Apple insect management by insecticides in Ohio, 2018

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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, as well as an emerging new pest, the brown marmorated stink bug. Efficacy information is needed for newer products for apples such as Gladiator and Beleaf, in combination with several older products: Mustang Maxx, Avaunt, Altacor, and Delegate. Gladiator is a pre-mix that was registered by FMC in 2012 for control of a broad range of pests including mites. Beleaf has been available since 2007 for control of aphids and various other pests. Hero was evaluated but is not yet registered on apples; Hero is a pre-mix that has potential for control of stink bugs.

Methods:

The trial was conducted in a 2-acre block of 16-year old apple trees at Ohio State University's Waterman Agricultural and Natural Resources Laboratory in Columbus, Franklin County. Plots were set up in a randomized complete block design with six treatments and four replicates. Insecticides included were chlorpyrifos (Lorsban), zeta-cypermethrin (Mustang Maxx), flonicamid (Beleaf), zeta-cypermethrin plus avermectin B1 (Gladiator), indoxacarb (Avaunt), chlorantraniliprole (Altacor), spinetoram (Delegate), phosmet (Imidan), zeta-cypermethrin plus bifenthrin (Hero), and acetamiprid (Assail). The sequence and rates of products in each treatment are shown in Table 1. There were five adjacent 'Scarlet Spur Red Delicious' trees per plot. 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.

Table 1. Sequence and rates of products applied in Red Delicious apple insecticide trial, Columbus, Ohio, 2018.

Treatment	Half-inch green (4/18)	Pink bud (4/26)	Petal-fall (5/14)	1C (5/29)	2C (6/13) & 3C (6/26)	4C (7/10)	5C (7/25) & 6C (8/9) & 7C (8/23)
1 FMC-1	-	Mustang Maxx 0.8EC: 4 fl oz/A + Beleaf 50 SG 2.8 oz	Gladiator: 18 fl oz/A + oil 0.5%	Beleaf 50 SG 2.8 oz/A + NIS 0.25%	Altacor 35WG: 3 oz/A	Altacor 35WG: 3 oz/A	Mustang Maxx 0.8EC: 4 fl oz/A + Avaunt eVo 30 DG: 6 oz/A
2 FMC-2	-	Mustang Maxx 0.8EC: 4 fl oz/A + Beleaf 50 SG 2.8 oz	Gladiator: 18 fl oz/A + oil 0.5%	Beleaf 50 SG 2.8 oz/A + NIS 0.25%	Delegate 25WG: 5.2 oz/A	Delegate 25WG: 5.2 oz/A	Mustang Maxx 0.8EC: 4 fl oz/A + Avaunt eVo 30 DG: 6 oz/A
3 FMC-3	-	Mustang Maxx 0.8EC: 4 fl oz/A + Beleaf 50 SG 2.8 oz	Avaunt eVo 30 DG: 6 oz/A	Beleaf 50 SG 2.8 oz/A + NIS 0.25%	Altacor 35WG: 3 oz/A	Imidan 70WP: 3 lb/A	Hero 1.24EC: 10.3 oz/A + NIS 0.25%
4 FMC-4	-	Mustang Maxx 0.8EC: 4 fl oz/A + Beleaf 50 SG 2.8 oz	Beleaf 50 SG 2.8 oz/A + NIS 0.25% +	Avaunt eVo 30 DG: 6 oz/A	Altacor 35WG: 3 oz/A	Altacor 35WG: 3 oz/A	Hero 1.24EC: 10.3 oz/A + NIS 0.25%
5 Standard	Lorsban Advanced: 1 qt/A + oil 2%	-	Avaunt eVo 30 DG: 6 oz/A	Altacor 35WG: 3 oz/A	Altacor 35WG: 3 oz/A	Imidan 70WP: 3 lb/A	Assail 30SG: 6 oz/A + oil 0.5%
6 Untreated	-	-	-	-		-	-

