vial under a stereomicroscope. Greenhouse white fly (GHWF) populations were evaluated on 27 August and 9 September by observing 10 leaves per treatment and recording the number of leaves infested with GHWF adults. Pink stage fruit were harvested at weekly intervals from 26 August through 23 September, and the total number of fruit, along with those damaged by tomato fruitworm (TFW), stink bug (SB) and thrips (FT), were recorded. All data were subjected to two-way ANOVA and means were separated by LSD (P = 0.05).

Results

Weather conditions during the course of this trial were very wet, with total rainfall of 6.2, 10.9, and 6.8 inches in June, July and August, respectively. This was 11.4 inches above normal for this 3-month period. Consequently, populations of indirect pests commonly attacking tomato in western NC were very low. Normally potato aphid populations reach 100% infested leaves by mid to late August, yet in this study infestations peaked at only 25% in the control (Table 1). With the exception of the SpinTor/Avaunt treatment, all treatments significantly reduced populations below the control. Populations of whiteflies and thrips were too low to detect treatment effects.

Tomato fruitworm and stink bug caused approximately 12 and 15% fruit damage in the control, respectively (Table 2). The pyrethroids, particularly Danitol and Warrior, and the SpinTor/Avaunt treatments were most effective against fruitworm. Although the neonicotinoids significantly reduced fruitworm damage below the control, they were less effective than the other insecticides. Stinkbug damage was relatively high in all treatments, with Danitol providing the most effective control.

Table 1. Mean number of potato aphid, greenhouse whitefly and *Frankliniella* spp. thrips on tomatoes treated with different insecticides. Fletcher, NC. 2003.

		% Aphid-infested leaves		% Whitefly infested leaves		Thrips per 10 flowers	
Insecticide[1]	lb(AI)/A	27 Aug	9 Sep	27 Aug	9 Sep	28 Jul	14 Aug
XR-225 CS	0.015	2.5a	0.0a	0.0a	27.5a	0.5b	0.5a
Danitol 2.4EC	0.20	2.5a	5.0a	5.0a	10.0a	0.0a	0.0a
Warrior T	0.03	0.0a	0.0a	0.0a	20.0a	0.0a	0.0a
Baythroid 2EC	0.03	0.0a	2.5a	0.0a	15.0a	0.0a	0.0a
Asana XL	0.03	5.0a	0.0a	2.5a	12.5a	0.0a	0.3a
SpinTor 2SC Avaunt	0.0625 0.065	12.5ab	10.0a	5.0a	12.5a	0.0a	0.0a
Assail 70WP	0.06	0.0a	0.0a	5.0a	10.0a	0.0a	0.3a
Calypso 480SC	0.06	2.5a	0.0a	0.0a	7.5a	0.5b	0.8a
Actara 25WDG	0.06	0.0a	0.0a	2.5a	5.0a	0.0a	0.3a
Control	—	25.0b	25.0b	0.0a	17.5a	0.8b	0.5a

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

[1] All insecticides were applied on 24 July; 1, 11, 20 and 29 August; and 5 and 12 September. In the SpinTor/Avaunt treatment, SpinTor was applied on 24 July, 1 August and 12 September, and Avaunt was applied on 11, 20 and 29 August, and 5 September.

Table 2. Mean percentage of insect damage to tomatoes treated with different insecticides. Fletcher, NC. 2003.

Insecticide[1]	lb(AI)/A	No. fruit	Percent damaged fruit			
			Fruitworm	Stink bug	Thrips	Gold flecking
XR-225 CS	0.015	203.8a	2.2ab	4.2a	0.0a	0.4a
Danitol 2.4EC	0.20	251.8a	1.2a	3.0a	0.3a	0.2a
Warrior T	0.03	267.3a	1.4a	4.3ab	0.4a	0.0a
Baythroid 2EC	0.03	220.8a	3.1ab	4.0a	0.0a	0.5a
Asana XL	0.03	249.3a	3.3ab	7.8abc	0.2a	0.2a
SpinTor 2SC Avaunt	0.0625 0.065	241.0a	1.6a	10.0bcd	0.2a	0.2a
Assail 70WP	0.06	223.3a	4.0abc	6.9abc	0.3a	0.1a
Calypso 480SC	0.06	248.0a	6.7c	10.3cd	0.5a	0.4a
Actara 25WDG	0.06	260.8a	4.9bc	4.3ab	0.3a	0.0a
Control	—	245.3a	11.6d	15.4d	0.7a	0.2a

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

[1] All insecticides were applied on 24 July; 1, 11, 20 and 29 August; and 5 and 12 September. In the SpinTor/Avaunt treatment, SpinTor was applied on 24 July, 1 August and 12 September, and Avaunt was applied on 11, 20 and 29 August, and 5 September.

Full Season Evaluation of Insecticides on Apples - Fletcher

The purpose of this trial was to evaluate different insecticides and insecticide programs for management of the direct and indirect arthropod pest complex on apples in North Carolina.

Materials and Methods

The trial was conducted at the Mountain Horticultural Crops Research Station (Fletcher, NC) in a 25-year-old block of 'Golden Delicious' apples with a tree-row-volume of approximately 250 gpa. Plots consisted of five-tree blocks with the second and fourth tree in each plot serving as sample trees. Treatments were arranged in a randomized complete block design with four replications. Applications were made with an air-blast sprayer delivering 106 gallons per acre. The treatment list appears in the tables, and all trees received the same season-long fungicide program. Applications made on 3 and 28 April corresponded to tight cluster and petal fall, respectively.

Rosy apple aphid (RAA) populations were assessed on 12 and 27 May by counting the number of RAA colonies on each sample tree. Populations of the apple/spirea aphid complex were counted on 9, 17 and 30 June by counting the number of aphid-infested leaves on each of 10 water sprout shoots per sample tree. Spotted tentiform leafminer (STLM) was assessed on 17 June and 23 July by counting the number of mines observed during a 3-minute search on each sample tree. Potato leafhopper populations were assessed on 17 and 30 June and 16 July by counting the number of nymphs on 10 shoots per sample tree. Because of low population densities of these insects, data are presented as total counts from all sample dates. European red mite populations were assessed by counting the number of mites observed on 10 leaves per sample tree using a 12X visor lens. Season total cumulative mite days were calculated by multiplying the mean mite population of two successive sample dates by the sampling interval (days), and cumulating mite days for successive sample dates. On 10 September, 100 fruit per sample tree were harvested and evaluated for insect damage. All live worms infesting fruit were collected and identified to species. All data were analyzed using a two-way ANOVA, and means were separated by LSD ($P < 0.05$).

Results

Populations of all indirect arthropods were very low in this trial, probably due to abundant rainfall during the months of May (10.8 inches), June (7.1 inches) and July (11.1 inches). Although there were no significant differences among treatments, ERM populations were highest in the high rate of Assail and lowest in the treatment that relied primarily on Esteem and Danitol (trt. no. 8 in Table 1). No RAA were observed in any treatments, and potato leafhopper and STLM populations were extremely low (Table 2). Summer aphid populations (apple and spirea aphid) were also low, and the treatment that used Avaunt and Intrepid for post bloom insect control (trt. no. 6) had the highest densities. Because of low aphid numbers, populations of generalist predators were also very low.

Fruit damage by internal-feeding lepidopterans was high in this study, with 32.3% of fruit in the control having entries, and 18% containing live worms (Table 3). Averaged across all treatments, live worms were collected from 52% of fruit with entries, indicating that a majority of this lepidopteran damage occurred late in the season. This is further supported by the fact that <5% of fruit were damaged during a preliminary damage assessment in mid July. Of the 72 live worms collected from the control, 61% were oriental fruit moth and 39% codling moth. The most effective treatments in minimizing damage by internal leps were treatments 9, which received four applications of Diamond and two applications of Intrepid, and 8, which received Danitol for the last 3 applications in July and August. Other treatments with relatively low levels of internal lepidopteran damage included the standard treatment (no. 10) that was treated with Guthion, Imidan and Intrepid, and the high rate of Assail.

The number of fruit damaged by leafrollers (predominately tufted apple bud moth) was relatively low, but the only treatments that significantly reduced damage below that in the control (4%) were those that received Intrepid (trts. 6, 7, and 10) or Danitol (trt. 8) on the last application on 13 August. Damage by apple maggot and Comstock mealy bug was low, and there were no differences among treatments for these damage categories.

Damage caused by early season plum curculio was difficult to assess, because two hail storms in May caused extensive damage to fruit. Hence, it was very difficult to differentiate hail damage from early season plum curculio feeding/oviposition scars. However, there was a considerable amount of damage caused by feeding of late-season plum curculio adults. Although we cannot be certain that all of this damage was indeed caused by this insect, we observed adults feeding on fruit in early August, and damage that resembled this type of injury was late-season plum curculio. This damage was observed on 21.3% of fruit in the control, and was relatively high in all treatments except trts. 6 and 10, which received Avaunt and Guthion, respectively, in July. The high rate of Calypso (3.9 oz) also had a relatively low level of damage. However, there was high plot-plot variation in this damage, and consequently there were no differences among treatments.

Table 1. Mean European red mite populations on 'Golden Delicious' apples treated with different insecticide programs. Fletcher, NC. 2003.

