Michigan Vegetable Insecticide Evaluation Studies

2012

Vegetable Entomology Insecticide Evaluation Studies
2012

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ACKNOWLEDGEMENTS

We would like to thank everyone involved in these research projects.

Asparagus:

John Bakker	Michigan Asparagus Advisory Board
Gerald Malberg	Malburg Farms, Hart, MI
Rob Morrison	Department of Entomology, MSU
Norm Myers	MSU Extension, Oceana County, MI
Beau Shacklette	TRICKL-EEZ Company

Cabbage:

Bill Chase	MSU Horticulture and Teaching Research Center
Dave Miedema	Elmer Miedema & Sons, Byron Center, MI

Carrots:

Mitch Fabus	MSU Muck Soils Research Farm, Bath, MI

Celery:

Mark Cnossen	Cnossen Farms, Wayland, MI
Mitch Fabus	MSU Muck Soils Research Farm, Bath MI
Jake Wilbrandt	Wilbrandt Farms, Decatur, MI

Onions:

Larry Krummrey	Krummrey Farms, Stockbridge, MI
Dr. Brian Nault	Department of Entomology, Cornell University

Potatoes:

Dr. Andrei Alyokhin	School of Biology and Ecology, University of Maine
Dr. Dave Douches	Department of Crop and Soil Sciences, MSU
Dr. Thomas Kuhar	Department of Entomology, Virgina Tech
Chris Long	Department of Crop and Soil Sciences, MSU/MPIC
Sandy Menasha	Cornell Cooperative Extension, NY
Mark Otto	Agri-Business Consultants, Lansing, MI
Bruce Sackett	Montcalm Research Farm, Entrican, MI
Brice Stine	Walther Farms, Cass City, MI

Thanks also to the chemical companies and their representatives for supporting these projects.

Bayer CropSciences	Bill DeWeese
Dow AgroSciences	Bradley Hopkins
DuPont	Scott Bishop and Marsha Martin
FMC Corporation	Joseph Reed
Gowan Company	Paul David
Nichino America	Dr. James Adams
Syngenta Crop Protection	Dr. Venance Lengkeek

Evaluation of systemic and foliar insecticides for control of asparagus miner in asparagus

The asparagus miner is a putative vector for pathogenic species of Fusarium fungus, which is the causative agent for "early decline syndrome" in asparagus fields. Fusarium can decrease the life span of an asparagus field by 5-8 years, making it economically unsustainable to continue production. So, it's important to explore options for controlling the asparagus miner.

METHODS

On 16 April 2012, the MSU vegetable entomology lab planted a new experimental asparagus field in Hart, MI. 'Millenium' crowns were planted at 7 inch spacing into 21 rows (140 feet long). Plots were single rows at 35 feet, separated from each other by single buffer rows. This design allowed for 10 treatments, each replicated four times.

On 22 May 2012, subsoil drip irrigation lines were installed just slightly offset from the initial furrow. Drip lines originated at the north end of the plot and were crisscrossed between blocks to allow only one line for each treatment (ie., the same line runs through all four replications). At the beginning of each drip line was an injection port for applying insecticides. These individual injection ports allowed for quick application of insecticides and prevented backflow/intermixing of chemicals into the main irrigation line, and thus, into other plots.

Nine insecticide treatments and two application methods (chemigation through drip irrigation and foliar spray) were tested (Table 1). None of the insecticides used in this trial are currently registered for use on asparagus. Drip treatments were applied twice during the season, on 22 May and 13 July. A red dye was used to indicate when the compound had completely moved through the lines. The first foliar applications of Movento were made on 7 June, with a second application required 7 days later for one treatment and 14 days later for the other treatment . Foliar treatments were applied using a single-nozzle hand-held boom at 30 gallons/acre and 30 psi. The adjuvant MSO was applied with Movento at a rate of 0.5% v/v.

Sampling for asparagus miner was conducted weekly by counting the total number and number of damaged stems per plot. The percent number of damaged stems was arcsine transformed prior to statistical 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

The two Movento 240 SC treatments resulted in no significant reduction in the percent number of damaged stems, compared to the untreated control. In 2010 and 2011, data suggested that Movento might be used to suppress asparagus miner damage early in the season, so these results were unexpected. However, a different surfactant was used this year (MSO instead of Dyne-Amic), so future work should investigate whether efficacy is tied to the specific surfactant used.

Among the seven drip treatments, five significantly reduced the percent number of damaged stems, compared to the untreated control (Fig. 1). Platinum 75 SG and Durivo, both of which contain thiamethoxam, were the only two products that provided a significant reduction of percent number damaged stems in comparison to other products, the high rate of Scorpion 35 SL and Coragen (both of which did not differ from the untreated control).

Future work will focus on improving the delivery of active ingredients into the asparagus stem. If both the surfactant issue with Movento 240 SC and the consistent uptake of these chemigation treatments can be improved, the combination of early season Movento 240 SC and mid- to late season chemigation applications offer promise for improved asparagus miner control.

Table 1. Treatment list with application modes, rates, and dates for asparagus trial conducted in Hart, MI, summer 2012.

Treatment	Insecticide class	Application mode	Rate	Application dates
Scorpion 35 SL	neonicotinoid	drip	10.5 fl oz./A	22 May, 13 July
Scorpion 35 SL	neonicotinoid	drip	13 fl oz./A	22 May, 13 July
Durivo	neonicotinoid + ryanodine receptor modulator	drip	13 fl oz./A	22 May, 13 July
Platinum 75 SG	neonicotinoid	drip	5.67 oz/A	22 May, 13 July
Coragen	ryanodine receptor modulator	drip	7.5 fl oz./A	22 May, 13 July
Admire Pro	neonicotinoid	drip	10.5 fl oz./A	22 May, 13 July
Admire Pro	neonicotinoid	drip	14 fl oz/A	22 May, 13 July
Movento 240 SC + MSO	acetyl CoA carboxylase inhibitor + adjuvant	foliar	8.0 fl oz./A + 0.5% v/v	7 & 14 June
Movento 240 SC + MSO	acetyl CoA carboxylase inhibitor + adjuvant	foliar	8.0 fl oz./A + 0.5% v/v	7 & 21 June
Untreated				

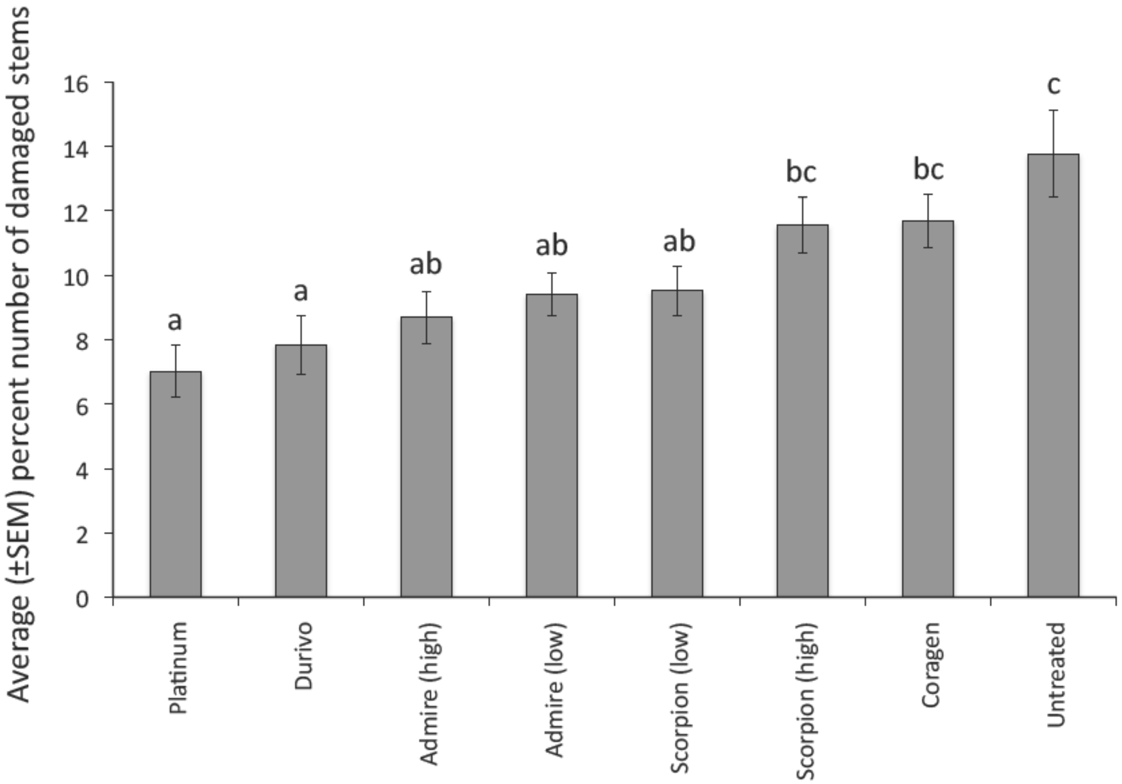


Figure 2. Mean percent asparagus stems damaged by asparagus miners during the 2012 field season. Bars with the same letter are not significantly different (α= 0.05).