Target timing of the first cover spray was based on observations of moth activity in pheromone traps. Populations of codling moth (CM), oriental fruit moth (OFM), and lesser appleworm (LAW) were monitored by pheromone traps that were checked three times per week. There were two traps each for CM and OFM, and one trap for LAW. There was a third trap for CM in a small apple block nearby and a third trap for OFM in a small peach block nearby but the data from these are not included here because moth catches were consistently lower than in the block where the experimental plots and other traps were located. The biofix dates were 5/2 for OFM and 5/14 for CM. Degree-day accumulations relative to biofix dates are shown in Table 2 for CM (base 50^{o} F with upper threshold of 88^{o}F) and OFM (base 45^{o} F with upper threshold of 90^{o}F). The first cover spray was delayed from the optimal date due to rainy and windy weather. The second and third cover sprays followed at 2-week intervals. For control of second-generation CM and third- and fourth-generation OFM, insecticides were applied in the fifth, sixth, and seventh cover sprays, with dates and degree-day accumulations as shown in Table 2.

Table 2. Degree-day accumulations relative to spray dates for apple insecticide trial, Columbus, Ohio, 2018.

Spray	Date	Degree-days after codling moth biofix on 5/14	Degree-days after OFM biofix on 5/2
Petal-fall	5/14	-	312 (ideal timing was 150-170 for 1st gen.)
1st cover	5/29	376 (ideal timing was 250 for 1st generation)	742
2nd cover	6/13	716	1157 (ideal 1125-1150 for 2nd gen.)
3rd cover	6/26	1048	1557
4th cover	7/10	1416	1997
5th cover	7/25	1790 (351 after re-biofix; ideal 250 for 2nd gen.)	2446 (ideal 2250-2280 for 3rd gen.)
6th cover	8/9	2162 (723 after re-biofix)	2895
7th cover	8/23	2477 (1038 after re-biofix)	3280 (ideal 3375-3430 for 4th gen.)

Treatments for pre-bloom control of San Jose scale and rosy apple aphid were applied at the half-inch green bud stage on 4/18 and at the pink bud stage on 4/26. Treatments for post-bloom control of plum curculio and leafrollers were applied at the petal-fall stage on 5/14.

For fruit thinning, MaxCel at 75 ppm in 100 gal water per acre was applied when king fruit were 10 mm diameter, on 5/17. For disease control, fungicides applied were mancozeb (Koverall 75DF) at 6 lb/A on 4/18, Captan 50WP at 8 lb/A on 4/26, Captan 80WDG at 5 lb/A on 5/9 and 5/25. All fungicide sprays 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. Thinner and fungicides were applied on all trees, including those in untreated check plots.

Trends in seasonal abundance of brown marmorated stink bug were determined by pheromone traps. Three clear sticky-panel traps on 5-foot wood posts, baited with dual Trécé lures, were placed along the west edge of the orchard in mid-April and checked once per week until late September.

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 5/22 and 6/10. Rosy apple aphid was evaluated in each of three trees per plot by counting the number of infested clusters in middle zone of the canopy in a 1-minute search per tree on 5/22 and 6/10. 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 5/22, 6/8, and 6/20; the number of potato leafhoppers and predatory insects on these leaves was also recorded. Insect injury on fruit was evaluated on 100 randomly selected fruit from the center of each plot, non-destructively on 7/9, and destructively at harvest on 9/14-9/16.

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.

<u>Results and Discussion</u>:

All three species of internal Lepidoptera were abundant in pheromone traps as shown in the graph with a single Y-axis (Fig. 1) and two Y-axes (Fig. 2). This is the second consecutive year that OFM has been present at high density in this orchard.

Damage from internal Lepidoptera in fruit at harvest was heavy: untreated check plots had 61.5% of fruit injured by internal Lepidoptera, which was the sum of 50.8% of fruit with deep entries and 10.8% of fruit with stings (Table 3). All insecticide programs resulted in fruit that was significantly less infested by internal Lepidoptera than untreated trees, but there were no significant differences among the insecticide treatments. Injury was slightly less in the standard and FMC-3 treatments, and slightly more in the FMC-2 treatment.

In early July, injury by first generation CM and first- and second-generation OFM in untreated plots was seen on 15.0% of fruit, which was the sum of 12.2% with deep entries and 2.8% with stings (Table 4). In early July, injury was significantly less in all insecticide treatments than in untreated plots but there were differences among insecticide programs: there were significantly fewer entries by internal Lepidoptera in FMC-4 and standard treatments than in the FMC-2 treatment, while entries in FMC-1 and FMC-3 treatments were intermediate (Table 4).