				Mites per leaf					Cumulative mite days
No.	Insecticide	Rate/acre	Application date	26 Jun	14 Jul	23 Jul	4 Aug	15 Aug	
1	Assail 70WP	1.0 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	0.0a	0.6a	0.5a	1.4a	0.4a	31.4a
2	Assail 70WP	2.2 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	0.0a	0.3a	0.4a	1.7a	0.4a	31.2a
3	Assail 70WP	3.4 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	0.1a	1.1a	1.6a	8.0a	5.7a	155.9a
4	Calypso 4SC	1.9 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	0.0a	1.0a	1.6a	2.6a	1.0a	65.0a
5	Calypso 4SC	3.9 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	0.0a	0.1a	0.5a	0.5a	0.3a	14.1a
6	Calypso 4SC Avaunt 30WDG Intrepid 2F	1.9 oz 6.0 oz 12.0 oz	4/3, 4/28 5/20, 6/2, 6/25, 7/15 7/30, 8/13	0.1a	0.4a	1.1a	1.3a	0.7a	36.7a
7	Danitol 2.4EC Avaunt 30WDG Esteem 35WP Dipel 2X Intrepid 2F	16.0 oz 6.0 oz 5.0 oz 1.0 lb 12.0 oz	4/3 4/28 5/20, 6/2 6/2, 6/25, 7/15 7/30, 8/13	0.0a	0.1a	0.6a	0.9a	0.3a	18.7a
8	Danitol 2.4EC Avaunt 30WDG Esteem 35WP	16.0 oz 6.0 oz 5.0 oz	4/3, 6/25, 7/15, 7/30, 8/13 4/28 5/20, 6/2	0.0a	0.3a	0.3a	0.2a	0.0a	8.7a
9	Calypso 4SC Diamond 7WDG Intrepid 2F Provado 1.6F	1.9 oz 53.0 oz 12.0 oz 6.0 oz	4/3, 4/28 5/20, 6/2, 7/30, 8/13 6/25, 7/15 6/25, 7/15	0.0a	0.2a	0.2a	2.0a	3.9a	48.2a
10	Actara 25WDG Guthion 50WP Imidan 70WP Intrepid 2F Provado 1.6F	4.5 oz 1.5 lb 2.0 lb 12.0 oz 6.0 oz	4/3 4/28, 7/15, 7/30, 5/20, 6/2 6/25, 8/13 6/25	0.0a	0.3a	0.3a	0.8a	0.4a	18.6a
11	Control			0.1a	0.9a	0.7a	2.1a	1.0a	50.0a

Means in the same column followed by the same letter are not significantly different by LSD (*P* = .05)

Table 2. Mean indirect pest and beneficial arthropod populations on 'Golden Delicious' apples treated with different insecticide programs. Fletcher, NC. 2003.

				Season Total Numbers			
No.	Insecticide	Rate/acre	Application date	PLH/shoot	STLM/min.	Aphids/shoot	Predators/shoot
1	Assail 70WP	1.0 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	1.3a	0.0a	0.6a	0.0a
2	Assail 70WP	2.2 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	1.8a	0.0a	2.2a	0.0a
3	Assail 70WP	3.4 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	0.8a	0.0a	2.5a	0.0a
4	Calypso 4SC	1.9 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	1.0a	0.0a	2.2a	0.3a
5	Calypso 4SC	3.9 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	1.0a	0.0a	1.3a	0.5a
6	Calypso 4SC Avaunt 30WDG Intrepid 2F	1.9 oz 6.0 oz 12.0 oz	4/3, 4/28 5/20, 6/2, 6/25, 7/15 7/30, 8/13	1.5a	0.3a	19.1c	0.5a
7	Danitol 2.4EC Avaunt 30WDG Esteem 35WP Dipel 2X Intrepid 2F	16.0 oz 6.0 oz 5.0 oz 3.0 lb 12.0 oz	4/3 4/28 5/20, 6/2 6/2, 6/25, 7/15 7/30, 8/13	2.8a	1.0a	12.6bc	0.0a
8	Danitol 2.4EC Avaunt 30WDG Esteem 35WP	16.0 oz 6.0 oz 5.0 oz	4/3, 6/25, 7/15, 7/30, 8/13 4/28 5/20, 6/2	1.5a	0.0a	4.6ab	0.5a
9	Calypso 4SC Diamond 7WDG Intrepid 2F Provado 1.6F	1.9 oz 53.0 oz 12.0 oz 6.0 oz	4/3, 4/28 5/20, 6/2, 7/30, 8/13 6/25, 7/15 6/25, 7/15	2.5a	0.0a	4.7ab	0.0a
10	Actara 25WDG Guthion 50WP Imidan 70WP Intrepid 2F Provado 1.6F	4.5 oz 1.5 lb 4.0 lb 12.0 oz 6.0 oz	4/3 4/28, 7/15, 7/30, 5/20, 6/2 6/25, 8/13 6/25	0.5a	0.5a	9.7bc	0.5a
11	Control			2.5a	0.3a	5.7ab	0.5a

Means in the same column followed by the same letter are not significantly different by LSD (*P* = .05)

Table 3 Mean percentage damage to 'Golden Delicious' apples treated with different insecticide programs. Fletcher, NC. 2003.

				Internal Leps				Plum Curculio			
No.	Insecticide	Rate/acre	Application date	Stings	Entries	Live worm	Leaf-roller	Early	Late	Apple maggot	Comstock mealybug
1	Assail 70WP	1.0 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	1.0a	15.5d	7.0cd	3.5cd	0.0a	6.3a	0.0a	0.5a
2	Assail 70WP	2.2 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	1.8a	11.0cd	5.3bcd	2.5abcd	1.5a	11.0a	0.0a	0.0a
3	Assail 70WP	3.4 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	1.5a	4.8ab	2.3ab	2.3abcd	0.5a	7.3a	2.0a	0.0a
4	Calypso 4SC	1.9 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	1.3a	13.0cd	9.0d	1.5abcd	0.3a	7.0a	0.5a	0.0a
5	Calypso 4SC	3.9 oz	4/3, 4/28, 5/20, 6/2, 6/25, 7/15, 7/30, 8/13	1.0a	9.8bcd	5.3bcd	3.0bcd	0.3a	3.0a	0.5a	0.0a
6	Calypso 4SC Avaunt 30WDG Intrepid 2F	1.9 oz 6.0 oz 12.0 oz	4/3, 4/28 5/20, 6/2, 6/25, 7/15 7/30, 8/13	0.3a	14.5cd	6.3cd	0.8ab	1.0a	1.3a	0.5a	0.5a
7	Danitol 2.4EC Avaunt 30WDG Esteem 35WP Dipel 2X Intrepid 2F	16.0 oz 6.0 oz 5.0 oz 5.0 Lb 12.0 oz	4/3 4/28 5/20, 6/2 6/2, 6/25, 7/15 7/30, 8/13	1.5a	8.5bc	4.5bcd	0.3a	0.0a	9.3a	0.8a	2.0a
8	Danitol 2.4EC Avaunt 30WDG Esteem 35WP	16.0 oz 6.0 oz 5.0 oz	4/3, 6/25, 7/15, 7/30, 8/13 4/28 5/20, 6/2	1.3a	4.0a	1.5a	0.8ab	0.0a	19.0a	2.0a	1.0a
9	Calypso 4SC Diamond 7WDG Intrepid 2F Provado 1.6F	1.9 oz 53.0 oz 12.0 oz 6.0 oz	4/3, 4/28 5/20, 6/2, 7/30, 8/13 6/25, 7/15 6/25, 7/15	0.0a	2.3a	1.3a	1.5abcd	0.3a	28.8a	0.0a	0.0a
10	Actara 25WDG Guthion 50WP Imidan 70WP Intrepid 2F Provado 1.6F	4.5 oz 1.5 lb 6.0 lb 12.0 oz 6.0 oz	4/3 4/28, 7/15, 7/30, 5/20, 6/2 6/25, 8/13 6/25	0.5a	5.3ab	3.3abc	0.5ab	0.0a	1.8a	0.3a	0.0a
11	Control			0.5a	32.3e	18.0e	4.0d	0.3a	21.3a	2.3a	2.8a

Means in the same column followed by the same letter are not significantly different by LSD (*P* = .05)

Full Season Evaluation of Inseciticides on Apples - Fruitland

This was a small trial conducted in an abandoned orchard to evaluate a reduced-risk insecticide program compared to a conventional organophosphate-based program. This reduced-risk program included Actara for early season control of aphids, scales, plant bugs, and plum curculio; Diamond applied post-bloom for codling moth and oriental fruit moth; Intrepid for leafrollers; and Provado for apple maggot.