Field evaluation of registered insecticides for managing caterpillars on cabbage

Cabbage has one of the longest developmental times among annual vegetable crops, with seeds planted indoors in March and harvest occurring in late Fall. During this time period in Michigan there are numerous insect pests that feed on cabbage, but because of low consumer tolerance for damage, stringent pest control tactics need to be in place to provide a high quality product. The cabbage insect pest complex consists of sporadic pests such as root maggots, thrips, aphids, flea beetles, cabbage loopers, and annual pests such as the imported cabbage worm and diamondback moth. Management strategies usually focus on the lepidopteran pests (loopers, imported cabbage worm, and diamondback moth), as they are consistently present and carry out multiple generations per season.

Natural enemies also contribute to pest control, however, broad-spectrum insecticides negatively impact beneficial insects, as well. The use of selective insecticides can contribute to an increase in biological control efficiency; therefore these two methods can be used simultaneously in an integrated pest management program to strengthen pest suppression. Thus, our objective was to compare a variety of registered insecticides that differ in their overall impact on beneficial insects.

METHODS

Four insecticide treatments and an untreated check (Table 1) were tested at the MSU Horticulture and Teaching Research Center, Holt, MI for control of caterpillars. Cabbage seeds, variety 'Blue Dynasty', were planted into 98-well flats on 12 April 2012. Baythroid XL was chosen as a disruptive product that would negatively impact beneficial insects; unlike other treatments, Baythroid XL was applied every two weeks. The remaining treatments were designed to be rotations between low- to moderately disruptive products that would be applied based on thresholds, however, low insect pressure resulted in only one of the treatments needing a second application during the season. Thresholds, measured in larval units, were derived using the system presented in the 2010 Ohio Vegetable Production Guide. Treatments were replicated four times in a randomized complete block design. Plots were 30 ft. long and four rows wide. Insecticides were applied using a single-nozzle hand-held boom (40 gallons/acre and 30 psi). All treatments were applied with Silwet L-77 at 0.25% v/v.

Number and size (small vs. large larvae) of caterpillars was recorded by species weekly from 10 randomly chosen plants in the middle two rows of each plot. On 30 August, a total of 20 cabbages from the two center rows of each plot were harvested, sorted as marketable (>4 inches in diameter) or non-marketable (diameter < 4 inches), and weighed. Data was log (x+1) transformed 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

All treatments significantly lowered caterpillar seasonal mean numbers compared to the untreated control (Fig. 1). Baythroid XL and Coragen resulted in the fewest number of caterpillars, while Avaunt was significantly outperformed by all the other insecticide treatments. Not surprising, the mean number of caterpillars was inversely related to the number of insecticide applications made during the season. Unfortunately, though, the low caterpillar pressure required only one application for the Avaunt treatment, while Coragen and Intrepid/Coragen treatments needed only two applications.

The seasonal mean number of beneficial insects also differed significantly between treatments (Fig. 2). The untreated control and Avaunt treatment resulted in significantly more beneficial insects compared to all other treatments. The treatments applied only twice (Intrepid/Coragen and Coragen treatments) had significantly more beneficial insects compared to the Baythroid XL treatment (which entailed five applications).

There were no differences between treatments for either the number of or weight of marketable cabbage. This could be due to the low caterpillar pressure, but it is also possible that increase in beneficial insects in untreated plots was able to keep pest pressure below economic threshold. Further work is needed to help determine the optimal number of insecticide applications, and the type of insecticides, in order to produce high quality marketable cabbage while also promoting an increase in beneficial insects in the field.

Table 1. Treatment list with impacts on beneficial insects, rates, and application dates for a cabbage trial conducted at the MSU Horticulture and Teaching Research Center, Holt, MI, summer 2012.

Treatment*	**Impact on beneficials**	**Rate**	**Application dates**
Baythroid XL	Disruptive	3.2 fl oz/A	25 Jun, 9 & 24 Jul, 6 & 21 Aug
Avaunt	Low/moderate	3.5 oz/A	25 Jun
Intrepid 2F Coragen	Low Low	16 fl oz/A 5 fl oz/A	25 Jun 24 Jul
Coragen	Low	3.5 fl oz/A	25 Jun & 24 Jul
Untreated			

*all treatments were applied in conjunction with Silwet L-77 at 0.25% v/v

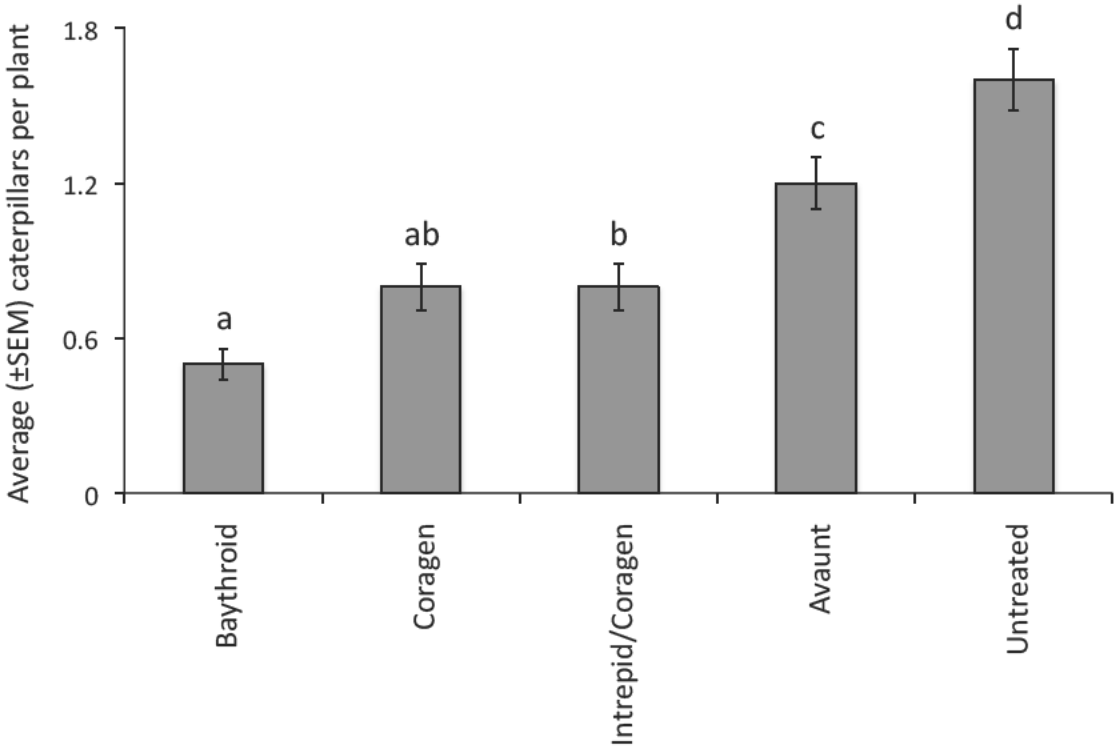


Figure 1. Impact of insecticide treatments on caterpillar numbers in a cabbage insecticide field-trial conducted by the MSU vegetable entomology laboratory. All products were applied in conjunction with the surfactant Silwet L-77 at 0.25% v/v. Bars with the same letter are not significantly different ($\alpha = 0.05$).