Injury to fruit by stink bugs was present, but with no significant difference among treatments either at harvest (Table 3) or in early July (Table 4). Pheromone traps showed that brown marmorated stink bugs were present in the orchard at trace levels in May and June but were present at higher density starting in early July, with peak density in early September (Figure 3). This suggests that the stink bugs should have been affected by the fourth cover through seventh cover sprays, but not from the third cover or earlier sprays. The green stink bug (*Chinavia hilaris*) was occasionally caught on the traps: on 5/14, 6/25, 7/9, and 9/10.

Injury to fruit by San Jose scale (SJS) was present on 14% of fruit in untreated plots at harvest; although there were no significant differences among treatments at harvest, there was a trend of the least injury by SJS in the standard treatment (Table 3). SJS was found on 6% of fruit in untreated plots in early July and did not differ among treatments (Table 4).

Injury to fruit by plum curculio, tarnished plant bug, apple curculio, woolly apple aphid, leafrollers, and early fruitworms was also present, but with no significant difference among treatments either at harvest (Table 3) or in early July (Table 4).

With all injuries combined, there was significantly more insect injury at harvest in the FMC-2 treatment than in the other insecticide treatments (Table 3). The trend was for the least insect injury in the standard and the FMC-3 treatments. Similar trends were seen in early July (Table 4).

Woolly apple aphid (WAA) was present on 0 to 33% of trees on 5/22, which was 8 days after the petal-fall sprays; it did not differ significantly among treatments, but was lowest in the FMC-3 treatment and highest in untreated and the FMC-4 treatment (Table 5). WAA was present on 0 to 25% of trees on 6/10 and did not differ among treatments (Table 5). Rosy apple aphid was not present in any plot, as determined by scouting on two dates (Table 5). Green apple aphid was present on 0.0 to 8.5% of leaves from mid-May until mid-June, and did not differ significantly among treatments (Table 6). Potato leafhopper became abundant in early June and also did not differ significantly among treatments but was slightly lower in the FMC-4 treatment than in other treatments (Table 6). The density of *Orius* predatory bugs was significantly higher in the FMC-2 treatment on 5/22 than in all other treatments. Other predators detected were lady beetles, lacewings, and spiders, which did not differ significantly among treatments on any of the three dates, but for which the general trend was more predators in the FMC-4 and untreated plots, and the fewest predators in the FMC-1 and standard treatments (Table 7).

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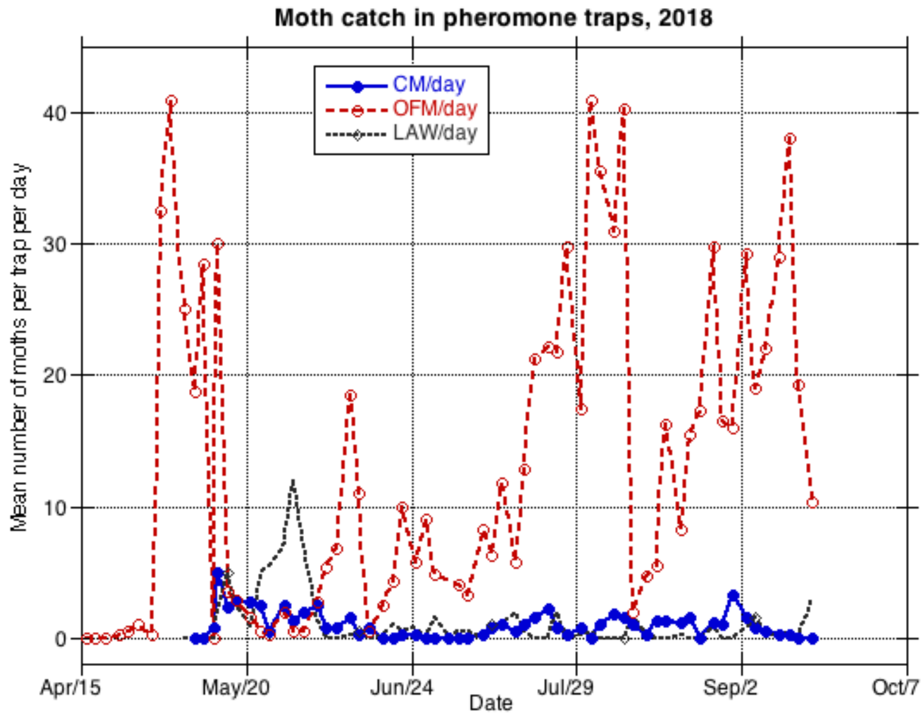

Fig. 1. Population trends in codling moth (CM), Oriental fruit moth (OFM), and lesser appleworm (LAW) in 2018 as measured by pheromone traps at OSU's Waterman Lab, Columbus, Ohio; shown with all three species on same scale on y-axis.