Materials and Methods

The trial was conducted in a recently abandoned orchard using 'Delicious' trees that had a tree-row-volume of approximately 250 gpa. Treatments were applied to two blocks of 8 trees each, with two samples collected from each block for a total of 4 samples per treatment. The first sample in each block was collected from the second and third trees, and the second sample from the sixth and seventh trees. Applications were made with an airblast sprayer delivering 161 gpa, and the spray adjuvant Latron B-1956 was added to all solutions at the rate of 2 oz/100 gal water. All trees received the same season-long fungicide program, which consisted of 2- to 3-wk interval applications of trifloxystrobin (Flint 50WP @ 6.0 oz/acre) from petal fall through early August. European red mite (ERM) populations were assessed on 6 and 20 June by recording the number of ERM per 10 leaves per 2-tree sample. Green apple aphid (GAA) populations also were assessed on 6 and 20 June by recording the number of GAA-infested leaves on each of 10 shoots per 2-tree sample. Spotted tentiform leafminer (STLM) populations were assessed on 6 and 23 June by recording the number of mines observed during a 1-minute search of each tree. On 12 September, 100 fruit per sample tree were harvested and assessed for damage by direct insect pests. All live worms infesting fruit were collected and identified to species. All data were analyzed using a two-way ANOVA, and means were separated by LSD ($P < 0.05$).

Results

ERM, GAA, and STLM populations were extremely low in this trial, due in part to abundant rainfall from May through July, and the fact that this orchard had not been managed for the previous two growing seasons. On 6 and 23 June, a total of only 1 (in rep I of control) and 3 (2 in rep I and 1 in rep II) STLM mines, respectively, were observed in the 36 samples. No aphids were observed on 6 June, and across all treatments GAA averaged only 2 infested leaves per 10 shoots. Finally, from the 36, 10-leaf samples on 6 and 23 June, a total of only 1 and 4 ERM, respectively, were observed.

In contrast to low indirect populations, populations of codling moth, oriental fruit moth, plum curculio, and apple maggot were very high. Unfortunately, two hail storms in May resulted in extensive damage to fruit, and it was not possible to differentiate hail damage from cosmetic damage caused by plum curculio or plant bug, or stings by lepidopteran larvae. Nevertheless, 25% of fruit in the control exhibited evidence of entries by codling moth or oriental fruit moth, and 10.5% of control fruit were infested with a live worm (Table 1). The standard treatment that included Guthion reduced larval entries below 1%, while the reduced-risk treatment that included two applications of Diamond had larval entries in 3.8% of fruit. Both of these treatments were significantly lower than the control. Based on live worms collected from fruit, the majority of internal-lepidopteran damage was caused by oriental fruit moth, with 70% of worms identified as OFM and 30% as CM (Table 2).

Damage by tufted apple bud moth was low, with only 1.0% of fruit in the control damaged by this insect. Although it was not possible to obtain data on early season plum curculio damage due to hail damage, there was a considerable amount of damage caused by second generation plum curculio (this damage consisted of larval tunnels in fruit). Second-generation plum curculio damage was highly aggregated, and there was no significant difference among treatments. Apple maggot damage was also very high, with 58% of fruit in the control infested with larvae. The standard treatment that incorporated Guthion reduced damage to 1.5%, while the reduced risk treatment that incorporated 3 applications of Provado had 19.5% damage. It is probable that damage in the Provado treatment would have been lower had additional applications been made, because apple maggot flies were active throughout August and September.

Table 1. Percentage of fruit (harvested 12 Sept) damaged by various insects on 'Delicious' apples treated with various insecticides. Fruitland, NC. 2003.

Insecticide	Lb(AI)/A	Application date	Internal Lepidopterans: Entries[a]	Internal Lepidopterans: Live worms[a]	Leafroller	Plum curculio entries	Apple maggot
Actara 25WP Guthion 2 lb Intrepid 10 oz	0.07 1.0 0.188	5/2 5/16, 5/30, 6/27, 7/11, 7/25, 8/8, 8/22 6/13	0.5a	0.0a	0.5a	1.8a	1.5a
Actara 2.5 oz Diamond 53 oz Intrepid 12 oz Provado 6 oz	0.07 3.3 0.188 0.05	5/2 5/16, 5/30, 8/8, 8/22 6/13, 7/11 6/27, 7/11, 7/25	3.8b	0.8a	1.3a	4.8a	19.5b
Control	—	—	25.0e	10.5b	1.0a	11.0a	58.0c

Means in the same column followed by the same letter are not significantly different by LSD ($P < 0.05$).
[a]Data were transformed using sqrt(x) before ANOVA, but means presented are back transformations.

Table 2. Species of live worms collected from 'Delicious' apples treated with various insecticides. Fruitland, NC. 2003.

Insecticide	Lb(AI)/A	Application date	*n*	Codling moth	Oriental fruit moth	Leafrollers	Plum curculio
Actara 25WP Guthion 2 lb Intrepid 10 oz	0.07 1.0 0.188	5/2 5/16, 5/30, 6/27, 7/11, 7/25, 8/8, 8/22 6/13	0	0	0	0	0
Actara 2.5 oz Diamond 53 oz Intrepid 12 oz Provado 6 oz	0.07 3.3 0.188 0.05	5/2 5/16, 5/30, 8/8, 8/22 6/13, 7/11 6/27, 7/11, 7/25	3	1	2	0	0
Control	—	—	33	9	21	2	1

Ovicidal and Larvacidal Effects of Reduced-Risk Insecticides to Codling Moth and Oriental Fruit Moth

The codling moth and oriental fruit moth (OFM) are two of the most important direct pests of apples in the eastern US. This complex of internal-feeding lepidopteran larvae has traditionally been managed with organophosphorus (OP) insecticides, such as azinphosmethyl and phosmet. Due to increasing instances of codling moth and OFM resistance to OPs, and concerns about the future availability of many OPs due to regulatory issues, there is a need for alternative methods of managing these insects. There are number of reduced-risk insecticides that have shown promise for managing this lepidopteran complex. However, the toxicity of these products to different life stages of these insects is now well understood. Reported here are studies designed to compare the relative toxicity of five reduced-risk insecticides to eggs and larvae of codling moth and OFM.

Materials and Methods

Toxicity Bioassay. To compare the relative toxicity of various insecticides against codling moth and OFM eggs and larvae, bioassays were conducted by allowing gravid females to oviposit onto fruit dipped into insecticide solutions. Insecticides tested included the insect growth regulators methoxyfenozide (Intrepid 2F) and novaluron (Diamond 7.5WG), the neonicotinoids acetamiprid (Assail 70WP) and thiacloprid (Calypso 4SC), and the oxadiazine indoxacarb (Avaunt 30WDG). Rates of insecticides were based on one-half the recommended field rates. One liter of each solution was prepared with 0.05% Trition X-100 added, while the control consisted only of water plus Trition X-100. For each insecticide treatment, three 'Golden Delicious' fruit, harvested from the control plots of an insecticide trial at the MHCRS in early July, were dipped into the test solutions, allowed to air dry for 2 hr, and placed in a 1 liter bucket containing 5-day-old codling moth or 2-day-old OFM adults for a 16-hr (overnight) oviposition period. After removing fruit from oviposition buckets, the number of eggs on each fruit were counted, placed in a 1 liter plastic container and stored for 8 days at 26°C (16:8 L:D). After 8 days, the number of hatched eggs, unhatched eggs, and larval entries into fruit were counted. Each insecticide treatment and insect species was replicated four times. Data (percentage egg hatch and larval entries per egg laid) were subjected to ANOVA and means were separated by LSD ($P = 0.05$).

Field Residual Bioassay. To estimate the residual activity of insecticides in the field against eggs and larvae of codling moth and OFM, apples on non-insecticide-treated trees were dipped into insecticide solutions while hanging on trees and allowed to age in the field for various time intervals before use in bioassays. On 10 September, a minimum of 50 fruit per insecticide treatment were dipped into insecticide solutions. This was accomplished by preparing 7 liters of test solution (plus 0.05% Triton X-100) in a 10 liter bucket and dipping fruit into solutions. Control fruit were dipped into buckets containing only water plus 0.05% Triton X-100. Fruit were dipped rather than sprayed to ensure uniform of coverage of insecticides on all fruit. Also, by delaying this test until 10 September when fruit were mature, fruit-growth effects on pesticide dilution were minimal. In addition to the above-mentioned insecticides, the organophosphate azinphosmethyl (Guthion 50WP) was also included. Rates of insecticides were based on the recommended field rate for each product. On 0 (2 hr after treatment), 7, 10, and 14 days after treatment, 8 fruit per treatment per insect were harvested from trees, and four each were exposed to codling moth and OFM adults in oviposition buckets as described above. Individual fruit were considered a replicate. After a 16-hr oviposition period, fruit were incubated and evaluated as described above. Data are presented as mean (± SEM) percentage egg hatch and larval entries per egg laid.

Results

Toxicity Bioassay. All insecticides exhibited toxicity to codling moth eggs, with <2% of eggs hatching in all treatments except Avaunt, which was less toxic than the other insecticides (Table 1). However, the toxicity of Avaunt to codling moth larvae was evident in that none of larvae hatching from eggs tunneled into fruit. In contrast to results with codling moth, the only insecticides that were highly toxic to OFM eggs were the neonicotinoids Assail and Calypso and the IGR Diamond, in which 7.4, 3.4 and 0% of eggs hatched, respectively. Intrepid was moderately toxic to OFM eggs with 34.9% of eggs hatching, and Avaunt did not differ significantly from the control. Although there were a few larval entries into apples treated with Intrepid and Avaunt, these values were significantly lower than the control.