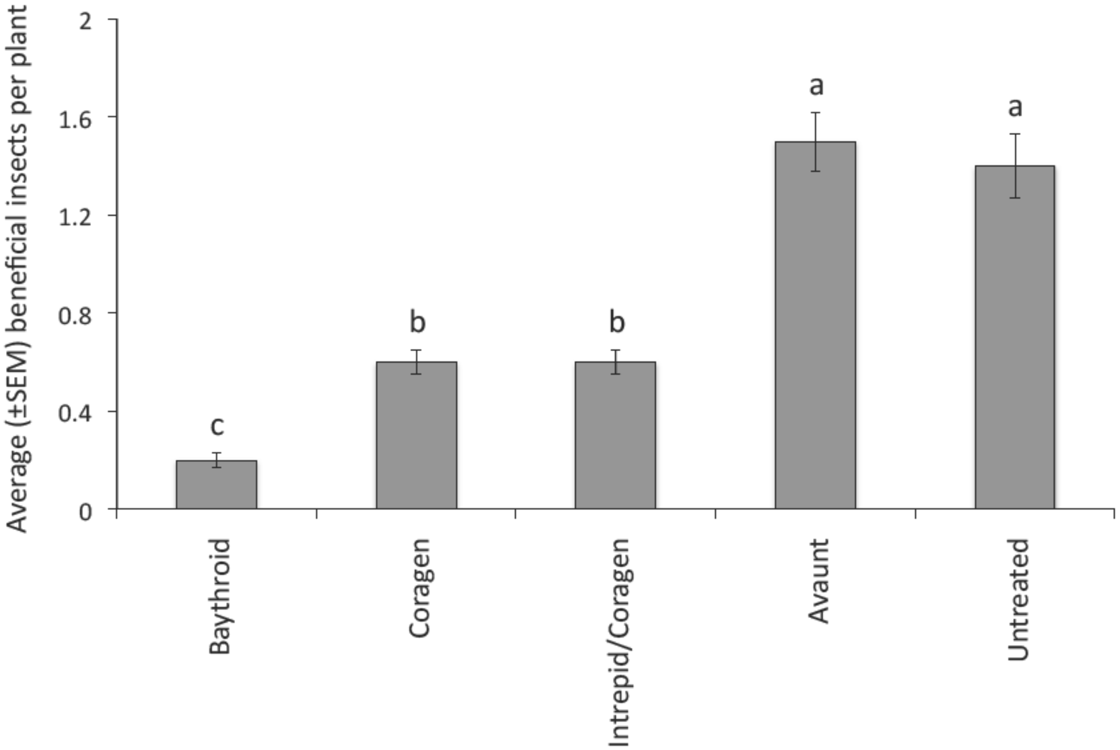


Figure 2. Impact of insecticide treatments on beneficial insect numbers in a cabbage insecticide field-trial conducted by the MSU vegetable entomology laboratory. All products were applied in conjunction with the surfactant Silwet L-77 at 0.25% v/v. Bars with the same letter are not significantly different (α= 0.05).

Field evaluation of registered and experimental insecticides for managing aster leafhoppers on carrots

Aster leafhoppers are a significant insect pest of carrots, primarily because they transmit *aster yellows phytoplasma*. Disease symptoms vary from crop to crop, but affected plants typically have distorted, discolored foliage, taste bitter, and are therefore unmarketable. Due to the wide range of host plants used by both the leafhoppers and phytoplasma, control or prevention of aster yellows is difficult. Current management practices rely on insecticides, making it important to evaluate both registered and experimental products for their efficacy in the field.

METHODS

Six insecticide treatments and an untreated check were tested at the MSU Muck Soils Research Farm in Bath, MI for control of aster leafhoppers. Carrot seeds, variety 'Carson', were planted on 5 June 2012. Treatments were replicated four times in a randomized complete block design. Plots were 50 ft. long and three rows wide.

Insecticides were applied on 24 July and 15 August 2012 using a single-nozzle hand-held boom (30 gallons/acre and 30 psi). The following products and rates were used: Actara (3 oz/acre), Admire Pro (1.2 fl oz/acre), Asana XL (9.6 fl oz/acre), pyrifluquinazon (3.2 fl oz/acre), Torac 15 EC (8 fl oz/acre (low) and 16 fl oz/acre (high)); pyrifluquinazon and both rates of Torac were applied with Induce at 0.25% v/v.

A single yellow sticky trap was placed in the center row of each plot and changed after 1, 3, 7, 11, 20, and 22 days following the first application and 2, 6, and 13 days after the second round of insecticide applications. The number of aster leafhoppers per trap was recorded and log (x+1) transformed 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

All products significantly lowered aster leafhopper seasonal mean numbers compared to the untreated control (Fig. 1). While performance of most products did not differ from one another, Asana XL significantly reduced the seasonal mean number of aster leafhoppers compared to Admire Pro and the high rate of Torac 15 EC. In early and mid-August, as leafhopper numbers started to increase, the two neonicotinoid products (Actara and Admire Pro) maintained low leafhopper abundance (Fig 2.), although there were no significant differences by date across treatments during this period.

Asana XL is an efficacious option currently available to carrot growers, especially given its relative low cost and efficacy, but the neonicotinoids may also be valuable products to use in rotation.

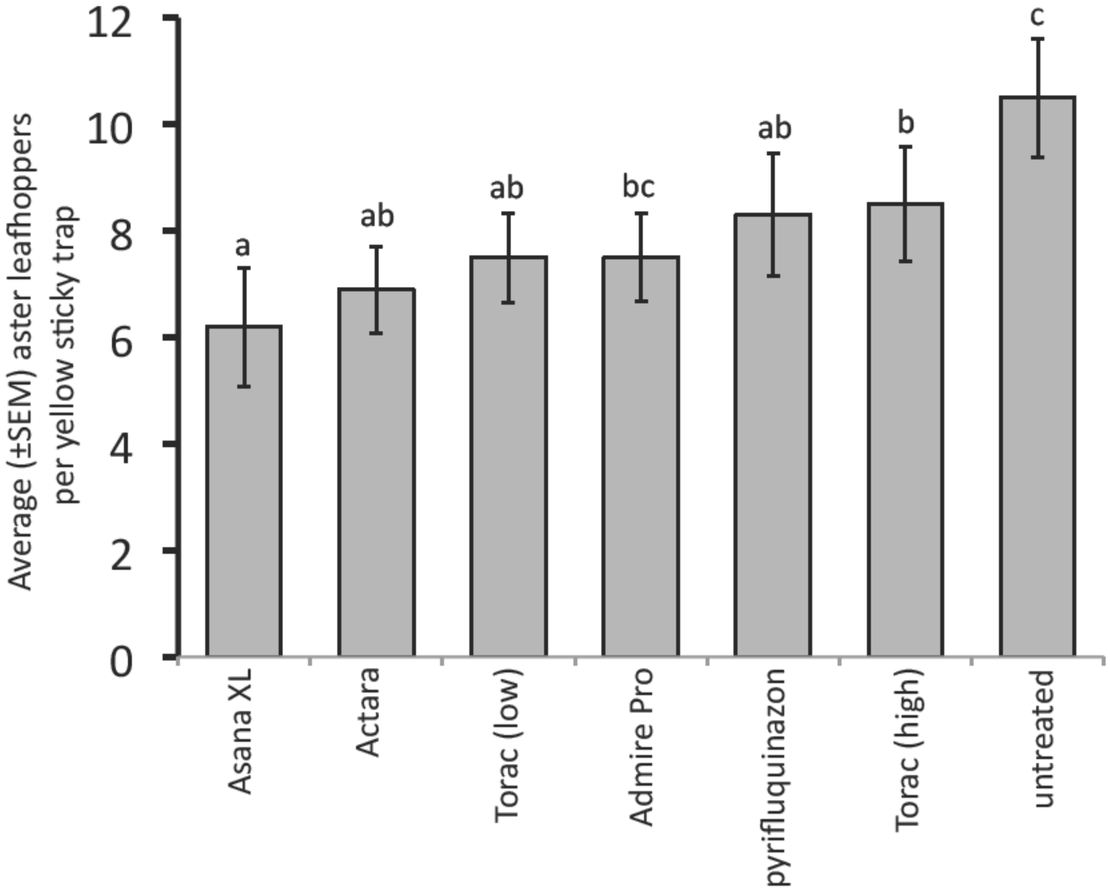
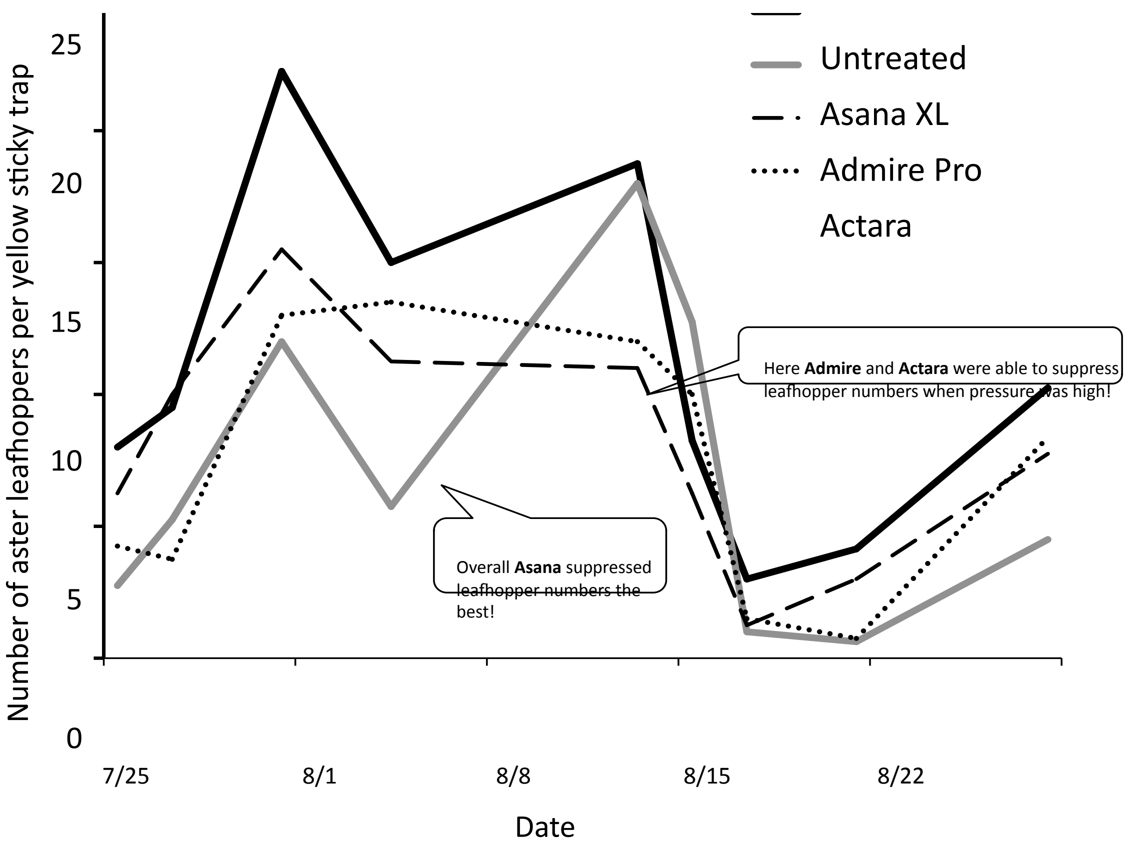