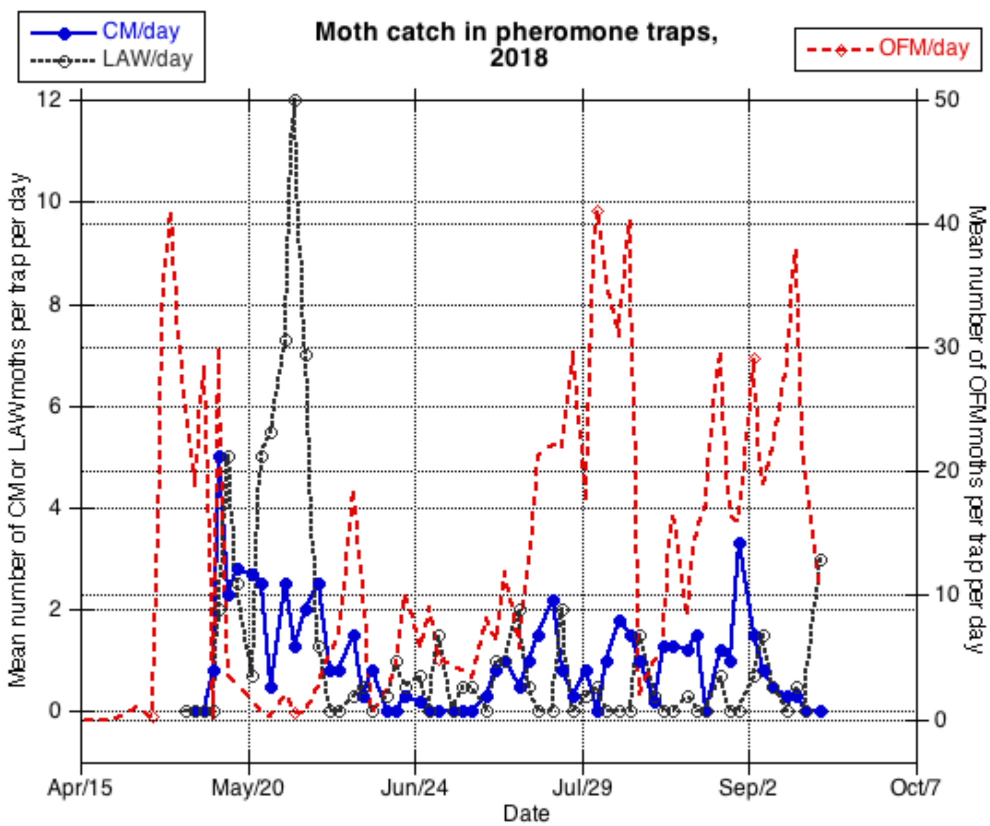

Fig. 2. Population trends in codling moth (CM), Oriental fruit moth (OFM), and lesser appleworm (LAW) in 2018 as measured by pheromone traps at OSU's Waterman Lab, Columbus, Ohio; shown with CM and LAW on larger scale on y-axis (labeled on left), and OFM on smaller scale on y-axis (labeled on right).

