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ENTOMOLOGY RESEARCH REPORT - 2013

Field evaluations of registered and experimental insecticides for managing Colorado potato beetle on potatoes

The Colorado potato beetle (*Leptinotarsa decemlineata*, Say, Coleoptera: Chrysomelidae) is the most widespread and destructive insect pest of potato crops in the eastern United States and Canada. Its ability to develop resistance to insecticides makes it very important to continue testing the efficacy of both new insecticide chemistries and existing compounds. Such tests provide data on comparative effectiveness of products and data to help support future registrations and use recommendations.

METHODS

Fifteen insecticide treatments and an untreated check (Table 1) were tested at the MSU Montcalm Research Farm, Entrican, MI for control of Colorado potato beetle. 'Atlantic' potato seed pieces were planted 12 in. apart, with 34 in. row spacing on 3 June 2012. Treatments were replicated four times in a randomized complete block design. Plots were 50 ft. long and three rows wide with untreated guard rows bordering each plot.

Brigadier 2SC, Verimark 20SC, Admire Pro 4.6SC, and Platinum 75SG treatments were applied as in-furrow sprays at planting on 3 June 2013. Post-plant directed sprays were applied when potatoes first started emerging from the soil, on 10 June 2013. Foliar treatments were first applied at greater than 50% Colorado potato beetle egg hatch on 28 June 2013. Based on the economic threshold of more than one large larva per plant, additional first generation sprays were needed for Gladiator (11 and 18 July), Athena (11 July), Blackhawk (11 July), the low rate of Torac 15 EC (11 July), and Admire Pro (11 and 18 July); no subsequent applications were necessary for any of the Dupont treatments. All applications were made using a single-nozzle hand-held boom (30 gallons/acre and 30 psi).

Post-spray counts of first generation Colorado potato beetle adults, small larvae (1^{st} and 2^{nd} instars), and large larvae (3^{rd} and 4^{th} instars) from five randomly selected plants from the middle row of each plot were made weekly, starting on 2 July. Plots were visually rated for defoliation weekly by estimating total defoliation per plot.

The numbers of small larvae, large larvae, and adults, as well as the defoliation ratings, were transformed log (x + 1) prior to analysis. Analysis of variance was used for data analysis and ad-hoc Tukey means separation was used to compare treatment means ($P < 0.05$).

RESULTS

Except for Admire Pro and Athena, all treatments resulted in significantly fewer small larvae than the untreated control, while all treatments significantly reduced the number of large larvae per plant, compared to the untreated (Table 2). There were also significant differences in numbers of large larvae among the insecticide treatments. All three systemic products (Admire Pro, A16901, and Platinum 75 SG) performed well, with A16901 having significantly fewer large larvae than six of the foliar products. Among the foliar products, Admire Pro required weekly sprays, while F9318 and the low rate of Torac 15 EC were applied three of the four weeks. Athena, Blackhawk, and the high rate of Torac 15 EC required one subsequent application, all two weeks after the initial application. Of these, however, only Blackhawk provided reduction in average large larvae below the threshold of one per plant. Despite one fewer application for the high rate of Torac 15 EC, no significant differences in beetle life stages or defoliation were noted between the high and low rates for this product. All three Benevia 10 OD treatments required only the initial foliar application to provide first generation beetle control.

The untreated plots had significantly greater defoliation compared to all other treatments. The seasonal defoliation average was 36.6% in the untreated plots, compared to less than 6% for all other treatments. Differences in defoliation among insecticide treated plots ranged from 1.1 to 5.9%. Neonicotinoid insecticides are still providing sufficient Colorado potato beetle control for Michigan farmers, but new chemistries like Benevia 10 OD are also proving to be effective.

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Table 1. Insecticide treatments for Colorado potato beetle management in a field trial conducted by MSU vegetable entomology in 2013.