Figure 1. Impact of insecticide treatments on aster leafhopper numbers in a celery insecticide field-trial conducted by the MSU vegetable entomology laboratory. The following rates were applied: Asana XL (9.6 fl oz/acre), Actara (3 oz/acre), Torac 15 EC (low) + Induce (8 fl oz/acre + 0.25% v/v), Admire Pro (1.2 fl oz/acre), pyrifluquinazon + Induce (3.2 fl oz/acre + 0.25% v/v), and Torac 15 EC (high) + Induce (16 fl oz/acre + 0.25% v/v).



Here **Admire** and **Actara** were able to suppress leafhopper numbers when pressure was high!

Overall **Asana** suppressed leafhopper numbers the best!

Figure 2. Number of aster leafhoppers per yellow sticky trap over time in 2012 for Actara, Admire Pro, Asana XL, and the untreated control.

Field evaluation of registered insecticides for managing aphids on celery

Aphid infestations present an annual challenge to Michigan's celery growers. Aphid infestations can be spotty, making scouting difficult and more time intensive. Once present, aphid numbers can increase rapidly and lead to significant problems. Their feeding is focused on the newer growth, causing curled foliage that can stunt the plant. If aphids are present at harvest, it can lead to the rejection of a load for the fresh market.

Aphid control is difficult, especially since they situate themselves on the underside of the leaves and deep down in the heart of the plant where it's difficult to get good insecticide coverage. Nevertheless, current control practices rely heavily on insecticides, making it important to evaluate registered products for their efficacy in the field.

METHODS

Six insecticide treatments and an untreated control were tested on a commercial farm in southwest Michigan for aphid management; all of the products tested are currently registered for use on celery. The study site was selected due to the presence high aphid numbers. Celery plants at the time of the trial were mature, roughly 3-4 weeks away from being harvested. Treatments were replicated four times in a randomized complete block design. Plots were 15 ft. long and two rows wide.

All tested insecticides were applied with the penetrating surfactant Silwet L-77 at 0.5% v/v. Insecticides were applied on 29 August 2012 using a single-nozzle hand-held boom (50 gallons/acre and 30 psi). The following products and rates were used: Actara (3 oz/A), Beleaf (2.8 oz/A), Dimethoate 4EC (1 pt/A), Fulfill (2.75 oz/A), Lannate LV (3 pt/A), and Movento 240 SC (5 fl oz/A).

A second insecticide trial was set up at a different commercial farm in western Michigan. This trial tested whether Movento 240 SC performs better with or without the addition of a penetrating surfactant. Two treatments (Movento with and without Silwet) and an untreated check were replicated four times in a randomized complete block design. Plots were 30 ft. long and two rows wide.

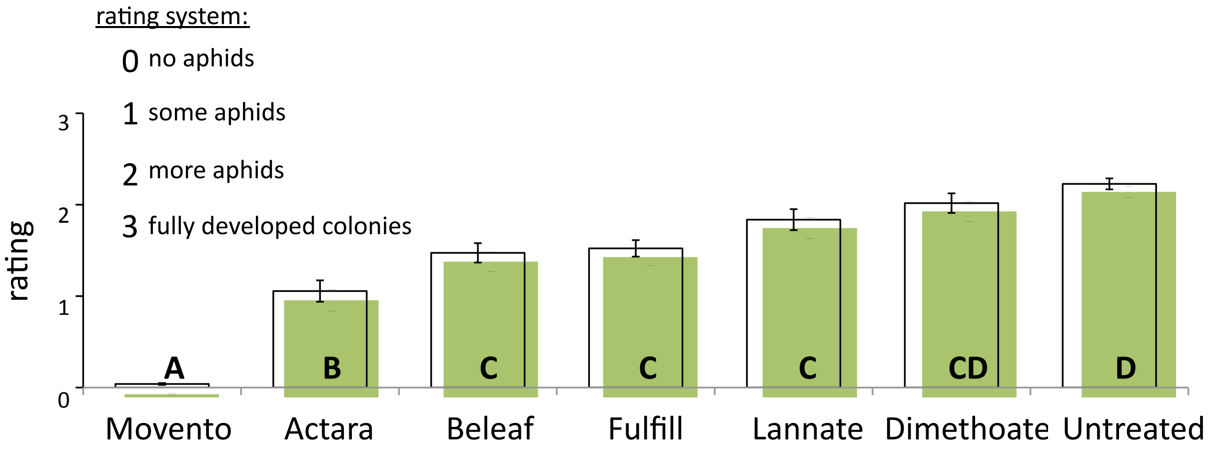
For both trials, we made visual evaluations of 20 randomly selected plants from each plot on 3, 7, 15, and 21 days post-application for the first insecticide trial and 7 and 10 days post-application for the second trial. Plants were rated based on the number of aphids present; 0 = no aphids, 1 = a few aphids, 2 = more aphids, and 3= fully developed colonies. Plant ratings were transformed log $(x+1)$ prior to statistical 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

Other than Dimethoate, all products significantly lowered aphid numbers compared to the untreated control (Fig. 1). Movento performed significantly better than all other tested products and was the only treatment that lowered aphid numbers to commercially acceptable levels. Actara resulted in a significantly lower aphid rating compared to all other products except Movento.

Movento with Silwet significantly lowered aphid numbers compared to the untreated control and Movento without Silwet treatment (Fig. 2). The Movento without Silwet treatment did not differ significantly from the untreated control.

While several insecticides were effective in lowering aphid numbers, Movento clearly outperformed all other compounds. However, if growers decide to use Movento, it's essential that it is applied with a penetrating surfactant.



Note: Different letters on bars denote significant differences in aphid rating.