Residual Activity Bioassay. Based on percentage egg hatch, all insecticides exhibited good ovicidal activity against codling moth eggs for a minimum of 10 days (Fig. 1). The residual activity of Avaunt, Assail and Calypso declined dramatically by day 14, but all materials remained effective in preventing larvae from entering fruit. Intrepid, Diamond and Guthion were all extremely toxic to eggs for at least 14 days after treatment, with no eggs hatching on Intrepid- and Diamond-treated fruit at 14 days after treatment.

Consistent with laboratory toxicity studies, OFM eggs were generally more tolerant to insecticides compared with codling moth eggs. Based on percentage egg hatch, residual activity of Intrepid, Avaunt and Calypso declined dramatically between 7 and 10 days, while that of Assail declined between 10 and 14 days (Fig. 2). Diamond was particularly effective against OFM eggs, more so than even Guthion, with no eggs hatching at 21 days after treatment. Although Assail and Calypso exhibited only 7- to 10-day residual activity against OFM eggs, these insecticides appeared to exhibit longer residual activity against neonate larvae, with no larval entries in fruit up to 21 days after treatment. Although larval entries into Intrepid- and Avaunt-treated fruit remained lower than the control, the residual activity of these materials against larvae was clearly declining by 10 to 14 days after treatment.

It should be noted that results from the residual bioassay represent a “best-case scenario” in that dipping fruit into insecticide solutions provided optimum coverage. These results should not be considered equivalent to those obtained by applying materials with an airblast sprayer, but they do provide relative toxicities and residual activity among the materials. During the course of the residual activity studies, there was only one significant rainfall event, which occurred on 22 September, or 12 days after treatment (Fig. 3). This may have contributed to the declined codling moth ovicidal activity of Avaunt, Calypso and Assail that occurred between 10 and 14 days after treatment, but it did not appear to affect results with OFM.

Table 1. Percentage egg hatch and larval entries into apples dipped into different insecticides 2 hr before exposure to ovipositing codling moth and oriental fruit moth adults, and incubated at 27°C, 16:8 (L:D) for 7 days.

			Codling moth			Oriental fruit moth		
Insecticide	g(AI)/liter	Equivalent rate (form.) per 100 gal	*n*	% egg hatch	Larval entries/egg	*n*	% egg hatch	Larval entries/egg
Intrepid 2F	0.112	6 oz.	382	0.0a	0.0a	623	34.9b	0.03b
Avaunt 30WDG	0.066	3.0 oz	276	32.4b	0.0a	666	73.9c	0.02ab
Calypso 4SC	0.075	2.0 oz	387	1.3a	0.0a	566	7.3a	0.0a
Assail 70WP	0.075	1.4 oz	396	1.5a	0.0a	648	3.4a	0.0a
Diamond 7.5WDG	0.149	26.5 oz	249	0.5a	0.0a	413	0.0a	0.0a
Control	-	-	371	69.0c	0.18b	328	83.6c	0.13c

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

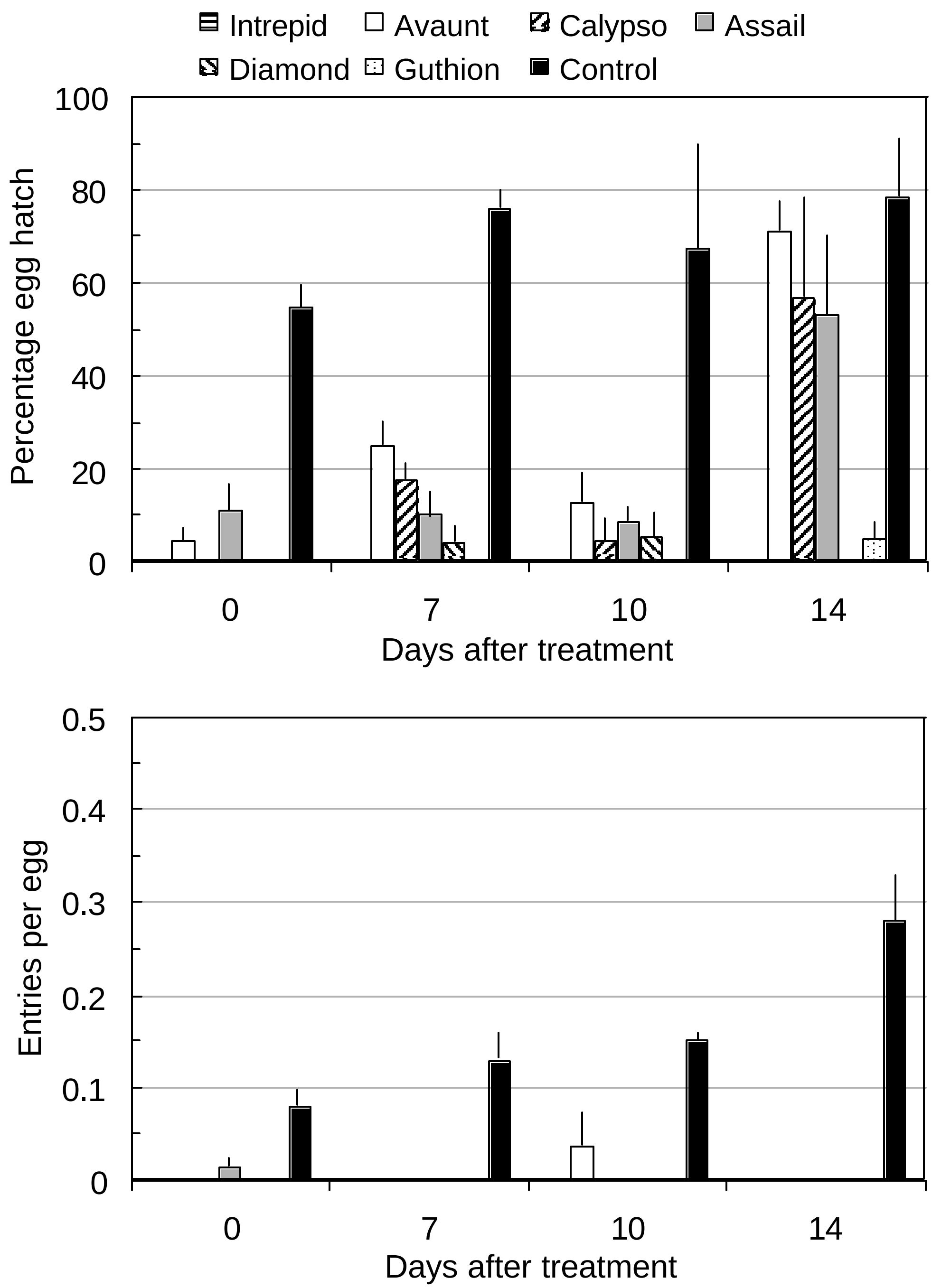

Fig. 1. Mean (±SEM) percentage of codling moth egg hatch (top) and number of larval entries into fruit (bottom) treated with various insecticides.

