Apple insect management by insecticides in Ohio, 2015

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Objective: A field trial was conducted for continued evaluation of insecticide options for control of apple insect pests with emphasis on control of the key pest, codling moth, and on newer products such as Delegate, Gladiator, and Beleaf, as well as an experimental product, cyclaniliprole. Gladiator is a pre-mix of avermectin and zeta-cypermethrin that was registered by FMC in 2012 for control of a broad range of pests including mites. Delegate (spinetoram) has been available since 2008. Beleaf (flonicamid) has been available since 2007. Cyclaniliprole is in the same chemical group as Exirel and Altacor, and is under development by ISK Biosciences.

Methods:

The trial was conducted in a 2-acre block of 13-year old apple trees at Ohio State University's Waterman Agricultural and Natural Resources Laboratory in Columbus, Franklin County. There were six treatments, each with four replicates in a randomized complete block design. There were five adjacent Scarlet Spur Red Delicious trees per plot. Three guard rows separated adjacent treatment rows. Insecticides were applied in a volume of 75 gallons of water per acre by an AgTech 4002 airblast sprayer operated at pressure of 20 psi, with TeeJet 6510 and 6520 nozzle tips.

Insecticide products used were Beleaf (flonicamid), Lorsban Advanced (chlorpyrifos), Esteem (pyriproxyfen), Mustang Maxx (zeta-cypermethrin), Gladiator (avermectin plus zeta-cypermethrin), Imidan (phosmet), cyclaniliprole, indoxacarb (Avaunt), Altacor (chlorantraniliprole), Delegate (spinetoram), and Assail (acetamiprid). The treatment plan included Closer (sulfoxaflor) in the second or third cover sprays if aphids were above threshold, but they were below threshold thus it was not applied. Formulations, rates, adjuvants, the sequence of product combinations, and spray application dates are shown in Table 1.

Table 1. Sequence of products applied in apple insecticide trial, Columbus, Ohio, 2015.

Treat-ment	Half-inch green (4/13)	Pink bud (4/21)	Petal-fall (5/9)	1C (5/26; 268 DD after biofix on 5/10) & 2C (6/9)	3C (6/24)	5C (7/22) & 6C (8/5) & 7C (8/19)
1 FMC-1	Beleaf 50 SG 2.8 oz/A	Mustang Maxx: 4 fl oz/A	Gladiator 0.33EW: 18 fl oz/A + oil 0.5%	Altacor 35WG: 3 oz/A	Altacor 35WG: 3 oz/A + Beleaf 50 SG 2.8 oz/A	Mustang Maxx: 4 fl oz + Avaunt 30 WDG 6 oz
2 FMC-2	-	Mustang Maxx: 4 fl oz/A + Beleaf 50 SG 2.8 oz	Gladiator 0.33EW: 18 fl oz/A + oil 0.5%	Altacor 35WG: 3 oz/A	Altacor 35WG: 3 oz/A + Beleaf 50 SG 2.8 oz/A	Mustang Maxx: 4 fl oz + Avaunt 30 WDG 6 Poz
3 Dow	Lorsban Advanced: 1 qt/A	-	Imidan 70WP: 3 lb/A	Delegate 25WG: 5.2 oz/A	Delegate 25WG: 5.2 oz/A	Altacor 35WG: 3 oz/A
4 ISK	Esteem 35WP: 4 oz/A	-	Cyclaniliprole 50SL, 22 fl oz/A (80 g ai/ha)	Cyclaniliprole 50SL, 22 fl oz/A	Cyclaniliprole 50SL, 22 fl oz/A	Cyclaniliprole 50SL, 22 fl oz/A
5 standard	Esteem 35WP: 4 oz/A	-	Avaunt 30WDG: 6 oz/A	Altacor 35WG: 3 oz/A	Altacor 35WG: 3 oz/A	Assail 30SG: 6 oz/A + oil 0.5%
6 un-treated	-	-	-	-	-	-

Three pheromone traps were used to monitor the population of codling moth and to determine the biofix date, which was 5/10. Treatments for control of first generation codling moth were applied on in the first cover spray on 5/26, which was 268 degree-days after biofix, and again on 6/9 (516 degree-days)

and 6/24 (894 degree-days). A fourth cover spray of insecticide was not needed due to lack of lingering activity of codling moth. For control of second-generation codling moth, insecticides were applied in the fifth cover spray on 7/22, which was 270 degree-days after re-biofix on 7/10, and applied again in the sixth cover spray on 8/5 (611 degree-days) and in the seventh cover spray on 8/19 (931 degree-days).