Figure 1. Impact of insecticide treatments on aphid infested celery plants. All products were applied with 0.5% v/v Silwet (penetrating surfactant). The following rates were applied: Movento 240 SC (5 fl oz/A), Actara (3 oz/A), Beleaf (2.8 oz/A), Fulfill (2.75 oz/A), Lannate LV (3 pt/A), and Dimethoate 4EC (1 pt/A).

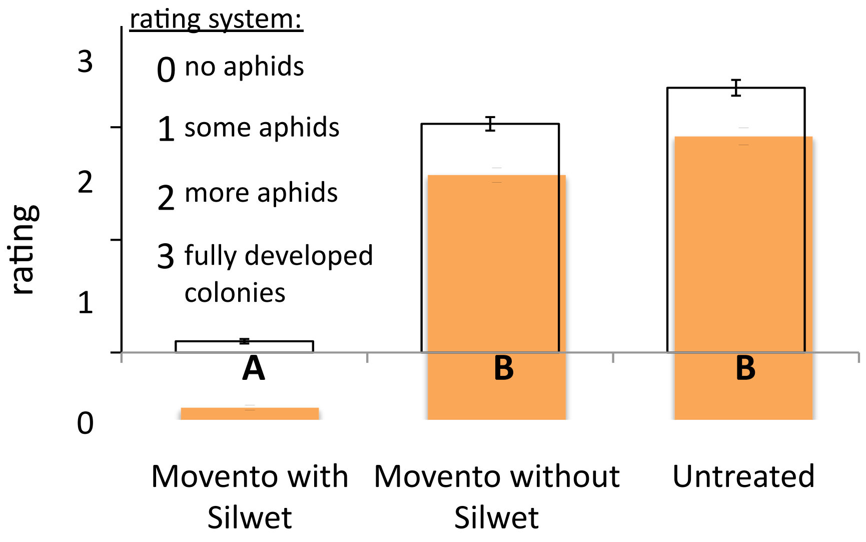


Figure 2. Suppression of aphid numbers on celery using Movento 240 SC with or without Silwet L-77 (a penetrating surfactant) in a field-trial conducted by the MSU vegetable entomology laboratory. Movento 240 SC was applied at 5 fl oz/acre and Silwet L-77 at 0.5% v/v.

Field evaluation of registered insecticides for managing aster leafhoppers on celery

Aster leafhoppers are a significant celery pest in Michigan because of their ability to infect plants with the aster yellows phytoplasma. Aster yellows disease can lead to severely stunted and yellow plants, bitter taste, and, thus, significant yield reduction. Due to the wide range of host plants used by both the leafhoppers and phytoplasma, control or prevention of aster yellows is difficult. Current practices rely heavily on insecticides, making it important to evaluate registered products for their efficacy in the field.

METHODS

Eight insecticide treatments and an untreated check were tested at the MSU Muck Soils Research Farm in Bath, MI for control of aster leafhoppers; all of the products tested are registered for use on celery. Celery transplants were planted on 5 June 2012. Treatments were replicated four times in a randomized complete block design. Plots were 25 ft. long and three rows wide.

Insecticides were applied on 18 July and 1 August 2012 using a single-nozzle hand-held boom (50 gallons/acre and 30 psi). The following products and rates were used: Acephate 97 UP (16 oz/acre), Actara (3 oz/acre), Baythroid XL (3.2 fl oz/acre), Lannate LV (3 pt/acre), Mustang Max (4 fl oz/acre), Scorpion 35SL (5.25 fl oz/acre), Sevin XLR Plus (1 qt/acre), and Voliam Flexi (7 oz/acre).

A single yellow sticky trap was placed in the center row of each plot and changed after 1, 5, and 13 days following the first application and 1, 3, 7, 12, and 16 days after the second round of insecticide applications. The number of aster leafhoppers per trap was recorded and log (x+1) transformed 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

Only Baythroid XL and Mustang Max significantly lowered aster leafhopper seasonal mean numbers compared to the untreated control (Fig. 1). Baythroid XL was the only product that significantly differed from another product, with Acephate 97 UP have a significantly higher seasonal mean. Most products showed some suppression compared to the control, but none appeared to give long-term protection from aster leafhoppers. Regardless, it's clear that growers will continue to rely on insecticides to try and limit exposure to aster yellows and that Baythroid XL may be one of the better aster leafhopper control options.

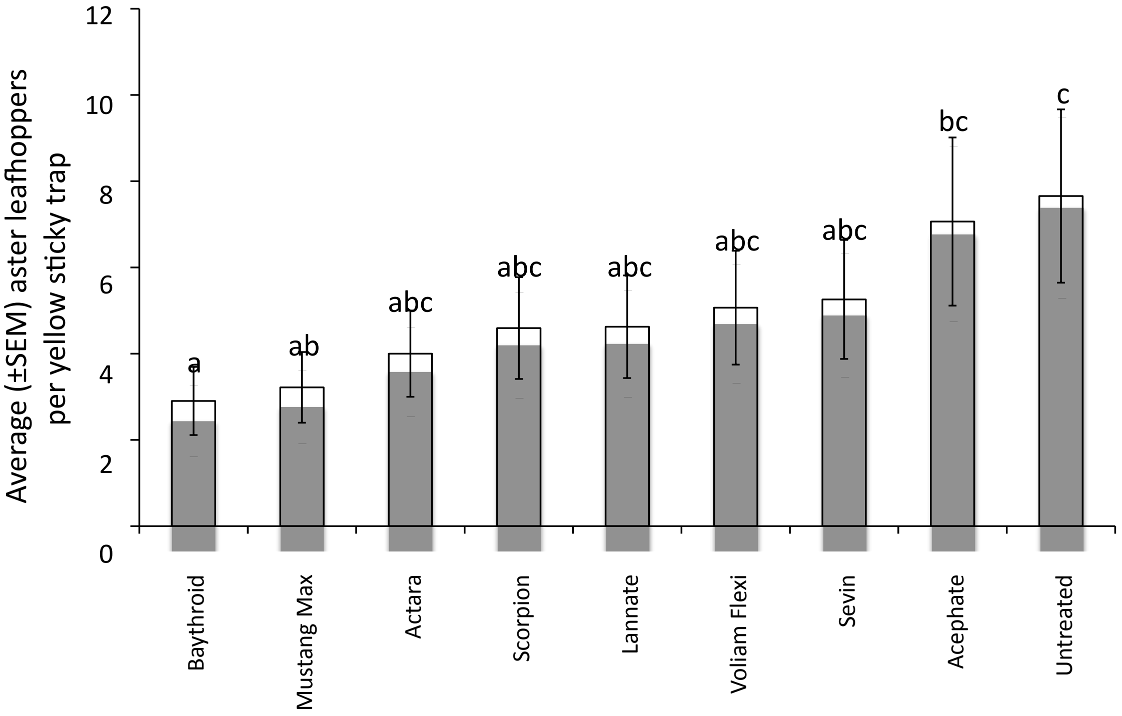


Figure 1. Impact of insecticide treatments on aster leafhopper numbers in a celery insecticide field-trial conducted by the MSU vegetable entomology laboratory. The following rates were applied: Baythroid XL (3.2 fl oz/acre), Mustang Max (4 fl oz/acre), Actara (3 oz/acre), Scorpion 35SL (5.25 fl oz/acre), Lannate LV (3 pt/acre), Voliam Flexi (7 oz/acre), Seven XLR Plus (1 qt/acre), and Acephate 97 UP (16 oz/acre).

Field insecticide evaluations of registered and experimental insecticides for managing onion thrips on onion

Onion thrips (*Thrips tabaci* Lindeman) is the most important insect pest of onions in the Great Lakes region. Adults and nymphs use their single sword-like mandible to rupture plant cells on the outer surface of leaves and other plant parts, and then suck out the contents by pressing their mouthparts onto the damaged surface. At first, damaged leaves turn silvery, but with continued severe damage, the leaves completely dry out, hampering photosynthesis and ultimately reducing plant growth and yield. Thrips are also vectors of *Iris yellow spot virus*, which causes a disease that can further reduce yield.

Currently, the most important tool for commercial onion growers is the judicious use of insecticides. Insecticides should be used as part of an integrated pest management strategy, keeping in mind the following points: (1) before making an application, determine the average number of thrips on your onions, and (2) check the weather forecast, since hot, dry spells will likely help the numbers of thrips rise quickly in the near future, but cool, wet weather will keep numbers low.