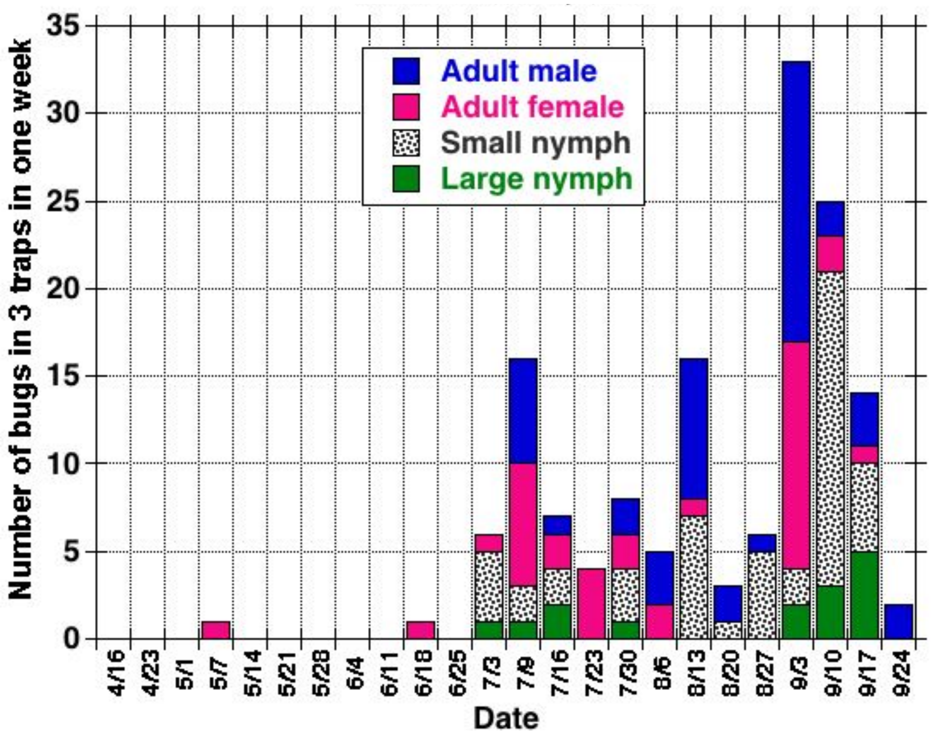

Figure 3. Seasonal abundance of brown marmorated stink bug as detected by three pheromone traps along the west edge of apple research orchard, Columbus OH, 2018.

Table 3. Insect injury[a] to 'Red Delicious' apple fruit after treatment by six insecticide programs, evaluated destructively at harvest on 14-16 September 2018; mean of four blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

Treatment	% Internal Lepidoptera			% San Jose scale	% Stink bug	% Plum curculio		% Tarnished plant bug	% Apple curculio	% Woolly apple aphid	% Leaf-roller (late)	% Clean of insect damage[b]
	Entry[b]	Sting	Total[b]			Ovipo-sition	Late feeding					
Standard	1.5 B	0.8	3.5 B	0.8	6.8	2.0	0.2	1.2	0.8	0.0	0.2	85.0 A
FMC-3	1.2 B	4.2	3.5 B	4.2	4.8	2.2	0.2	0.8	0.2	0.5	0.0	84.5 A
FMC-4	2.0 B	9.2	4.8 B	9.2	6.5	3.2	0.2	2.0	0.0	0.0	0.0	77.5 A
FMC-1	1.8 B	9.8	6.0 B	9.8	8.2	2.2	0.8	0.0	0.8	2.0	0.0	75.2 A
FMC-2	5.0 B	10.8	8.8 B	10.8	9.8	9.5	0.2	0.8	10.0	0.8	0.2	57.2 B
untreated	50.8 A	14.8	61.5 A	14.8	6.5	4.0	0.5	1.2	0.8	0.0	0.2	25.2 C
P (treatment effect)	<0.0001	*0.12*	<0.0001	*0.12*	*0.60*	*0.10*	*0.99*	*0.17*	*0.10*	*0.37*	*0.45*	<0.0001

[a] Values shown are actual percentages but ANOVA based on transformed values.

[b] Within each column, means followed by same letter are not significantly different (*P*>0.05); mean separations by LSD.