For fruit thinning, Sevin XLR Plus at 1 qt/A was applied on 5/20. For disease control, fungicides applied were Captec 4L at 2 qt/A plus Rally 40WSP at 5 oz/A at half-inch green on 4/14; Captan 50WP at 8 lb/A plus Rally on 4/21; Captan 50W plus Fontelis at 16 oz/A on 4/27 and 5/6; Captan 50WP plus Rally on 5/20; Benolate at 3 oz/A on 6/18; and Captec 4L at 1 qt/A on 7/1, 7/13, 7/29, 8/12, and 8/19. For corkspot management, pelletized lime was spread under trees on 4/1; Solubor at 2 lb/A and NutriLeaf 20-20-20 at 2 lb/A were sprayed at pink on 4/21 and at petal-fall on 5/6; Apogee at 18 oz/A plus Regulaid at 18 fl oz/A and Choice at 24 fl oz/A were sprayed at petal-fall on 5/6; and calcium chloride at 2 lb/A was sprayed on 6/4, 6/11, 6/18, and 7/1. Thinner, fungicides, nutrients, and growth regulator were applied on all trees, including checks, by an AgTech 4002 airblast sprayer operated at pressure of 20 psi, with TeeJet 6510 and 6520 nozzle tips, with a spray volume of 75 gal/A.

Insect injury was evaluated on 100 randomly selected fruit from the center of each plot, non-destructively on 7/10 to 7/13, and destructively at harvest from 9/22 to 9/28. Green apple aphid was evaluated in the center tree of each plot by scouting its presence or absence on each of the five endmost leaves on each of ten terminal shoots on 5/28, 6/8, and 6/22; the number of predatory insects was also recorded. Woolly apple aphid infestation was evaluated by scouting its presence or absence in a one-minute search per tree in three trees per plot on 5/28, 6/8, 6/22, and 9/30. Formal scouting for rosy apple aphid was not needed due to the negligible presence of this species.

Mite populations were sampled on 7/27. A sample of 50 randomly selected leaves was taken from one tree at the center of each plot; this sample size was twice the usual 25 leaves per plot due to low mite density. Leaves were brushed with a mite-brushing machine, and mites were counted in sub-samples to determine the average number of European red mite and predatory mites per leaf. The density of apple rust mite was rated as low (<5 mites per leaf), moderate (5 to 50 mites per leaf), or high (>50 mites per leaf) for each sample.

Data were subjected to analysis of variance (ANOVA) and mean comparisons by least significant difference (LSD) tests in the SAS 9.3 microcomputer statistics program. Percentage data were transformed by arcsine square root before analysis.

Results and Discussion:

Codling moth pressure was moderate as indicated by trap counts (Fig. 1); traps detected sustained flight on 5/10/2015, which was used as the biofix date. Lesser appleworm and oriental fruit moth were also present at moderate density.