Trt #	Commercial Name	Manufacturer	Formulation	Active Ingredient	Chemical Class	Rate	Type	Application Dates in 2013*
1	Untreated							
2	Brigadier 2SC	FMC	2 SC	bifenthrin	pyrethroid	25.6 oz/A	at planting	6/3
	Gladiator	FMC	0.25 EW	abamectin, z-cypernethrin	avermectin, pyrethroid	14 oz/A	foliar	6/28, 7/18
3	Capture LFR	FMC	1.5 SC	bifenthrin	pyrethroid	25.6 oz/A	at planting	6/3
	Admire PRO	FMC	4.6 SC	imidacloprid	neonicotinoid	5.22 oz/A	post-plant, directed	6/19
	Athena	FMC	0.87 EW	abamectin, bifenthrin	avermectin, pyrethroid	16 oz/A	foliar	6/28, 7/11
4	Brigadier 2 SC	FMC	2 EC	bifenthrin, imidacloprid	pyrethroid, neonicotinoid	25.6 oz/A	post-plant, directed	6/19
	Gladiator	FMC	0.25 EW	abamectin, z-cypernethrin	avermectin, pyrethroid	14 oz/A	foliar	6/28, 7/11
5	Verimark	Dupont	20SC	cyazypyr	diamide	13.5 oz /A	at planting	6/3
	Asana XL	Dupont	0.66 EC	esfenvalerate	pyrethroid	9.6 oz/A	foliar	6/28
6	Exirel	Dupont	10 SE	cyazypyr	diamide	5 oz/A	foliar	6/28
7	Platinum	Syngenta	2 SL	thiamethoxam	neonicotinoids	8 oz/A	at planting	6/3
	Benevia	Dupont	10 OD	cyazypyr	diamide	5 oz/A	foliar	6/28
8	Platinum	Syngenta	2 SL	thiamethoxam	neonicotinoids	8 oz/A	at planting	6/3
9	Benevia +	Dupont	10 OD	cyazypyr	diamide	5 oz/A	foliar	6/28
	MSO			methylated seed oil	surfactant	0.5% v/v		
10	Benevia +	Dupont	10 OD	cyazypyr	diamide	5 oz/A	foliar	6/28
	MSO			methylated seed oil	surfactant	0.5% v/v		
11	Exirel	Dupont	10 SE	cyazypyr (cyatraniliprole)	diamide	6.75 oz/A	foliar	6/28
12	Admire PRO	Bayer	4.6 SC	imidacloprid	neonicotinoid	1.3 oz/A	foliar	6/28, 7/11, 7/18
13	Blackhawk	Dow	36	spinosad	spinosyns	3.2fl oz/A	foliar	6/28, 7/11
14	Torac	Nichino	15 EC	tolfenpyrad	pyrazoles	14 oz/A	foliar	6/28, 7/11
15	Torac	Nichino	15 EC	tolfenpyrad	pyrazoles	21 oz/A	foliar	6/28
16	Admire PRO	Bayer	4.6 SC	imidacloprid	neonicotinoid	7 oz/A	at planting	6/3

* First foliar application was made at 50% egg-hatch, all subsequent foliar applications are based on 1 large larva per plant threshold.

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Table 2. Mean Colorado potato beetle (CPB) per plant by date in the 2013 MSU vegetable entomology field trial. The bold numbers in the top row correspond to the treatment numbers in Table 1. Bold letters in the green colored 'small and large larvae' rows at the bottom of the table indicate significant differences among the treatments, Tukey HSD (α = 0.05).