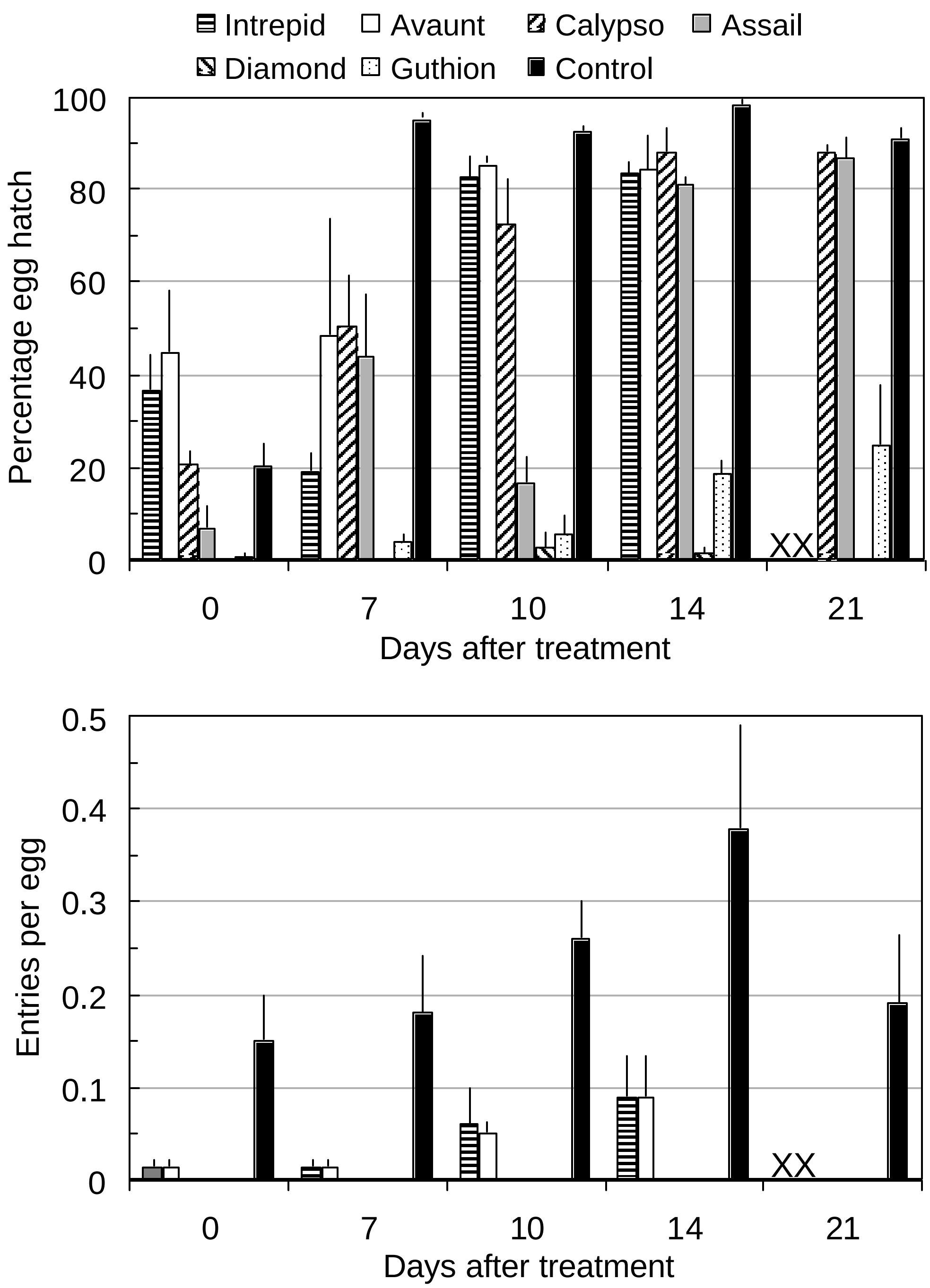

Fig. 2. Mean (±SEM) percentage of oriental fruit moth egg hatch (top) and number of larval entries into fruit (bottom) treated with various insecticides. XX indicates that Intrepid and Avaunt were not included in 21-day bioassays.

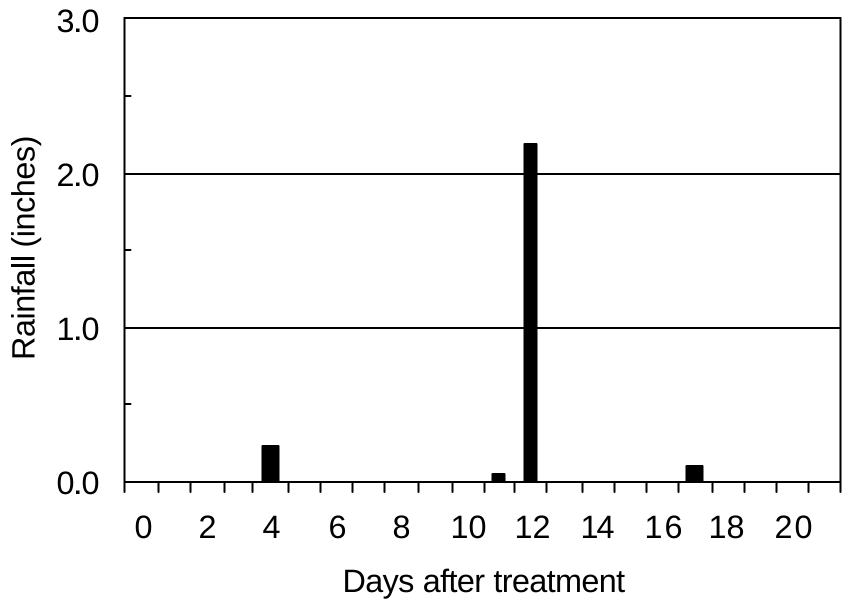

Fig. 3. Rainfall at the Mountain Horticultural Crops Research Station (Fletcher, NC) during the residual activity bioassay. Day 0 corresponds to September 10.

Apple Maggot Trial

The apple maggot has been a primary concern to apple growers in North Carolina since 2001, when widespread severe infestations occurred for the first time. The organophosphate insecticides Guthion and Imidan have been the standard materials used to control apple maggot, and regulatory actions that have reduced the availability OPs have created a need for additional options for managing this insect. Studies in 2002 in an abandoned orchard in Henderson County, NC, suggested that the neonicotinoid insecticides Provado and Calypso were viable alternatives to OPs for apple maggot control. The purpose of this trial was to evaluate different rates of Assail, a neonicotinoid that was registered on apple in 2003. Avaunt, an insecticide which has shown inconsistent results against apple maggot, was also included in the trial.

Materials and Methods

The trial was conducted on 'Golden Delicious' apples in a recently abandoned orchard in Fruitland, NC, that has a history of high apple maggot populations. Based on fly capture on baited red spheres, apple maggot fly emergence was first detected in mid July, reached high densities the first week of August, and remained high through mid September. Single-tree plots were separated by 1 to 5 non-treated trees, and each treatment was replicated 3 times and arranged in a randomized complete block design. Insecticide applications were applied on 7 and 21 July and 18 August, using an airblast sprayer applying materials at 126 gal/acre. Latron B-1956 was added at 4 oz/100 gal to all treatments. Assail was evaluated at 1.0, 2.2 and 3.4 oz/acre, and Avaunt was evaluated at 6.0 oz/acre. A preliminary assessment of damage was conducted on 30 July by examining 20 fruit per plot. On 5 September, 100 fruit per plot were examined for infestation by apple maggot and internal-feeding lepidopterans. All data were subjected to a two-way ANOVA, and means were separated by LSD (P =0.05).

Results

Apple maggot damage was high in this study, with 65.3% damage in the control on the 5 September evaluation date. Based on the absence of damage in the control on 30 July, it was apparent that the majority of damage was inflicted during August, although it is likely that tunneling by early instar larvae was not detected during the July assessment. There was a clear rate response with Assail, with damage ranging from 48% in the 1.0 oz/acre rate to 13.7% in the 3.4 oz/acre rate. Damage in the Avaunt treatment did not differ significantly from the control, with 70% of fruit infested. It should be noted that under the conditions of this trial, treatments were subjected to continuous infestation by gravid females, because plots were surrounded by a large number of non-sprayed trees.

Based on identification of larvae collected from infested fruit, 79.9% of internal-feeding lepidopterans were oriental fruit moth, and 20.1% were codling moth. It should be noted that the majority of infestations by oriental fruit moth occurred in mid to late August, and insecticide applications were not timed for internal lepidopteran control. Consequently, there was no difference among treatments in the level of damage in these treatments.

Table 1. Mean percentage of fruit infested by apple maggot larvae and internal feeding lepidopteran larvae. Fruitland, NC. 2003.

		Percentage of fruit infested		
		Apple Maggot		Internal Lep. Entries – 9/5
Insecticide	Rate/acre	7/30	9/5	
Assail 70WP	1.0 oz	0.0a	48.0c	28.0a
Assail 70WP	2.2 oz	0.0a	19.3b	21.3a
Assail 70WP	3.4 oz	0.0a	13.7a	23.7a
Avaunt 30WP	6.0 oz	0.0a	70.3d	19.3a
Control	-	0.0a	65.3d	23.0a

Means within the same column followed by the same letter are not significantly different by LSD ($p<0.05$).

Evaluation of Insecticides for Control of Comstock Mealybug and European Red Mite on Apples

The Comstock mealybug (CMB) is an insect of relatively recent concern to the North Carolina apple industry. Adult mealybugs infest, feed, and reproduce within the calyx end of apples. Honeydew exuded by mealybugs accumulates on the calyx end of apples and serves as a substrate for the growth of sooty mold. The presence of sooty mold and/or mealybugs usually renders fruit unmarketable for the fresh market. Adult CMB are first detected on fruit in June, but populations do not increase to levels where infestations are readily evident until late July or August. Infestations are sporadic in NC orchards, but infestations have been most common in orchards where organophosphate insecticide use is minimal and/or where pyrethroid use is high. Previous studies have identified dimethoate and diazinon as the most effective insecticides for mealybug control. This study was undertaken to determine the efficacy of a diversity of new insecticides against CMB.

Materials and Methods

Field Studies. A study was conducted in a mature block of 'Golden Delicious' apples in Polk County, NC, with a history of CMB infestations. Trees were approximately 20 years old with a tree-row-volume of 275 gpa. Plots consisted of 4 consecutive trees within a row, and samples were collected from the middle two trees. Each treatment was replicated four times and arranged in a randomized complete block design. Treatments consisted of buprofezin (Applaud 70DF), fenpyroximate (FujiMite 0.417EC), a mixture of fenpyroximate (4%AI) plus buprofezin (20%AI) denoted NNI-750D 2.23EC, an experimental compound denoted Labs 140-F01 1.8EC, a standard consisting of clofentezine (Apollo 4SC) + dimethoate (Dimethoate 4EC), and a non-treated control. A single application of all materials was made on 11 June, which coincided with the third cover spray. Applications were made with an airblast sprayer that delivered 125 gal/acre. All plots were sprayed with the same season-long insecticide and fungicide program. Insecticides applied to all treatments included four applications each of Asana XL (6 oz/acre) and Avaunt 30WDG (6 oz/acre).

Populations of European red mite, apple rust mite and the phytoseiid mites (*Amblyseius fallacis*) were counted on all treatments except Applaud by collecting 10 leaves per treatment, placing them through a mite brushing machine, and observing mites under a stereomicroscope. Season total mite days were calculated by multiplying the mean mite population of two successive sample dates by the sampling interval (days), and cumulating mite days for successive sample dates. Mealybug populations were monitored on 30 June, 16 July, and 16 August by collecting 50 fruit per treatment, cutting the fruit in half, observing the calyx end under a stereomicroscope, and recording the number of adults and nymphs in each apple. Data were subjected to two-way ANOVA and means were separated by LSD ($P = 0.05$).