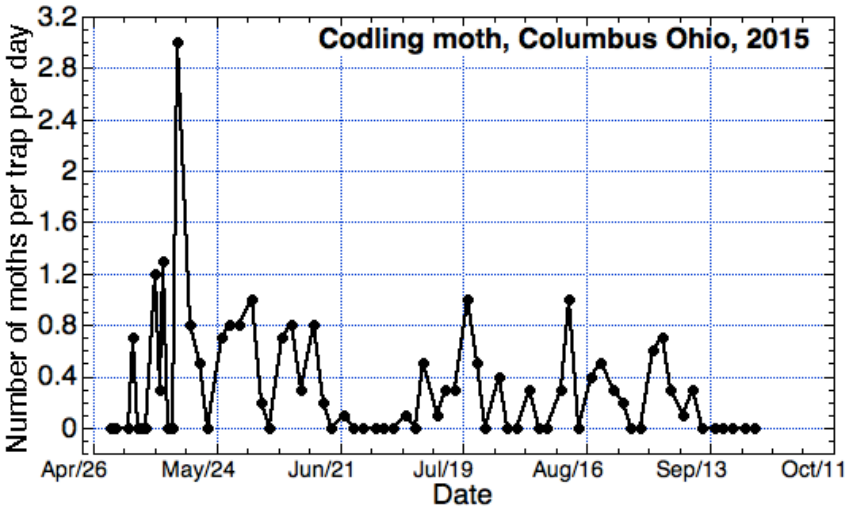

Figure 1. Seasonal trends in the adult population of codling moth as detected by pheromone trap captures in apple trees at Waterman Orchard, Columbus, Ohio, 2015; mean of three traps.

The percentage of fruit damaged by codling moth or other internal Lepidoptera in early July, which reflects control of first generation codling moth, was not significantly lower in any of the five insecticide programs than in untreated plots (P = 0.12; Table 2). The percentage of fruit that was clean of any insect damage was also not significantly different among treatments, and ranged from 77 to 94% (P = 0.16; Table 2). The percentage of fruit damaged by San Jose scale was significantly lower than the untreated check in four of the five insecticide programs (P = 0.0452), but was no different than the untreated check in the FMC-1 program. Damage by San Jose scale was higher in the FMC-1 program, which differed from the FMC-2 program only in the positioning of the pre-bloom application of Beleaf; in FMC-1, Beleaf was applied by itself at the half-inch green bud stage followed by Mustang Maxx by itself at the pink bud stage, whereas in FMC-2 there was no insecticide at half-inch green and Beleaf was tank mixed with Mustang Maxx at pink. The best control of San Jose scale was in plots where Lorsban Advanced applied at half-inch green followed by Imidan and Delegate. Other insects that caused damage to fruit by early July were tarnished plant bug and plum curculio, but these did not differ significantly among treatments (P > 0.05; Table 2).

At harvest in September, damage by internal Lepidoptera, which reflects control of both first and second generations of codling moth, ranged from 1.5 to 12.0% and was significantly less than in untreated checks in four of the five insecticide programs but was not significantly different than the check in the standard treatment of Altacor for first generation and Assail for second generation (P < 0.0497; Table 3). Other insects that caused damage to harvested fruit were San Jose scale, stink bugs, and plum curculio, none of which were significantly different among treatments (P > 0.05; Table 3). Damage by tarnished plant bug differed among treatments, with significantly less in the FMC-1 program and significantly more in the cyclaniliprole treatment (P < 0.0001; Table 3). No apple maggot was detected. No phytotoxicity was observed.

Woolly apple aphid (WAA) colonies were detected in most plots. When first scouted on 5/28, significantly more WAA were found in the standard treatment where Esteem and Avaunt had been sprayed, than in the untreated or other insecticide-treated plots (P = 0.0109; Table 4). On 6/8, presence of WAA did not differ significantly among plots (P = 0.23; Table 4). On 6/22, WAA reached peak abundance at which time it was significantly less abundant in the Dow treatment in which Lorsban, Imidan, and Delegate had been sprayed, than in any other treatment. Scouting for WAA after harvest on 9/30 showed no significant difference among treatments (P = 0.68; Table 4).

Green apple aphid was present at low density in most plots. Scouting of aphids on terminal shoots on 5/28 and 6/8 showed that infestations did not differ significantly among treatments, but on 6/22 there were significantly more aphids in the ISK and FMC-1 programs than in the untreated, standard, or Dow program (P = 0.0396; Table 5). Predatory insects that were found in green apple aphid colonies were *Orius insidiosus* adults, lady beetle adults and larvae, and *Aphidoletes* larvae, but none of these differed significantly among treatments (P > 0.05, Table 6).

Mites were at low density, as they have been in this orchard for the past few years. In late July, there was only a trace of European red mite, which did not show any significant treatment effect (P > 0.05; Table 7). Apple rust mite density was negligible. Stigmaeids were the most abundant predatory mite but they did not show a significant treatment effect; they were slightly more abundant in the Dow program plots and slightly less abundant in the FMC-2 program plots (Table 7). Phytoseiid predatory mites were found in all treatments but at low densities that did not differ significantly among treatments (P > 0.05; Table 7).