date	Mean CPB	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**TOTAL**
2-Jul	intact egg masses	0.7	0.7	0.25	0.5	0.5	0.3	0	0.15	0.5	0.7	0.25	0.9	0.8	0.6	0.45	0.6	0.52
	hatched egg masses	0	0	3.2	0.55	0	2.45	0	0	0.2	0.3	3.55	2.4	0	0.8	0	0.7	0.92
	small larvae	7.1	0	0.05	0.5	0	0.7	0	0	1.15	0.25	0.75	0.45	0.65	0.9	1	0	0.79
	large larvae	1.35	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.09
	adults	0.3	0.1	0.1	0.15	0.1	0.25	0.15	0.55	0.15	0.05	0.15	0.4	0.2	0.05	0.05	0.25	0.19
5-Jul	intact egg masses	0.85	0.55	0.4	0.95	0.6	0.3	0	0	0.2	0.25	0.65	1	0.3	0.7	0.2	1.1	0.49
	hatched egg masses	1.05	2.2	3.9	0.1	1.3	2.75	0	0	2.45	2.05	1.95	3.05	0	0.25	0.45	0.05	1.52
	small larvae	2.5	0.25	1.25	5.35	0.35	0.15	0	0	0.25	0.05	0	3.65	0.4	1.25	0.3	0.1	0.94
	large larvae	2.95	0	0	0	0	0	0	0	0	0	0	0.3	0.05	0.15	0	0.15	0.21
	adults	0.55	0.35	0.35	0.35	0.75	0.3	0.25	0.1	0.15	0.2	0.1	0.2	0.25	0.1	0.05	0.1	0.26
10-Jul	intact egg masses	0.65	0.35	0.15	0.5	0.15	0.15	0.05	0	0.15	0.5	0.15	0.1	0.25	0.25	0.4	0.4	0.25
	hatched egg masses	2.05	0	1.05	0.2	0.55	0.1	0	0	0.8	0	0	1.9	0	1.25	0.6	0	0.61
	small larvae	7.85	0.7	1.9	3.15	0.35	0.3	0	0	0.8	1.35	0.5	4.7	1.9	1.25	1.55	3.45	2.09
	large larvae	10.7	0.3	1.1	3.15	0	0.05	0	0	0	0	0.05	6.95	1.45	2	0.1	0.9	1.66
	adults	0	0.25	0.35	0.25	0.25	0.3	0.3	0.1	0.15	0.25	0.25	1.25	0.3	0.1	0.1	0.2	0.26
17-Jul	intact egg masses	0	0	0	0	0.05	0.05	0	0	0.15	0	0.05	0	0.05	0	0.2	0.15	0.04
	hatched egg masses	0	0	0	0	0.25	0	0	0	0.7	0	0.4	0	0	0.25	0.55	0	0.13
	small larvae	2.05	0.65	0.15	0.65	0.05	0.45	0	0.1	0.5	0.6	0.6	0.45	0.05	0.1	0.45	1.35	0.54
	large larvae	4.05	1.65	0.3	1.25	0.25	0.6	0	0	0.25	0.8	0.55	1.35	0	0.75	0.3	1.1	0.93
	adults	0	0	0	0.05	0.05	0.1	0	0.15	0	0	0	0.05	0.05	0	0	0	0.03
24-Jul	intact egg masses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
	hatched egg masses	0	0	0	0	0	0.2	0.15	0	0	0	0	0	0.25	0.65	0	0	0.07
	small larvae	0.35	0.4	0.1	0.3	0.45	0.25	0	0.1	0.5	0.55	0.5	0	0.05	0	0.2	0	0.22
	large larvae	0.8	0.45	0.65	0.65	0.05	0.1	0	0	0.55	0.6	0.45	0	0.15	0.2	0.6	0	0.31
	adults	1.35	0.15	0.1	0.25	0.1	0.15	0.1	0.15	0	0.1	0.2	0.25	0.2	0.25	0.2	0.1	0.23
TOTAL	intact egg masses	0.44	0.32	0.16	0.39	0.26	0.16	0.01	0.03	0.2	0.29	0.22	0.4	0.28	0.31	0.25	0.45	0.26
	hatched egg masses	0.62	0.44	1.63	0.17	0.42	1.1	0.03	0	0.83	0.47	1.18	1.47	0.05	0.64	0.32	0.15	0.65
	small larvae	**3.97a**	**0.4bc**	**0.69bc**	**1.99b**	**0.24bc**	**0.37bc**	**0c**	**0.04c**	**0.64bc**	**0.56bc**	**0.47bc**	**1.85b**	**0.61bc**	**0.7bc**	**0.7bc**	**0.98bc**	**0.92**
	large larvae	**3.97a**	**0.48bc**	**0.41bc**	**1.01bc**	**0.06c**	**0.15c**	**0c**	**0c**	**0.16c**	**0.28bc**	**0.21c**	**1.72b**	**0.33bc**	**0.62bc**	**0.22c**	**0.43bc**	**0.64**
	adults	0.44	0.17	0.18	0.21	0.25	0.22	0.16	0.21	0.09	0.12	0.14	0.43	0.2	0.1	0.08	0.13	0.19