Most onion growers have to make multiple applications of insecticides in a season. Before choosing a product for onion thrips control, the following points should be considered: (1) there are relatively few products registered on onion, so (2) maximum application rates are quickly exceeded if the same product is applied multiple times in a season, therefore, (3) multiple products have to be used in rotation. Its important to use different products within a season, because the more often a product is used, the higher the chances are of onion thrips becoming resistant to it. So we need to find out which rotations/combinations are the most effective at suppressing onion thrips numbers while not exceeding maximum application thresholds and reducing the number of insecticide applications in a season.

METHODS

Fifteen insecticide treatments and an untreated check (Table 1) were tested for their efficacy to control onion thrips in a commercial onion field at Krummrey Farms, near Stockbridge, MI. Dry bulb onions (variety 'Sedona') were planted around 26 April 2012 into three-row beds, with 6 in. row spacing and beds spaced 25 in. apart. Treatments were replicated four times in a randomized complete block design. Plots were 15 ft. long. In 2012, an emphasis was placed on a program-based approach, with some treatments applied on a weekly basis and others based on thresholds (3 thrips/leaf for Radiant SC; 1 thrips/leaf for all other compounds). All treatments included the non-ionic surfactant Dyne-Amic at a rate of 0.5% v/v to improve penetrability of the insecticide into the onion leaves.

Foliar treatments were applied using a single-nozzle hand-held boom at 50 gallons/acre and 40 psi (see Table 1 for application dates). Plots were initially sprayed on 20 June when there were about 4 leaves/plant and the density of onion thrips averaged 5.5 thrips/plant (~1.4 thrips/leaf). Thereafter, post-spray counts of adult and nymph thrips on 10 randomly selected plants from each plot were made 5-7 days after each foliar application. Most of the treatments/rotations were designed to run for 8-weeks, however, for the threshold-based treatments, we monitored and sprayed, as needed, throughout the season.

Plots were also visually rated for thrips damage using a scale from 1 to 10. A rating of 1 indicated complete devastation by thrips (leaves all white instead of green), while a rating of 10 indicated no detectable thrips feeding. A rating of 8 or above would be considered commercially acceptable. Visual ratings were made on 17 & 24 August 2012.

All onion bulbs in each plot were pulled on 12 September 2012 and left in the field to finish drying. On 25 & 26 September, bulbs were taken back to the lab for grading and weighing. US No. 1 grade bulbs were graded as jumbo (≥3 in. diam.), standard (2.0 to 2.9 in. diam.), and boiler (1.5 to 1.9 in. diam.), and the number in each class was recorded and weighed; extremely small or misshapen bulbs were discarded.

Data was log (x+1) transformed prior to analysis. Analysis of variance was used for data analysis and Tukey means separation was used to compare treatment means ($P < 0.05$).

RESULTS

All treatments resulted in a significant reduction to the seasonal mean number of thrips relative to the untreated check (Table 2). There were also differences noted between the insecticide treatments. In general, the most effective treatments were those that had Movento 240 SC applied during the first two weeks. Alternatively, those treatments completely lacking Movento 240 SC in their rotation resulted in the highest mean number of thrips/plant.

We also compared weekly and threshold-based spray programs. We carried out these comparisons for eight weeks, allowing us to rotate four different products (each applied twice in a row) through our weekly spray programs. Not surprisingly, programs with weekly insecticide applications resulted in a lower mean number of thrips/plant. However, the two threshold-based programs that started with Movento 240 SC required only six insecticide applications over the eight-week period, while the other needed only five applications to keep thrips numbers below threshold. A slight increase in thrips numbers, especially late in the season when the plants are larger, in order to skip two to three insecticide applications, could provide cost reductions without economical damage.

We scouted the threshold treatment plots after the eight-week period, to see how far into the season we could go with as few sprays as possible. Treatments 9 & 10 both required eight insecticide applications in a 10-week period, with the last two applications on 17 & 24 August (Radiant @ 10 fl oz/A and Lannate @ 3 pt/A, respectively, for treatment 9; two applications of Lannate @ 3 pt/A for treatment 10). Treatment 12 did not require any further applications over the extended 2-week period, resulting in only six insecticide applications over the 10 weeks. After 10 weeks, a majority of the onions had started to lay down, bringing an end to our monitoring.

On 17 & 24 August, plots were visually rated, with most plots receiving a rating of 7 or higher (mean = 7.1). All treatments resulted in a significantly higher rating than the untreated control. The differences that were noted among spray-programs involved significantly lower ratings for two programs that lacked Movento 240 SC in its rotation compared to some programs that included Movento 240 SC. Overall yield was 210,902 bulbs/acre or 726.8 cwt/acre on average. All treatments resulted in significantly greater mean yield, compared to the untreated control, but there were no differences between the insecticide treatments. The weight or number of bulbs harvested in the boiler and standard categories did not differ among treatments. All but one treatment (14) resulted in significantly more jumbo bulbs than the untreated, while all but two treatments (5 & 14) had a significantly greater mean weight of jumbo bulbs compared to the untreated control.

The results of this trial indicate that there are multiple insecticides (both registered and experimental) and insecticide rotations that can provide good thrips suppression in the field. However, since not all insecticides have the same efficacy, the proper sequence of insecticides has to be carefully considered to achieve the best results. The number of new and effective compounds for thrips control is increasing thus growers should remain committed to resistance management practices to help assure that these compounds will remain effective into the future.

Table 1. Treatment list, application dates, and rates for an onion thrips trial conducted in Stockbridge, MI in 2012.

Trt	20 Jun	28 Jun	5 Jul	11 Jul	18 Jul	25 Jul	1 Aug	8 Aug
1	Benevia 10 OD 13.5 fl oz/A	Benevia 10 OD 13.5 fl oz/A	Movento 240 SC 5 fl oz/A	Movento 240 SC 5 fl oz/A	Lannate LV 3 pt/A	Lannate LV 3 pt/A	Radiant SC 8 fl oz/A	Radiant SC 8 fl oz/A
2	Movento 240 SC 5 fl oz/A	Movento 240 SC 5 fl oz/A	Benevia 10 OD 13.5 fl oz/A	Benevia 10 OD 13.5 fl oz/A	Lannate LV 3 pt/A	Lannate LV 3 pt/A	Radiant SC 8 fl oz/A	Radiant SC 8 fl oz/A
3	Movento 240 SC 5 fl oz/A	Movento 240 SC 5 fl oz/A	Lannate LV 3 pt/A	Lannate LV 3 pt/A	Benevia 10 OD 13.5 fl oz/A	Benevia 10 OD 13.5 fl oz/A	Radiant SC 8 fl oz/A	Radiant SC 8 fl oz/A
4	Movento 240 SC 5 fl oz/A	Movento 240 SC 5 fl oz/A	Lannate LV 3 pt/A	Lannate LV 3 pt/A	Radiant SC 8 fl oz/A	Radiant SC 8 fl oz/A	Benevia 10 OD 13.5 fl oz/A	Benevia 10 OD 13.5 fl oz/A
5	Torac 15 EC 24 fl oz/A	Torac 15 EC 24 fl oz/A	Agri-Mek SC 3 fl oz/A	Agri-Mek SC 3 fl oz/A	Radiant SC 8 fl oz/A	Radiant SC 8 fl oz/A	Lannate LV 3 pt/A	Lannate LV 3 pt/A
6	Movento 240 SC 5 fl oz/A	Movento 240 SC 5 fl oz/A	Torac 15 EC 24 fl oz/A	Torac 15 EC 24 fl oz/A	Radiant SC 8 fl oz/A	Radiant SC 8 fl oz/A	Lannate LV 3 pt/A	Lannate LV 3 pt/A
7	Movento 240 SC 5 fl oz/A	Movento 240 SC 5 fl oz/A	Agri-Mek SC 3 fl oz/A	Agri-Mek SC 3 fl oz/A	Torac 15 EC 24 fl oz/A	Torac 15 EC 24 fl oz/A	Radiant SC 8 fl oz/A	Radiant SC 8 fl oz/A
8	Movento 240 SC 5 fl oz/A	Movento 240 SC 5 fl oz/A	Agri-Mek SC 3 fl oz/A	Agri-Mek SC 3 fl oz/A	Torac 15 EC + Lannate LV 24 fl oz + 3 pt/A	Torac 15 EC + Lannate LV 24 fl oz + 3 pt/A	Radiant SC 8 fl oz/A	Radiant SC 8 fl oz/A
9*	Benevia 10 OD 20.5 fl oz/A	Benevia 10 OD 20.5 fl oz/A		Radiant SC 10 fl oz/A		Radiant SC 10 fl oz/A	Lannate LV 3 pt/A	Lannate LV 3 pt/A
10*	Movento 240 SC 5 fl oz/A	Movento 240 SC 5 fl oz/A			Agri-Mek SC 3 fl oz/A	Agri-Mek SC 3 fl oz/A	Radiant SC 7 fl oz/A	Radiant SC 7 fl oz/A
11	Movento 240 SC 5 fl oz/A	Movento 240 SC 5 fl oz/A	Agri-Mek SC 3 fl oz/A	Agri-Mek SC 3 fl oz/A	Radiant SC 7 fl oz/A	Radiant SC 7 fl oz/A	Lannate LV 3 pt/A	Lannate LV 3 pt/A
12*	Movento 240 SC 5 fl oz/A	Movento 240 SC 5 fl oz/A			Agri-Mek SC 3 fl oz/A	Agri-Mek SC 3 fl oz/A	Radiant SC 10 fl oz/A	
13	Movento 240 SC 5 fl oz/A	Movento 240 SC 5 fl oz/A	Agri-Mek SC 3 fl oz/A	Agri-Mek SC 3 fl oz/A	Radiant SC 10 fl oz/A	Radiant SC 10 fl oz/A	Lannate LV 3 pt/A	Lannate LV 3 pt/A
14*	Lannate LV 3 pt/A	Lannate LV 3 pt/A	Agri-Mek SC 3 fl oz/A	Agri-Mek SC 3 fl oz/A	Benevia 10 OD 20.5 fl oz/A	Benevia 10 OD 20.5 fl oz/A	Lannate LV 3 pt/A	Lannate LV 3 pt/A
15	Lannate LV 3 pt/A	Lannate LV 3 pt/A	Agri-Mek SC 3 fl oz/A	Agri-Mek SC 3 fl oz/A	Benevia 10 OD 20.5 fl oz/A	Benevia 10 OD 20.5 fl oz/A	Lannate LV 3 pt/A	Lannate LV 3 pt/A
16								