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Table 2. Insect injury to 'Delicious' apple fruit after treatment by six management programs, evaluated non-destructively on 10-13 July 2015; mean of four blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

Treatment (prebloom/ petalfall/ codling moth 1st generation)	% Internal Lepidoptera			% San Jose scale[a]	% Plum curculio	% Tarnished plant bug	% Clean of insect damage
	Entry	Sting	Total				
ISK (Esteem/cyclaniliprole/ cyclaniliprole)	0.0	0.2	0.2	1.8 BC	5.0	0.8	92.5
FMC-1 (Beleaf/Mustang/Gladiator/Altacor)	0.0	0.6	0.6	10.3 AB	1.0	0.5	87.6
Dow (Lorsban/Imidan/Delegate)	0.2	1.0	1.3	0.2 C	3.3	0.8	94.5
FMC-2 (Mustang+Beleaf/Gladiator/Altacor)	0.2	2.5	2.8	3.2 BC	9.0	0.0	85.0
standard (Esteem/Avaunt/Altacor)	0.5	3.0	3.5	1.8 BC	6.2	1.0	87.8
untreated	1.8	1.8	3.6	14.0 A	5.5	0.8	76.7
Probability for treatment effect	*P = 0.09*	*P = 0.17*	*P = 0.12*	*P = 0.0452*	*P = 0.76*	*P = 0.45*	*P = 0.16*

[a] Within each column, means followed by same letter are not significantly different (*P*>0.05); mean separations by LSD. Values shown are actual percentages but ANOVA based on transformed values.

Table 3. Insect injury to 'Delicious' apple fruit after treatment by six insecticide programs, evaluated destructively at harvest on 22-28 September 2015; mean of four blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

Treatment (codling moth 1st generation/ 2nd generation)	% Internal Lepidoptera			% San Jose scale	% Stink bug	% Plum curculio		% Tarnished plant bug[a]	% Leaf-roller	% Clean of insect damage
	Entry[a]	Sting	Total[a]			Ovipo-sition	Late feeding			
ISK (cyclanilitrole)	0.0 B	1.5	1.5 B	3.7	17.7	6.4	0.0	3.2 A	0.2	71.7
FMC-1 (Altacor/Mustang+Avaunt)	0.5 B	1.0	1.5 B	22.8	13.9	2.2	0.2	1.5 B	0.0	59.4
FMC-2 (Altacor/Mustang+Avaunt)	0.2 B	2.8	3.0 B	9.6	12.9	8.0	0.0	0.0 D	0.0	70.0
Dow (Delegate/ Altacor)	0.8 B	2.5	3.2 B	0.2	15.5	6.8	0.8	2.8 AB	0.0	74.0
standard (Altacor/Assail)	0.5 B	3.8	4.2 AB	3.2	13.2	9.5	0.5	0.8 C	0.0	70.8
untreated	5.0 A	7.0	12.0 A	30.7	19.0	6.2	1.7	1.7 AB	0.0	40.9
Probability for treatment effect	*0.0139*	*0.09*	*0.0497*	*0.15*	*0.86*	*0.54*	*0.10*	*<0.0001*	*0.45*	*0.11*

[a] Within each column, means followed by same letter are not significantly different (*P*>0.05); mean separations by LSD. Values shown are actual percentages but ANOVA based on transformed values.

Table 4. Woolly apple aphid (WAA) infestation detected on 'Delicious' apple trees, Columbus, Ohio, 2015.

Treatment (prebloom/ petalfall/ codling moth 1st generation)	WAA presence or absence (0 = absent; 1 = present) on four sampling dates			
	5/28 [a]	6/8	6/22 [a]	9/30
FMC-1 (Beleaf/Mustang/Gladiator/Altacor)	0.08 B	0.50	0.75 A	0.33
ISK (Esteem/cyclaniliprole/ cyclaniliprole)	0.17 B	0.33	0.75 A	0.33
untreated	0.08 B	0.42	0.67 A	0.00
FMC-2 (Mustang+Beleaf/Gladiator/Altacor)	0.08 B	0.33	0.67 A	0.25
standard (Esteem/Avaunt/Altacor)	0.50 A	0.58	0.50 A	0.25
Dow (Lorsban/Imidan/Delegate)	0.00 B	0.00	0.00 B	0.08
Probability for treatment effect	*P = 0.0109*	*P = 0.23*	*P = 0.0481*	*P = 0.68*

[a] Within each column, means followed by same letter are not significantly different (*P*>0.05); mean separations by LSD. Values shown are actual proportions but ANOVA based on transformed values.