Laboratory Bioassays: To gain additional information on the toxicity of various insecticides to CMB, laboratory bioassays were conducted on mealybugs collected from a heavily infested orchard in Polk County, NC (different from that used for the above field studies). Mealybugs were exposed to pesticides by first dipping non-treated 'Golden Delicious' apples into pesticide solutions so that the lower half of apples (calyx end included) were treated. (Apples were obtained from the control plots of insecticide trials at the Mountain Horticultural Crops Research Station, where CMB occurs at very low levels.) To ensure that the inner calyx end was treated, a 250 *u*l aliquot of test solution was also squirted into the calyx of each apple. Apples were allowed to dry for a minimum of 2 hr. Insecticide solutions were prepared with commercially formulated product, and Triton X-100 (0.05% v/v) was added to all solutions, including the water control. After drying, a ring of Tanglefoot® insect trap coating was placed around the calyx end of fruit to confine mealybugs to that area of the apple. Young nymphs (first and second instars) were then removed from the calyx of infested fruit with a camel hair brush and placed on the calyx end of treated fruit. For each study, 10 to 20 nymphs were placed on each of four apples, and depending on the availability of mealybugs, experiments were repeated one to three times. Fruit were placed at 25°C (16:8 L:D) for 3 days, after which fruit were cut in half and examined under a stereomicroscope to record the number of live and dead individuals, as well as the number trapped in the ring of Tanglefoot. Percentage mortality was based on the number of live and dead mealybugs; i.e., numbers trapped in Tanglefoot were excluded. Data were analyzed as a one-way ANOVA, and means were separated by LSD (P = 0.05).

Results

Field Studies. On the first two sample dates of 30 June and 16 July, CMB populations were low, with an average of only 5.0 and 5.9% of fruit infested (Table 1). Only nymphs were present on both sample dates, and averaged about 6 nymphs per 50 apples present. Due to the low populations and high degree of variation, there were no differences among treatments. Populations increased by the 16 August assessment, when there was an average of 11.8% infested fruit, consisting of approximately 4 adults and 6 nymphs per 50 apples, across all treatments. Although there were no differences among treatments, the percentage of infested fruit and number of motiles were lowest in the Dimethoate and Applaud treatments.

Despite the four applications of esfenvalerate, European red mite populations were relatively low in this trial, peaking at only 4.3 mites/leaf on 30 June (Table 2). Nevertheless, FujiMite, NNI-750, and Apollo treatments all significantly reduced mite populations below the control, while populations in Labs 140-F01 were numerically but not significantly lower than the control. Apple rust mites were of moderate intensity, peaking in the control at about 80 mites on 30 June. With the exception of Labs 140-F01, all treatments significantly reduced seasonal apple rust mite populations below the control, and there were no differences among FujiMite, NNI-750 or Apollo. Phytoseiid mite densities (primarily *Amblyseius fallacis*) reached high densities by July, averaging 2.5 mites per leaf. Although populations of this predatory mite in all chemical treatments were significantly reduced below the control, it is difficult to differentiate whether this reduction was due to the toxicity of pesticides or a numerical response to low prey densities.

Laboratory Bioassays. Mealybug mortality in all treatments was significantly higher than that in the control, but Dimethoate (91.4%) and Assail (89.0%) were clearly the most toxic insecticides. Mortality in the Calypso treatment (69.7%) did not significantly differ from Assail, and was also significantly higher than Applaud, FujiMite, NNI-750 and Labs 140-F01. Mortality in these latter treatments ranged from 18.1 to 32.1%. The number of mealybugs trapped in the ring of Tanglefoot ranged from 4.4 (Assail) to 36.4% (Labs 140-F01), with 13.2% in the control. Labs 140 F01 was the only insecticide treatment to differ significantly from the control.

A second experiment was conducted with two insect growth regulators, Applaud (buprofezin) and Esteem (pyrproxifen), to determine mealybug mortality after 7-d exposure, rather than 3 days as in the above experiment. In this experiment, Applaud resulted in 66.7% mortality of nymphs after 7 days (Table 4), which was considerably higher than the 19.8% after 3 days in the previous experiment. Mortality on Esteem-treated apples was only 31% after 7 days.

Table 1. Mean percentage of apples infested with Comstock mealybug, and number of adults and immatures in 'Golden Delicious' apples treated with various insecticides on 11 June (3^{rd} Cover). Mill Spring, NC. 2003.

Material	Lb[AI]/acre	Percent infested fruit	No. per 50 fruit		
			Adults	Nymphs	Total motiles
		30 June			
Applaud 70DF	0.5	5.0a	0.0a	1.5a	1.5a
FujiMite 0.417EC	0.1	9.0a	0.0a	12.5a	12.5a
NNI-750 2.23EC	0.36	1.0a	0.0a	0.3a	0.3a
Labs 140-F01 1.8SC	0.714	7.0a	0.0a	3.0a	3.0a
Apollo SC + Dimethoate 4EC	0.125 1.0	5.0a	0.0a	14.8a	14.8a
Control	—	3.0a	0.0a	4.3a	4.3a
		16 July			
Applaud 70DF	0.5	4.5a	0.0a	2.8a	2.8a
FujiMite 0.417EC	0.1	13.5a	0.0a	14.0a	14.0a
NNI-750 2.23EC	0.36	4.5a	0.0a	2.8a	2.8a
Labs 140-F01 1.8SC	0.714	4.5a	0.0a	6.5a	6.5a
Apollo SC + Dimethoate 4EC	0.125 1.0	5.0a	0.0a	4.5a	4.5a
Control	—	3.5a	0.0a	3.8a	3.8a
		16 August			
Applaud 70DF	0.5	6.0a	3.5a	1.5a	5.0a
FujiMite 0.417EC	0.1	19.5a	6.5a	12.8a	19.3a
NNI-750 2.23EC	0.36	15.5a	5.5a	10.5a	16.0a
Labs 140-F01 1.8SC	0.714	15.5a	3.8a	6.3a	10.0a
Apollo SC + Dimethoate 4EC	0.125 1.0	3.5a	1.8a	0.5a	2.3a
Control	—	10.5a	2.3a	5.0a	7.3a

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

Table 2. Mean European red mite, apple rust mite, and phytoseiids on ‘Golden Delicious’ apples treated with insecticides on 11 June (3rd Cover). Mill Spring, NC. 2003.

Material	Lb[AI]/acre	Mites per leaf 6/5	6/13	6/23	6/30	7/9	7/14	Cumulative mite days
		European red mite motiles (adults + immatures) per leaf						
FujiMite 0.417EC	0.1	0.1a	0.1a	0.2a	0.1a	0.2a	0.3a	4.6a
NNI-750 2.23EC	0.36	0.1a	0.1a	0.3a	0.2a	0.2a	0.5a	8.0a
Labs 140-F01 1.8SC	0.714	0.1a	0.4a	1.9b	1.2a	0.5a	1.0a	35.0ab
Apollo SC + Dimethoate 4EC	0.125 1.0	0.3a	0.3a	0.0a	0.2a	0.3a	0.0a	7.3a
Control	—	0.0a	0.5a	1.4b	4.3b	3.3a	0.4a	74.3b
		Apple rust mites per leaf						
FujiMite 0.417EC	0.1	3.3a	1.8a	0.5a	4.7a	10.0a	17.6a	184.6a
NNI-750 2.23EC	0.36	1.5a	0.9a	0.6a	4.6a	15.9ab	18.6a	214.0a
Labs 140-F01 1.8SC	0.714	0.7a	8.5a	27.3b	40.8ab	35.4bc	49.9a	1009.6b
Apollo SC + Dimethoate 4EC	0.125 1.0	1.5a	2.9a	4.2a	7.6a	14.3ab	17.7a	272.0a
Control	—	2.2a	17.3a	31.7b	79.7b	47.8c	49.6a	1529.4b
		Phytoseiid mites per leaf						
FujiMite 0.417EC	0.1	0.0a	0.0a	0.0a	0.1a	0.3ab	0.3a	3.3a
NNI-750 2.23EC	0.36	0.0a	0.0a	0.1a	0.0a	0.2ab	0.5a	3.7a
Labs 140-F01 1.8SC	0.714	0.0a	0.0a	0.1a	0.2a	1.6bc	1.9b	18.0b
Apollo SC + Dimethoate 4EC	0.125 1.0	0.1a	0.0a	0.1a	0.2a	0.9ab	1.1ab	11.9ab
Control	—	0.0a	0.0a	0.3a	1.3b	2.5c	1.9b	35.0c

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

Table 3. Comstock mealybug nymphal mortality 3 days after being placed on apples treated with various insecticides.