Table 4. Insect injury[a] to 'Red Delicious' apple fruit after treatment by six insecticide programs, evaluated non-destructively on 9 July 2018; mean of four blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

Treatment	% Internal Lepidoptera			% San Jose scale	% Plum curculio (ovi-position)	% Stink bug	% Tarnished plant bug	% Apple curculio	% Leaf-roller	% Early fruit-worm	% Clean of insect damage[b]
	Entry[b]	Sting	Total[b]								
FMC-3	0.5 BC	2.0	2.5 B	2.2	1.5	0.8	0.5	0.0	0	0	92.5 A
Standard	0.0 C	3.0	3.0 B	0.2	1.5	1.0	1.8	0.2	0	0.2	92.5 A
FMC-4	0.2 C	4.5	4.8 B	6.5	1.2	0.8	2.8	0.0	0	0	84.0 AB
FMC-1	1.0 BC	4.8	5.8 B	3.2	1.2	3.8	0.2	0.0	0.2	0	86.2 AB
FMC-2	2.2 B	4.8	7.0 AB	3.2	7.8	1.2	0.5	2.2	0.2	0	79.0 BC
untreated	12.2 A	2.8	15.0 A	6.0	4.2	2.2	2.8	0.0	0.8	0	69.5 C
P (treatment effect)	*<0.0001*	*0.41*	*0.0253*	*0.08*	*0.0578*	*0.48*	*0.17*	*0.54*	*0.34*	*0.45*	*0.0036*

[a] Values shown are actual percentages but ANOVA based on transformed values.

[b] Within each column, means followed by same letter are not significantly different (*P*>0.05); mean separations by LSD.

Table 5. Woolly apple aphid and rosy apple aphid infestation on 'Red Delicious' apple trees, Columbus, Ohio, 2018, as detected by scouting in early summer.

Treatment	Presence or absence of woolly apple aphid (0 = absent; 1 = present)[a] on two sampling dates		Number of clusters infested with rosy apple aphid per tree on two sampling dates	
	5/22 (3 trees/plot)	6/10 (1 tree per plot)	5/22 (3 trees/plot)	6/10 (1 tree per plot)
FMC-3	0.00	0.25	0	0
FMC-2	0.08	0.00	0	0
standard	0.08	0.00	0	0
FMC-1	0.17	0.00	0	0
FMC-4	0.25	0.25	0	0
untreated	0.33	0.00	0	0
Probability for treatment effect	*P = 0.52*	*P = 0.60*	-	-

[a] Values shown are actual proportions but ANOVA based on transformed values.

Table 6. Green apple aphid and potato leafhopper on terminal shoots of 'Red Delicious' apple trees, Columbus, Ohio, 2018, as detected by scouting in early summer.

Treatment	Percentage[a] of terminal leaves infested by green apple aphid on three sampling dates			Number of leafhoppers per leaf on three sampling dates		
	5/22	6/08	6/20	5/22	6/08	6/20
standard	1.5	0.0	0.0	0	0.45	0.055
FMC-4	3.0	8.5	8.0	0	0.06	0.060
FMC-2	2.0	1.0	4.5	0	0.31	0.065
untreated	0.0	1.5	2.0	0	0.62	0.065
FMC-3	3.5	2.0	5.5	0	0.40	0.075
FMC-1	6.5	2.5	7.0	0	0.38	0.095
Probability for treatment effect	*P = 0.18*	*P = 0.31*	*P = 0.54*	-	*P = 0.064*	*P = 0.94*

[a] Values shown are actual percentages but ANOVA based on transformed values.

Table 7. Predators associated with green apple aphid and potato leafhopper on terminal shoots of 'Red Delicious' apple trees, Columbus, Ohio, 2018, as detected by scouting in early summer.

Treatment	Number of predators per leaf on terminal shoots						
	5/22			6/08		6/20	
	Orius (nymphs)[a]	Lady beetle (adults)	Lacewing (adults)	*Orius* (nymphs + adults)	Lady beetle (adults)	Orius (nymphs + adults)	Spiders
FMC-2	0.01 A	0.000	0.000	0.005	0.000	0.010	0.015
FMC-4	0.00 B	0.020	0.000	0.015	0.005	0.020	0.005
untreated	0.00 B	0.005	0.005	0.010	0.010	0.020	0.005
FMC-3	0.00 B	0.000	0.000	0.005	0.000	0.015	0.025
standard	0.00 B	0.000	0.000	0.010	0.000	0.010	0.000
FMC-1	0.00 B	0.000	0.000	0.010	0.000	0.000	0.000
Probability for treatment effect	*P = 0.045*	*P = 0.15*	*P = 0.45*	*P = 0.90*	*P = 0.13*	*P = 0.59*	*P = 0.33*

[a] Within each column, means followed by same letter are not significantly different (P>0.05); mean separations by LSD.