Table 5. Green apple aphid on terminal shoots of 'Delicious' apple trees, Columbus, Ohio, 2015.

Treatment (prebloom/ petalfall/ codling moth 1st generation)	Percentage of terminal leaves infested on three sampling dates		
	5/28	6/8	6/22[a]
ISK (Esteem/cyclaniliprole/ cyclaniliprole)	3.0%	9.5%	13.0% A
FMC-1 (Beleaf/Mustang/Gladiator/Altacor)	0.5%	6.0%	12.5% A
FMC-2 (Mustang+Beleaf/Gladiator/Altacor)	2.5%	6.5%	5.5% AB
standard (Esteem/Avaunt/Altacor)	4.0%	7.5%	2.0% B
Dow (Lorsban/Imidan/Delegate)	1.5%	9.5%	1.5% B
untreated	0.0%	1.5%	1.0% B
Probability for treatment effect	*P = 0.55*	*P = 0.34*	*P = 0.0396*

[a] Within each column, means followed by same letter are not significantly different (*P*>0.05); mean separations by LSD. Values shown are actual percentages but ANOVA based on transformed values.

Table 6. Predators associated with green apple aphid on 'Delicious' apple trees, Columbus, Ohio, 2015.

Treatment (prebloom/ petalfall/ codling moth 1st generation)	Number of predators on endmost 5 leaves of terminal shoot					
	Orius (adults) on 5/28	Orius (adults) on 6/08	Lady beetle (adults) on 6/8	Lady beetle (adults) on 6/22	Lady beetle (larvae) on 6/22	Orange midge, *Aphidoletes aphidimyza* on 5/28
ISK (Esteem/cyclaniliprole/ cyclaniliprole)	0.025	0.05	0.025	0.025	0.000	0.025
FMC-1 (Beleaf/Mustang/Gladiator/Altacor)	0	0.025	0.000	0.000	0.000	0
FMC-2 (Mustang+Beleaf/Gladiator/Altacor)	0	0.000	0.000	0.025	0.000	0
standard (Esteem/Avaunt/Altacor)	0	0.025	0.025	0.000	0.000	0
Dow (Lorsban/Imidan/Delegate)	0	0.075	0.075	0.000	0.025	0.025
untreated	0	0.025	0.025	0.000	0.000	0
Probability for treatment effect	*P = 0.45*	*P = 0.45*	*P = 0.32*	*P = 0.60*	*P = 0.45*	*P = 0.45*

Table 7. Density of European red mite (ERM) and associated mites on 'Delicious' apple leaves on 27 July 2015, Columbus, Ohio.

Treatment (prebloom/petalfall/codling moth 1st generation)	Mean number per leaf		Apple rust mite rating[a]	Mean number of predators per leaf	
	ERM motiles	ERM eggs		Stigmaeid motiles	Phytoseiid motiles
untreated	0.05	0.00	0.0	0.78	0.07
Dow (Lorsban/Imidan/Delegate)	0.08	0.14	0.5	0.96	0.02
FMC-1 (Beleaf/Mustang/Gladiator/Altacor)	0.11	0.16	0.0	0.40	0.12
ISK (Esteem/cyclaniliprole/ cyclaniliprole)	0.15	0.19	0.0	0.60	0.05
standard (Esteem/Avaunt/Altacor)	0.15	0.21	0.8	0.60	0.10
FMC-2 (Mustang+Beleaf/Gladiator/Altacor)	0.16	0.49	0.2	0.44	0.16
Probability for treatment effect	*P = 0.85*	*P = 0.28*	*P = 0.14*	*P = 0.23*	*P = 0.15*

[a] Density rating scale: 0 = none; 1 = low (<5 per leaf); 2 = moderate (5 to 50 per leaf); 3 = high (>50 per leaf).