Insecticide	gm(AI)/liter	Equivalent rate (form.)/100 gal	*n*	Percentage mortality	Percentage in Tanglefoot®
Applaud 70DF	0.595	11.4 oz	178	19.8b	9.7ab
FujiMite 0.417EC	0.120	30.7 oz	183	31.6b	26.8bc
NNI-750 D 2.23EC	0.435	20.7 oz	159	32.1b	12.5ab
Labs 140-F01 1.8SC	0.855	50.8 oz	191	18.1b	36.4c
Dimethoate 4EC	1.200	1.0 qt	165	91.4d	19.0bc
Assail 70WP	0.105	2.0 oz	200	89.0cd	4.4a
Calypso 4SC	0.105	2.8 oz	162	69.7c	14.2ab
Control	–	–	213	2.0a	13.2ab

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

Table 4. Comstock mealybug nymphal mortality 3 days after being placed on apples treated with various insecticides.

Insecticide	gm(AI)/liter	Equivalent rate (form.)/100 gal	*n*	Percentage mortality	Percentage in tanglefoot
Applaud 70DF	0.595	11.4 oz	43	66.7c	15.5a
Esteem 35WP	0.105	4.0 oz	52	30.7b	18.5a
Control	–	–	62	4.0a	12.7a

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

Evaluation of Miticides on Apples

The purpose of this study was to compare the efficacy of various miticides applied preventively (at petal fall) or on a threshold basis for control of the European red mite (ERM), *Panonychus ulmi*, and apple rust mite (ARM), *Aculus schlechtendali*.

Materials & Methods

The trial was conducted at the Mountain Horticultural Crops Research Station (Fletcher, NC) in a 25-year-old block of 'Delicious' apples with a tree-row-volume of approx. 225 gpa. Plots consisted of two trees separated by at least one non-treated tree between plots. Treatments were arranged in a randomized complete block design with four replications. Applications were made with an airblast sprayer delivering 112 gallons per acre. Treatments for preventive control of ERM were applied at petal fall (1 May) and included Envidor 2SC at 14.0 and 18.0 oz per acre, and Agri-mek at 10.0 oz per acre plus Summer Oil at 1 gallon per acre. Treatments applied on a threshold basis for curative control of ERM were applied on 20 June when mite populations averaged about 4 adults per leaf on non-treated plots. Threshold treatments included Pyramite at 4.4 oz per acre, Acramite 50WS at 12 oz per acre, and Biomite at 1.5, 2.0 and 3.0 pt per acre. A second application of all Biomite treatments was made on 2 July. All treatments also received a standard fungicide program.

Mite populations were monitored by removing 10 leaves per plot at approximately 7-d intervals beginning in early June (4, 13, 19 and 27 June; 3, 11, 18, and 25 July; and 1 August). Leaves were placed through a mite brushing machine, and the number of ERM eggs, immatures and adults; ARM; and predator mites (*Amblyseius fallacis* AF) were counted under a stereomicroscope. Cumulative mite days were calculated for ERM and ARM by multiplying the mean mite population of two successive sample dates by the sampling interval (days), and cumulating mite days for successive sample dates. All data were analyzed using a two-way ANOVA, and means were separated by LSD ($P < 0.05$).

Results

ERM populations were high in this trial, with populations increasing from less than 1 motile (adults + immatures) per leaf to about 7 per leaf between 4 June and 13 June (Table 1). In the non-treated control, adult populations peaked at about 20 per leaf on 18 July (Table 2), and immatures were at their highest on 1 August (the last sample date) at 61 per leaf (Table 3). Envidor and Agri-Mek both provided excellent season-long control of ERM. Although the total cumulative mite days were slightly higher in the 14 oz rate of Envidor compared with 18 oz rate, these differences were not significant. In addition, Pyramite and Acramite both provided excellent initial knockdown of ERM when applied on 20 June, and maintained populations at relatively low levels the remainder of the season. There was no difference in cumulative mite days between the Pyramite and Acramite treatments.

The efficacy of the Biomite treatments against ERM appeared to relate more to the density of mites present at the time of application rather than to the rate of material applied.

Based on season total cumulative mite days, there was no difference between the 1.5 and 3.0 pt rate treatments, but the 2.0 pt rate had significantly higher mite populations than the other rates. Motile populations one day before the 20 June application averaged about 3, 18 and 7 in the 1.5, 2.0 and 3.0 pt rates, respectively.

The efficacy of materials against ARM paralleled that of ERM. Envidor and Agri-Mek were most effective, followed by Pyramite and Acramite, while Biomite exhibited little activity against ARM (Table 4). Predatory mite populations were low in all treatments, with season total numbers of mites not exceeding 2 mites/leaf in any treatment (Table 5).

Table 1. Motile European red mite populations on 'Delicious' apples treated with various miticides. Fletcher, NC. 2003.

Material	Rate (form.) per acre	Application date	Mean motiles (adults + immatures) per leaf									Cumulative mite days
			4 Jun	13 Jun	19 Jun	27 Jun	3 Jul	11 Jul	18 Jul	25 Jul	1 Aug	
Envidor 2SC	14 oz	5/1 (PF)	0.0a	0.4a	0.1a	0.8a	0.9a	2.2ab	7.2a	2.5a	6.6a	121.7a
Envidor 2SC	18 oz	5/1 (PF)	0.0a	0.1a	0.1a	0.6a	1.1a	3.1ab	2.2a	4.6ab	4.8a	100.5a
Agri-Mek + Oil	10 oz 0.25%	5/1 (PF)	0.0a	0.2a	0.2ab	1.3ab	1.6a	0.4a	2.6a	7.6abc	2.6a	106.1a
Pyramite 60WP	4.4 oz	6/20	0.6a	1.6ab	7.4abc	2.8ab	3.5a	2.4ab	4.7a	4.5ab	6.4a	215.7a
Acramite 50WP	12.0 oz	6/20	0.4a	5.0abc	3.4abc	0.9ab	2.5a	2.1ab	2.0a	6.7ab	3.5a	174.8a
Biomite	1.5 pt	6/20, 7/2	0.3a	6.2bcd	3.1abc	2.1ab	10.0ab	13.6cd	10.5ab	22.8cd	30.6b	597.2b
Biomite	2.0 pt	6/20, 7/2	1.2a	10.7d	17.5c	8.5b	29.2bc	21.4d	51.0d	34.1de	73.3c	1484.8c
Biomite	3.0 pt	6/20, 7/2	0.7a	7.2cd	6.9abc	7.0ab	10.2ab	10.4bc	31.7bc	12.3bc	10.0ab	645.6b
Control	—	—	0.3a	7.0bcd	9.2abc	17.3c	42.8c	39.1e	62.2d	59.4e	97.3c	1935.0c

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

Table 2. Mean European red mite adults on 'Delicious' apples treated with various miticides. Fletcher, NC. 2003.

Material	Rate (form.) per acre	Application date	Mean adults per leaf									Cumulative mite days
			4 Jun	13 Jun	19 Jun	27 Jun	3 Jul	11 Jul	18 Jul	25 Jul	1 Aug	
Envidor 2SC	14 oz	5/1 (PF)	0.0a	0.0a	0.0a	0.4a	0.1a	0.8a	2.5ab	0.5a	1.6a	35.3a
Envidor 2SC	18 oz	5/1 (PF)	0.0a	0.0a	0.1a	0.2a	0.1a	0.5a	0.5a	1.6ab	1.9a	27.0a
Agri-Mek + Oil	10 oz 0.25%	5/1 (PF)	0.0a	0.0a	0.1a	0.4a	0.2ab	0.1a	0.8a	1.2a	0.4a	19.7a
Pyramite 60WP	4.4 oz	6/20	0.2a	0.3ab	5.7bc	0.5a	0.4ab	0.8a	1.0ab	0.7a	1.1a	42.1a
Acramite 50WP	12.0 oz	6/20	0.2a	0.7abc	1.9ab	0.1a	0.1a	0.5a	0.4a	0.5a	1.4a	20.1a
Biomite	1.5 pt	6/20, 7/2	0.1a	0.4ab	1.8abc	0.9ab	1.4bc	4.9bc	4.1b	4.0bc	9.3b	146.5b
Biomite	2.0 pt	6/20, 7/2	0.8b	1.2c	10.2c	3.6c	4.9de	9.3cd	15.5cd	9.1d	12.5b	371.1c
Biomite	3.0 pt	6/20, 7/2	0.3ab	0.9bc	3.2bc	2.5bc	2.5cd	3.1b	4.3bc	5.5cd	2.5a	144.5b
Control	—	—	0.1b	0.9bc	7.8bc	6.1c	8.6e	11.4d	20.2d	9.9d	11.3b	453.7d

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

Table 3. Mean European red mite immatures on 'Delicious' apples treated with various miticides. Fletcher, NC. 2003.