*insecticides applied based on thresholds (3 thrips/leaf for Radiant, 1 thrips/leaf for all other products)

Table 2. Weekly and seasonal averages of onion thrips per plant and total yield in an insecticide trial conducted in Stockbridge, Michigan in 2012. Numbers within a column followed by different letters are statistically significant from each other. For product rates, see Table 1.

Treatment	20 Jun	28 Jun	5 Jul	11 Jul	18 Jul	25 Jul	1 Aug	8 Aug	Seasonal Mean	Yield (cwt/acre)
1	Benevia 9.7 ab	Benevia 8.1 a	Movento 46.1 d	Movento 17.5 cde	Lannate 10.3 ab	Lannate 11.2 a	Radiant 9.3 ab	Radiant 5.2 a	14.7 bc	747.2 a
2	Movento 14.1 b	Movento 5.1 a	Benevia 2.0 ab	Benevia 6.1 a	Lannate 20.9 bc	Lannate 39.8 b	Radiant 21.4 bc	Radiant 7.1 a	14.6 abc	756.8 a
3	Movento 10.0 ab	Movento 4.7 a	Lannate 2.0 a	Lannate 9.6 bcd	Benevia 14.2 ab	Benevia 22.8 abcd	Radiant 8.7 ab	Radiant 4.7 a	9.6 ab	747.0 a
4	Movento 11.1 b	Movento 6.2 ab	Lannate 2.7 abc	Lannate 7.4 ab	Radiant 13.3 ab	Radiant 20.3 ab	Benevia 6.6 a	Benevia 9.1 a	9.6 ab	725.6 a
5	Torac 3.9 a	Torac 6.1 a	Agri-Mek 35.7 d	Agri-Mek 23.2 e	Radiant 66.6 e	Radiant 27.7 abcd	Lannate 12.1 ab	Lannate 7.0 a	22.8 ef	715.6 a
6	Movento 11.6 ab	Movento 6.1 a	Torac 2.4 abc	Torac 7.6 ab	Radiant 19.8 bc	Radiant 21.6 abc	Lannate 21.2 ab	Lannate 5.2 a	11.9 abc	809.8 a
7	Movento 10.9 ab	Movento 6.0 a	Agri-Mek 2.7 abc	Agri-Mek 9.8 abcd	Torac 10.4 ab	Torac 15.1 ab	Radiant 22.6 bc	Radiant 3.4 a	10.1 abc	715.9 a
8	Movento 11.8 b	Movento 6.9 ab	Agri-Mek 3.4 abc	Agri-Mek 16.9 bcde	Torac + Lannate 15.8 abc	Torac + Lannate 15.8 ab	Radiant 13.6 ab	Radiant 2.9 a	10.9 abc	733.7 a
9*	Benevia 8.6 ab	Benevia 6.8 a	35.2 d	Radiant 17.5 de	57.8 e	Radiant 48.0 c	Lannate 16.3 ab	Lannate 7.2 a	24.7 ef	712.7 a
10*	Movento 8.6 ab	Movento 5.1 a	4.7 bc	12.7 bcde	Agri-Mek 49.7 de	Agri-Mek 35.1 b	Radiant 24.5 bc	Radiant 5.9 a	18.3 bcd	709.5 a
11	Movento 13.4 b	Movento 6.8 ab	Agri-Mek 3.1 abc	Agri-Mek 8.8 abcd	Radiant 19.3 bc	Radiant 22.7 abc	Lannate 13.3 ab	Lannate 8.2 ab	11.9 bc	800.3 a
12*	Movento 11.3 b	Movento 5.3 a	4.6 c	13.6 bcde	Agri-Mek 44.3 de	Agri-Mek 23.0 abcd	Radiant 7.6 ab	5.0 ab	13.9 cde	716.9 a
13	Movento 9.8 ab	Movento 4.1 a	Agri-Mek 3.3 abc	Agri-Mek 8.8 abc	Radiant 7.4 a	Radiant 8.7 a	Lannate 8.6 ab	Lannate 5.3 a	7.0 a	751.8 a
14*	Lannate 10.2 ab	Lannate 10.2 ab	Agri-Mek 52.1 de	Agri-Mek 27.2 e	Benevia 26.8 cd	Benevia 19.4 a	Lannate 11.6 ab	Lannate 3.9 a	21.0 def	695.9 a
15	Lannate 7.8 ab	Lannate 14.0 bc	Agri-Mek 49.0 de	Agri-Mek 21.9 e	Benevia 42.1 de	Benevia 36.1 b	Lannate 21.6 abc	Lannate 5.4 a	24.7 f	755.0 a
16	15.5 b	17.3 c	76.9 e	66.9 f	142.3 f	54.1 d	44.2 c	28.2 b	55.7 g	522.6 b

*insecticides applied based on thresholds (3 thrips/leaf for Radiant, 1 thrips/leaf for all other products)

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

The Colorado potato beetle 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

Twelve 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 9 May 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.

A16901, Admire Pro, and Platinum 75 SG treatments were applied as in-furrow sprays at planting. Foliar treatments were first applied at greater than 60% Colorado potato beetle egg hatch on 11 June. Based on the economic threshold of more than one large larva per plant, additional first generation sprays were needed for Admire Pro (19 & 26 June, 3 July), Athena (26 June), Blackhawk (26 June), F9318 (26 June & 3 July), the low rate of Torac 15 EC (26 June & 3 July), and the high rate of Torac 15 EC (26 June); no subsequent applications were necessary for any of the Benevia 10 OD 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 (1st and 2nd instars), and large larvae (3rd and 4th instars) from five randomly selected plants from the middle row of each plot were made weekly, starting on 18 June. 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 1). 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.

Table 1. Seasonal mean number of Colorado potato beetle life stages per plant and % defoliation in an insecticide field-trial conducted by the MSU vegetable entomology laboratory.