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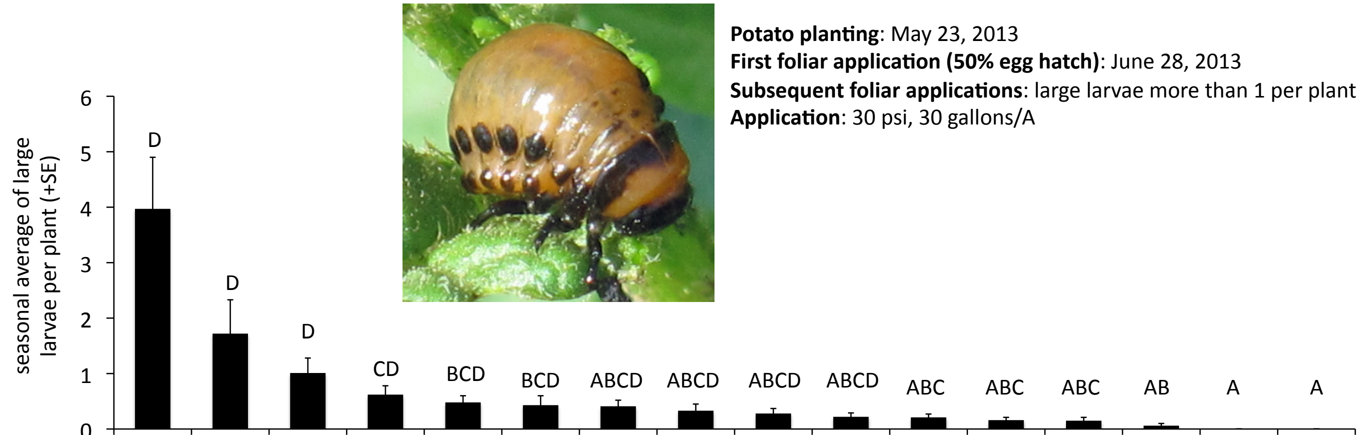
Overwintering generation Colorado potato beetle insecticide trial

Potato planting: May 23, 2013
First foliar application (50% egg hatch): June 28, 2013
Subsequent foliar applications: large larvae more than 1 per plant
Application: 30 psi, 30 gallons/A



treatment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
at-planting	-	-	-	-	Brigadier 25.6 oz/A	Admire Pro 7 oz/A	Capture 25.6 oz/A	-	-	-	-	-	-	Verimark 13.5 oz/A	Platinum 8 oz/A	Platinum 8 oz/A
at-cracking	-	-	Brigadier 25.6 oz/A	-	-	-	Admire Pro 5 oz/A	-	-	-	-	-	-	-	-	-
foliar	-	Admire Pro 1.3 oz/A (3)	Gladiator 14 oz/A (2)	Torac 14 oz/A (2)	Gladiator 14 oz/A (2)	-	Athena 16 oz/A (2)	Black-hawk 3.2 oz/A (2)	Benevia 5 oz/A (1) *	Torac 21 oz/A (1)	Exirel 6.7 oz/A (1)	Benevia 5 oz/A (1) *	Exirel 5 oz/A (1)	-	Benevia 5 oz/A (1)	-

*two different formulations

Note: Numbers in parentheses are the number of foliar applications needed to keep first generation CPB below threshold.
Bars with the same letters are not statistically different from each other.

Benevia, Exirel, Verimark, Torac – not currently registered

Summary of 2013 CPB insecticide trial results, Moncalm Potato Research Farm.

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Susceptibility of Colorado potato beetle populations to imidacloprid and thiamethoxam

Imidacloprid (i.e.: Admire Pro) and thiamethoxam (i.e.: Platinum, Actara) continue to be the most common means of Colorado potato beetle management. Today, greater than 75% of the commercial potato acres in the northeastern and midwestern United States are protected by these compounds (NASS 2006). Such consistent and heavy dependency on any compound sets the stage for resistance development. Further complicating the issue is the availability of generic imidacloprid formulations; these formulations drive down product cost, which will likely lead to even greater field exposure to these compounds. All of these reasons strongly support the need to continue monitoring resistance development and to encourage growers to adopt resistance management strategies.