Material	Rate (form.) per acre	Application date	Mean immatures per leaf									Cumulative mite days
			4 Jun	13 Jun	19 Jun	27 Jun	3 Jul	11 Jul	18 Jul	25 Jul	1 Aug	
Envidor 2SC	14 oz	5/1 (PF)	0.0a	0.3a	0.0a	0.4a	0.8a	1.4a	4.7ab	1.9a	5.0a	85.4a
Envidor 2SC	18 oz	5/1 (PF)	0.0a	0.1a	0.0a	0.4a	1.0ab	2.6a	1.7a	3.0a	3.0a	72.6a
Agri-Mek + Oil	10 oz 0.25%	5/1 (PF)	0.0a	0.2a	0.1a	0.9a	1.4ab	0.4a	1.8a	6.4a	2.2a	84.9a
Pyramite 60WP	4.4 oz	6/20	0.4a	1.3ab	2.5a	2.2ab	3.2abc	1.6a	3.8a	3.8a	5.3a	145.5a
Acramite 50WP	12.0 oz	6/20	0.2a	4.3abc	1.8a	0.8a	2.4abc	1.6a	1.6a	6.2a	2.2a	139.7a
Biomite	1.5 pt	6/20, 7/2	0.3a	5.8bcd	1.2a	1.2ab	8.6c	8.8b	6.4abc	18.8bc	21.4bc	436.6b
Biomite	2.0 pt	6/20, 7/2	0.4a	9.6d	7.6a	4.9b	24.3d	12.1b	35.5cd	25.0c	60.9c	1045.7c
Biomite	3.0 pt	6/20, 7/2	0.4a	6.3cd	2.6a	4.5b	7.7bc	7.3b	27.4bcd	6.8ab	7.5ab	466.5b
Control	—	—	0.2a	6.1cd	2.1a	11.2c	34.2d	27.7c	42.0d	49.5d	61.0c	1426.6c

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

Table 4. Mean apple rust mite populations on 'Delicious' apples treated with various miticides. Fletcher, NC. 2003.

Material	Rate (form.) per acre	Application date	Mean rust mites per leaf								Cumulative mite days
			4 Jun	13 Jun	19 Jun	27 Jun	3 Jul	11 Jul	18 Jul	1 Aug	
Envidor 2SC	14 oz	5/1 (PF)	0.0a	0.7a	0.1a	2.8a	4.5a	5.2a	11.7abc	22.5a	366.8a
Envidor 2SC	18 oz	5/1 (PF)	0.0a	1.0a	0.4a	3.8a	2.7a	13.5ab	4.2a	9.9a	325.9a
Agri-Mek + Oil	10 oz 0.25%	5/1 (PF)	0.0a	1.1a	0.5a	5.8a	3.8a	8.3ab	7.5ab	15.2a	254.3a
Pyramite 60WP	4.4 oz	6/20	1.3a	19.2ab	1.8a	15.3a	15.8abc	15.6ab	16.0abcd	24.6a	833.0b
Acramite 50WP	12.0 oz	6/20	1.1a	31.4b	3.5a	17.2a	6.7ab	27.9bc	16.9abcd	12.0a	925.8bc
Biomite	1.5 pt	6/20, 7/2	0.9a	27.9b	2.2a	21.1a	40.7c	75.8d	17.2abcd	57.6a	1559.0cd
Biomite	2.0 pt	6/20, 7/2	0.6a	16.0ab	7.6a	20.1a	45.8c	46.6cd	30.7bcd	139.7a	1950.5d
Biomite	3.0 pt	6/20, 7/2	0.1a	17.5ab	1.5a	20.3a	21.7abc	64.6d	34.1cd	44.5a	1401.3bcd
Control	—	—	0.3a	7.9a	3.1a	27.6a	29.1bc	83.1d	44.2d	39.1a	1547.9cd

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

Table 5. Mean *Amblyseius fallacies* populations on 'Delicious' apples treated with various miticides. Fletcher, NC. 2003.

Material	Rate (form.) per acre	Applicati on date	Mean mites per leaf									Total Mites
			4 Jun	13 Jun	19 Jun	27 Jun	3 Jul	11 Jul	18 Jul	25 Jul	1 Aug	
Envidor 2SC	14 oz	5/1 (PF)	0.0a	0.0a	0.0a	0.0a	0.1a	0.1a	0.1a	0.1a	0.4a	0.8a
Envidor 2SC	18 oz	5/1 (PF)	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.1a	0.2a	0.2a
Agri-Mek + Oil	10 oz 0.25%	5/1 (PF)	0.0a	0.1a	0.0a	0.0a	0.2a	0.0a	0.0a	0.2a	0.0a	0.5a
Pyramite 60WP	4.4 oz	6/20	0.0a	0.0a	0.0a	0.0a	0.1a	0.1a	0.1a	0.6a	0.2a	1.1ab
Acramite 50WP	12.0 oz	6/20	0.0a	0.1a	0.0a	0.1a	0.0a	0.5b	0.0a	0.5a	0.3a	1.4bc
Biomite	1.5 pt	6/20, 7/2	0.0a	0.1a	0.1a	0.0a	0.1a	0.2a	0.2a	0.5a	0.8a	1.7abc
Biomite	2.0 pt	6/20, 7/2	0.0a	0.1a	0.0a	0.1a	0.2a	0.1a	0.1a	0.6a	0.4a	1.6c
Biomite	3.0 pt	6/20, 7/2	0.0a	0.1a	0.0a	0.3a	0.2a	0.2a	0.2a	0.4a	0.5a	1.8a
Control	—	—	0.0a	0.1a	0.0a	0.2a	0.1a	0.2a	0.1a	0.6a	0.5a	1.6abc

Means in the same column followed by the different letters are significantly different by LSD (P<0.05).

Assessment of European Red Mite Resistance to Miticides

During the 2002 growing season, a high population of European red mites (ERM) was observed in a Polk County orchard (Hill) treated with the miticide clofentezine (Apollo). The Apollo application was made in mid May when mite populations averaged <1 mite per leaf, and populations increased to >25 mites per leaf by late June. Hence, studies were conducted in 2003 to assess the resistance status of the ERM population of this orchard to Apollo. In addition, the dose response to hexythiazox (Savey) and pyridaben (Pyramite) was also measured, because both of these miticides had previously been used in the orchard.

Materials and Methods

The dose-response of Apollo, Savey and Pyramite was assessed against two mite populations: the Hill orchard in Polk county suspected of supporting Apollo-resistant mites, and the Mountain Horticultural Crops Research Station (MHCRS) entomology orchard where control failures with Apollo had not been previously observed. A third ERM population, at Lynch orchard in Polk County, was also included in the Apollo test. All ERM used in bioassays were collected from orchards in June and July before the application of miticides. For the Apollo and Savey bioassays, 10 adult female ERM were allowed a 24-h oviposition period on 2.5 cm diameter leaf disks ('Golden Delicious' apple leaves collected from the control of insecticide trials at the MHCRS) that were placed on moist cotton in a 15 cm diameter Petri dish. After the 24-h oviposition period, adults were removed and leaf disks were dipped into various serial dilutions of miticide prepared with tap water. Concentrations tested were 0, 0.1, 1.0, 10 and 100 ppm, and 0.05% Triton X-100 was added to each solution, including the control. Leaf disks were allowed to dry for approximately 1 hr on paper towels, and were then placed back onto moist cotton in Petri dishes. The number of eggs on each leaf disk were counted under a stereomicroscope, and were then incubated for 7 d at 25^{o}C. Water was added daily to the cotton. After 7 d, the number of unhatched eggs, hatched eggs, and larvae were counted. For each of the 2 to 3 replicates, four disks per concentration were used. Eggs that did not hatch were considered dead. Data were subjected to probit analysis.

For Pyramite bioassays, whole 'Golden Delicious' leaves were dipped into various 1 liter serial dilutions prepared with tap water. Concentrations tested were 0, 0.1, 0.35, 1.23, 4.29, and 15.01 ppm, with 0.05% Triton X-100 added to each solution, including the control. Leaves were allowed to dry for 2 h, after which 2.5 cm diameter leaf disks were removed and placed on moist cotton in a 15 cm diameter Petri dish. Then 10 adult female ERM were placed on each disk. Leaf disks were incubated at 25^{o}C, 12:12 L:D, and the number of live and dead mites were recorded 24 h later. Mites that left the leaf disk and/or drowned at the periphery of the disk were discounted. Four leaf disks per concentration (40 mites) were tested in each of two replications. Data were subjected to probit analysis.

Results

Results suggested that the Hill population was highly resistant to Apollo (Fig. 1), with only ≈25% morality at 100 ppm. This is in contrast to the MHCRS and Lynch populations, which had LC_{50} values of 4.9 (95% FL, 1.8 – 11.4) and 7.2 (95% FL, 2.1 – 22.9) ppm, respectively.

Similar results were obtained with Savey; with the LC50 value of the MHCRS population being 1.2 ppm (95% FL, 0.4 – 2.5), and the 100 ppm rate of Savey resulting in only 26.1% mortality of eggs. Reissig and Hull (1991, J. Econ. Entomol. 84:727-735) have previously demonstrated Savey resistance in an ERM population from a research station in PA. In contrast to our results, this PA population was not resistant to Apollo. It should be noted, however, that our bioassay results with Savey should be considered preliminary, because our dose-response curve is based on only one replicate (n = 139 for Hill population and n = 135 for MHCRS population). Control mortality was excessively high (>35%) in the latter two replicates, so this data was not included in the analysis.

There was no evidence of resistance to Pyramite in either the Hill or MHCRS populations. Estimate LC_{50} values of Pyramite to the MHCRS and Hill populations were 1.1 (95% FL, 0.5 – 2.3) and 3.1 (95% FL, 1.4 – 6.9) ppm, respectively. The same bioassay method was used to establish baseline dose-response curves for the MHCRS population in 1997, at which time the estimated LC_{50} value was 2.0 ppm (95% FL, 1.3 – 2.8).