Treatment	Insecticide class	Application mode	Rate	Adult	Small Larva	Large Larva	% defoliation
Untreated				1.2 b	6.3 f	5.0 f	36.6 e
Benevia 10 OD	Ryanodine receptor modulator	foliar	5 fl oz/A	0.3 a	0.5 abc	0.7 abcd	3.8 abcd
Benevia 10 OD + MSO	Ryanodine receptor modulator	foliar	5 fl oz/A + 0.5% v/v	0.6 ab	0.7 abc	0.9 abcd	5.6 cd
Benevia 10 OD	Ryanodine receptor modulator	foliar	6.75 fl oz/A	0.5 ab	0.8 abc	0.9 bcd	5.9 bcd
Admire Pro	Nicotinic acetylcholine receptor agonist	foliar	1.3 fl oz/A	0.5 ab	3.8 ef	1.6 de	3.1 bcd
Blackhawk	Nicotinic acetylcholine allosteric activator	foliar	2.5 oz/A	0.5 ab	0.7 abc	0.8 abcd	3.0 bcd
Athena	Sodium channel modulator & chloride channel activator	foliar	17 fl oz/A	0.5 ab	3.2 def	2.1 e	3.7 cd
F9318		foliar	19 fl oz/A	0.3 a	2.0 cde	2.1 e	4.2 d
Torac 15 EC + Dyne-Amic	Mitochondrial complex I electron transport inhibitor	foliar	14 fl oz/A + 0.5% v/v	0.4 a	1.7 bcd	1.6 cde	4.4 d
Torac 15 EC + Dyne-Amic	Mitochondrial complex I electron transport inhibitor	foliar	17 fl oz/A + 0.5% v/v	0.3 a	1.8 cd	1.0 cde	2.6 abcd
Admire Pro	Nicotinic acetylcholine receptor agonist	infurrow	8.7 fl oz/A	0.5 ab	0.4 abc	0.5 abc	1.9 abc
Platinum 75 SG	Nicotinic acetylcholine receptor agonist	infurrow	2.66 oz/A	0.6 ab	0.2 ab	0.0 ab	1.1 ab
A16901		infurrow	10 oz/A	0.5 ab	0.0 a	0.0 a	1.1 a

Different letters within a column denote statistically significant differences among treatments ($P < 0.05$, Tukey's HSD). Data transformed for analysis with log (x+1), non-transformed means presented in table.

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, 13 Colorado potato beetle populations (eight Michigan populations and five populations collected in other states) were bioassayed with imidacloprid and/or thiamethoxam.

METHODS

During 2012, eight Colorado potato beetle populations were collected from four Michigan counties (Ingham, Montcalm, Tuscola, and Washtenaw). Cooperators also provided populations from Idaho, New York, Maine, and Virginia. One susceptible laboratory strain was also tested (Table 1). 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.

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 [Painter, VA was assessed after 6 days]. 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 imidacloprid LD_{50} value (dose lethal to 50% of the beetles) for the susceptible laboratory strain was 0.075 µg/beetle (Table 2). The LD_{50} values from the field for imidacloprid ranged from 0.195 µg/beetle (MSU) to 3.164 µg/beetle (Sackett Potatoes Field 153) for Michigan populations. The imidacloprid LD_{50} values from the out-of-state populations ranged from 0.210 µg/beetle (Painter, VA) to 11.570 (Jamesport, NY).

LD_{50} values for all populations were significantly higher than the susceptible laboratory strain. In 2012, 75% of the Michigan samples were greater than 10-fold resistant to imidacloprid, compared to 57% in 2011, 60% in 2010, and 85% in 2009.

The thiamethoxam LD_{50} value for the susceptible laboratory strain was 0.090 µg/beetle (Table 1). LD_{50} values for thiamethoxam in Michigan ranged from 0.140 µg/beetle (MSU) to 0.464 µg/beetle (Sackett Potatoes Field 153), and from 0.109 µg/beetle (Painter, VA) to 0.861 µg/beetle (Jamesport, NY) for out-of-state populations. No Michigan populations were greater than 10-fold resistant to thiamethoxam.

In general, resistance values across the country are very similar to those in recent years. As long as growers continue to use a variety of insecticide modes of action when managing Colorado potato beetles, it appears that the neonicotinoids can continue to play a major role. Most importantly, it is essential that growers refrain from using foliar products containing neonicotinoids, when a neonicotinoid was applied at planting.

Table 1. Colorado potato beetle populations tested for susceptibility to imidacloprid and thiamethoxam in 2012.

Michigan populations

Anderson Brothers Field 26 Summer adults were collected on 24 July 2012 by Mark Otto, Agri-Business Consultants, Inc., from commercial potato fields in Montcalm County.

DuRussell Summer adults were collected on 3 July 2012 from a commercial potato field near Manchester, Washtenaw County.

Greenville Summer adults were collected on 20 July 2012 by Mark Otto, Argi-Business Consultants, Inc. from a commercial potato field (ABC-TB 7 & 22) near Greenville, Montcalm County.

MSU Overwintered adults were collected on 8 June 2012 from potato research plots on the campus of Michigan State University, Ingham County.

Sackett Potatoes Adults were collected by Mark Otto and/or Loren Wernette, Agri-Business Consultants, Inc. from commercial potato fields in Montcalm County.

- *Field 9* Summer adults were collected on 9 July 2012.
- *Field 26* Overwintered adults were collected in early June 2012.
- *Fields 153* Summer adults were collected on 9 July 2012.

Tuscola Summer adults were collected on 3 July 2012 by Brice Stine, Walther Farms, from a commercial potato field near Caro, Tuscola County.

Out-of-state populations

Aroostook, Maine Overwintered adults were collected on 22 June 2012 by Andrei Alyokhin, University of Maine, from the Aroostook Research Farm near Presque Isle, ME.

Bridgewater, Maine Summer adults were collected on 6 August 2012 by Aaron Buzza, University of Maine, from an organic seed farm near Bridgewater, ME.

Jamesport, New York Overwintered adults were collected on 31 May 2012 by Sandra Menasha, Cornell Cooperative Extension, from a commercial potato field in Jamesport, Suffolk County, NY.

North Hampton, Virginia Summer adults were collected on 18 June 2012 by Adam Wimer, Virginia Polytechnic Institute and State University, from volunteer potatoes in a cotton field in North Hampton County, VA.

Painter, Virginia Summer adults were collected on 4 June 2012 by Adam Wimer, Virginia Polytechnic Institute and State Universiy, from untreated research plots at Virgina Polytechnic Institute and State University's Agricultural Research and Extension Center in Painter, VA

Laboratory strain

New Jersey Adults obtained in 2008 from the Phillip Alampi Beneficial Insects Rearing Laboratory, New Jersey Department of Agriculture and since reared at Michigan State University without contact to insecticides.

Table 2. LD_{50} values (μg/beetle) and 95% fiducial limits for Colorado potato beetle populations treated with imidacloprid and thiamethoxam at 7 days post treatment.

IMIDACLOPRID	**LD_{50} (μg/beetle)**	**95% Confidence Intervals**
Michigan populations		
Anderson Brothers Field 26	0.873	0.747 – 1.013
DuRussell	1.008	0.810 – 1.719
Greenville	0.959	0.846 – 1.090
MSU	0.195	0.147 – 0.299
Sackett Potatoes Field 9	0.946	0.626 – 1.347
Sackett Potatoes Field 26	0.814	0.720 – 0.925
Sackett Potatoes Field 153	3.164	2.566 – 3.897
Tuscola	0.675	*
Out-of-state populations		
Aroostook, Maine	0.595	0.407 – 1.332
Bridgewater, Maine	1.723	1.458 – 2.048
Jamesport, New York	11.570	6.357 – 30.550
North Hampton, Virginia	0.862	*
Painter, Virginia	0.210	0.141 – 0.516
Laboratory strain		
New Jersey	0.075	0.054 – 0.100
THIAMETHOXAM		
Michigan populations		
Anderson Brothers Field 26	0.374	*
Greenville	0.408	0.359 – 0.467
MSU	0.140	0.119 – 0.167
Sackett Potatoes Field 9	0.426	0.351 – 0.581
Sackett Potatoes Field 26	0.251	0.150 – 0.509
Sackett Potatoes Field 153	0.464	0.398 – 0.525
Tuscola	0.434	0.287 – 0.540
Out-of-state populations		
Aroostook, Maine	0.197	0.173 – 0.225
Bridgewater, Maine	0.598	0.338 – 1.440
Jamesport, New York	0.861	0.766 – 0.967
North Hampton, Virginia	0.276	0.221 – 0.324
Painter, Virginia	0.109	0.046 – 0.295
Laboratory strain		
New Jersey	0.090	0.078 – 0.104

* no confidence limits calculated due to insufficient fit to the model