Our objective was to continue gathering data on susceptibility to imidacloprid and thiamethoxam in Colorado potato beetle populations collected from commercial potato fields in Michigan and other regions of the United States. To accomplish this objective, Colorado potato beetle populations were bioassayed with imidacloprid and/or thiamethoxam.

METHODS

During 2013, 11 Colorado potato beetle populations were collected from Michigan. Cooperators also provided populations from New York (1), Maine (1), and Virginia (3). One susceptible laboratory strain was also tested (Table 3). To assure only healthy beetles were tested, newly received beetles were maintained at room temperature and 16:8 L:D photoperiod and fed pesticide-free, greenhouse-grown potato foliage for 3-7 days before they were used in the bioassay.

Adult Colorado potato beetles were treated with 1 µl of acetone/insecticide solution of known concentration applied to the ventral surface of the abdomen using a 50 µl Hamilton® microsyringe. Two populations with known resistance issues (Jamesport, NY and Tuscola, MI) required two applications of 1 µl of acetone/insecticide solution per beetle to achieve the desired dose (ie., 1 µl of 20.0 µg/µl plus 1 µl of 10.0 µg/µl to get a dose of 30.0 µg/µl). A range of four to 11 concentrations, plus an acetone-only control, was selected for each population, depending on the number of available beetles and known resistance history for each population. In each bioassay, 27-40 adults were treated with each concentration (nine to 10 beetles per dish and three to four dishes per concentration). Following treatment, beetles were placed in 100 mm diam. Petri dishes lined with Whatman® No. 1 filter paper and provided with fresh potato foliage. They were kept at 25±1°C and the foliage and filter paper were checked daily and changed as needed.

Beetle response was assessed 7 days post treatment. A beetle was classified as dead if its abdomen was shrunken, it did not move when its legs or tarsi were pinched, and its elytra were darkened. A beetle was classified as walking and healthy if it was able to grasp a pencil and walk forward normally. A beetle was classified as poisoned if its legs were extended and shaking, it was unable to right itself or grasp a pencil, and it was unable to walk forward normally at least one body length. Beetles that had died due to *Beauvaria* spp. infection were excluded from analysis; these beetles were easily recognized by their pale, petrified appearance and/or presence of white filamentous fungi. Dead and poisoned beetle numbers were pooled for analysis. Data were analyzed using standard log-probit analysis (SAS Institute, 2009).

RESULTS

The LD_{50} value (dose lethal to 50% of the beetles) for the susceptible laboratory strain was 0.042 µg/beetle for imidaclorid and 0.054 µg/beetle for thiamthoxam (Table 4).

The LD_{50} values from the field for imidacloprid ranged from 0.215 µg/beetle (Sackett Potatoes Field 2) to 4.435 µg/beetle (Sackett Ranch LJ7) for Michigan populations. The imidacloprid LD_{50} values for the out-of-state populations ranged from 0.088 µg/beetle (Aroostook, Maine) to 0.496 (Jamesport, NY). LD_{50} values for imidacloprid for all populations were significantly higher than the susceptible laboratory strain. In 2013, 60% of the Michigan samples were greater than 10-fold resistant to imidacloprid, compared to 75% in 2012, 57% in 2011, 60% in 2010, and 85% in 2009.

The LD_{50} values for thiamethoxam in Michigan ranged from 0.044 µg/beetle (Main Farms H6) to 0.478 µg/beetle (Kalkaska), and from 0.002 µg/beetle (Montgomery, VA) to 0.496 µg/beetle (Jamesport, NY) for out-of-state populations. None of the populations were greater than 10-fold resistant to thiamethoxam.

Table 3. Colorado potato beetle populations tested for susceptibility to imidacloprid and thiamethoxam in 2013.

Michigan populations

Anderson Brothers Field 23 Summer adults were collected on 12 Aug 2013 by Mark Otto, Agri-Business Consultants, Inc., from commercial potato fields in Montcalm County.

Kalkaska Summer adults were collected on 31 July 2013 from a commercial potato field near Kalkaska MI.

Main Farms Summer adults were collected by Mark Otto, Argi-Business Consultants, Inc. from commercial potato fields in Mecosta and Montcalm Counties.

Field C10 Adults were collected on Aug 7 2013.
Field H6 Adults were collected on June 28 2013.
Field R6 Adults were collected on July 30 2013.

Sackett Potatoes

Sackett Potatoes Field 2 Adults were collected on June 14 2013.
Sackett Potatoes Field 19 Adults were collected on June 14 2013.
Sackett Potatoes Field 26 Adults were collected on Aug 19 2013.
Sackett Potatoes Field 150-1 Adults were collected on June 24 2013.

Sackett Ranch

Sackett Ranch LJ7 Adults were collected on June 25 2013.
Sackett Ranch LJ7 Adults were collected on July 23 2013.
Sackett Potatoes Field 26 Adults were collected on Aug 19 2013.
Sackett Potatoes Field 150-1 Adults were collected on June 24 2013.

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Table 4. LD_{50} values (µg/beetle) and 95% fiducial limits for Colorado potato beetle populations treated with imidacloprid and thiamethoxam, 7 days post treatment.

IMIDACLOPRID

Michigan Populations	**LD_{50} (ug/beetle)**	**95 % confidence intervals**
Anderson Brothers Field 23*	0.370	0.184 - 0.593
Kalkaska*	4.119	1.879 - 16.505
Main Farms C10*	1.088	0.076 – 4.344
Main Farms H6^	0.536	0.386 – 0.697
Main Farms R6*	1.843	1.039 - 2.791
Sackett Potatoes Field 2^	0.215	0.104 – 0.353
Sackett Potatoes Field 19^	0.469	0.140 – 0.926
Sackett Potatoes Field 26*	0.301	0.118 – 0.570
Sackett Potatoes Field 150-1^	0.493	0.274 – 0.693
Sackett Ranch LJ7 ^	0.665	0.309 – 1.102
Sackett Ranch LJ7 *	4.435	3.283 – 6.103
Out of State Populations		
Aroostook, Maine*	0.088	0.051 – 0.129
Jamesport, New York^	5.577	3.829 – 6.971
Modestown, VA^	0.655	0.507 – 0.857
Painter, VA^	0.081	0.057 – 0.110
Montgomery, VA(Whitehorne)*	0.089	n/a
Laboratory strain		
New Jersey	0.042	0.037 – 0.055

THIAMETHOXAM

Michigan Populations	**LD_{50} (ug/beetle)**	**95 % confidence intervals**
Anderson Brothers Field 23*	0.122	0.085 – 0.168
Kalkaska*	0.478	0.291 – 0.816
Main Farms C10*	0.207	0.094 – 0.455
Main Farms H6^	0.044	0.020 – 0.080
Main Farms R6*	0.177	0.051 – 0.327
Sackett Potatoes Field 2^	0.182	0.132 – 0.236
Sackett Potatoes Field 19^	0.206	n/a
Sackett Potatoes Field 26*	0.111	0.054 – 0.199
Sackett Potatoes Field 150-1^	0.071	0.041 – 0.101
Sackett Ranch LJ7 ^	0.177	0.133 – 0.225
Sackett Ranch LJ7 *	0.377	n/a
Out of State Populations		
Aroostook, Maine*	0.021	0.014 – 0.03
Jamesport, New York^	0.496	0.376 – 0.620
Modestown, VA^	0.294	0.244 – 0.334
Painter, VA^	0.050	0.289 – 0.070
Montgomery, VA(Whitehorne)*	0.002	n/a
Laboratory strain		
New Jersey	0.054	0.0357 – 0.0947

^ Overwintered generation
* Summer generation

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Molecular genetic mechanisms of CPB insecticide resistance

In 2013 we identified numerous genes that play a role in CPB insecticide resistance using our laboratory CPB populations and RNA sequencing. We developed primers for some of the genes of interest and investigated the level of gene expression using real-time PCR method (MSU Research and Technology Support Facility). We determined that a selection event with an insecticide causes over-expression of these genes, which confirmed that these genes are truly involved in the insecticide resistance mechanism, and we also compared these genes in different populations. These results showed that in geographically different populations (MI vs. NY, both imidacloprid resistant) different genes have evolved to play a role in insecticide resistance (see figure below).