Michigan Vegetable Insecticide Evaluation Studies

2010

Vegetable Entomology Insecticide Evaluation Studies
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ACKNOWLEDGEMENTS

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

Asparagus:

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

Onions:

Larry Krummery	Krummery Farms, Stockbridge, MI
Dr. Brian Nault	Department of Entomology, Cornell University
Matt Zuehlke	Department of Crop and Soil Sciences, MSU

Potatoes:

Dr. Andre 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
Karl Ritchie	Walther Farms, Three Rivers, MI
Bruce Sackett	Montcalm Research Farm, Entrican, MI
Matt Zuehlke	Department of Crop and Soil Sciences, MSU

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

AgraQuest, Inc.	Dr. Dennis Warkentin
BASF	Caren A. Judge
Bayer CropSciences	John O. Martin
Chemtura Corporation	Gilbert W. Angle, Jr.
Dow AgroSciences	Bradley Hopkins
DuPont	Marsha Martin and Kent Hughes
Gowan Company	Paul David
Syngenta	Dr. Venance Lengkeek

Evaluation of systemic, drip, and foliar insecticides for control of asparagus miner and asparagus beetle in asparagus

The MSU vegetable entomology lab conducted an insecticide trial in an experimental asparagus field in Hart, MI in summer 2010. We had nine insecticide treatments including six products and tested three application methods (chemigation through drip irrigation, foliar spray, and in-furrow at planting) (Table 1). The asparagus crowns were planted on 19 May 2010 and the drip irrigation system was set up on 10 June 2010. The only currently registered insecticides in asparagus used in this trial were Sevin 4F and Radiant SC. Foliar and drip treatments were applied twice during the season; drip applications were made on 21 June and 4 August and foliar applications on 12 July and 4 August. In-furrow and foliar treatments were applied using a single-nozzle hand-held boom at 30 gallons/acre at 30 psi; in-furrow treatments were applied to the crowns prior to closing the furrows. Drip applications were made by injecting the insecticide into the main irrigation line and allowing it to flow into only the appropriate treatment drip lines. A red dye was used to indicate when the compound had completely moved through the lines. The time to flow through for the various treatments varied due to the spatial arrangement of the plots, but watering times were adjusted to be equal for all plots (including those that received no drip treatments). The main line was flushed with water between each treatment to prevent cross contamination. Sampling for asparagus miner was done by visually surveying 20 stems per treatment and recording the number of damaged stems. Complete counts of asparagus beetle eggs, larvae, and adults were conducted weekly, starting on 4 August, on five plants per plot.

Chemigation was able to suppress asparagus miner damage (Figure 1) and asparagus beetle eggs (Figure 2) and larvae (Figure 3). In general, insecticides applied through drip irrigation performed the best for insect pest suppression, followed by the foliar applied products. In-furrow, at planting applications were the least effective in controlling asparagus miner and beetles.

Since the asparagus field was established this year, pest pressure in general was at low levels especially early in the season. This is likely because pests need some time to immigrate into and colonize new fields.

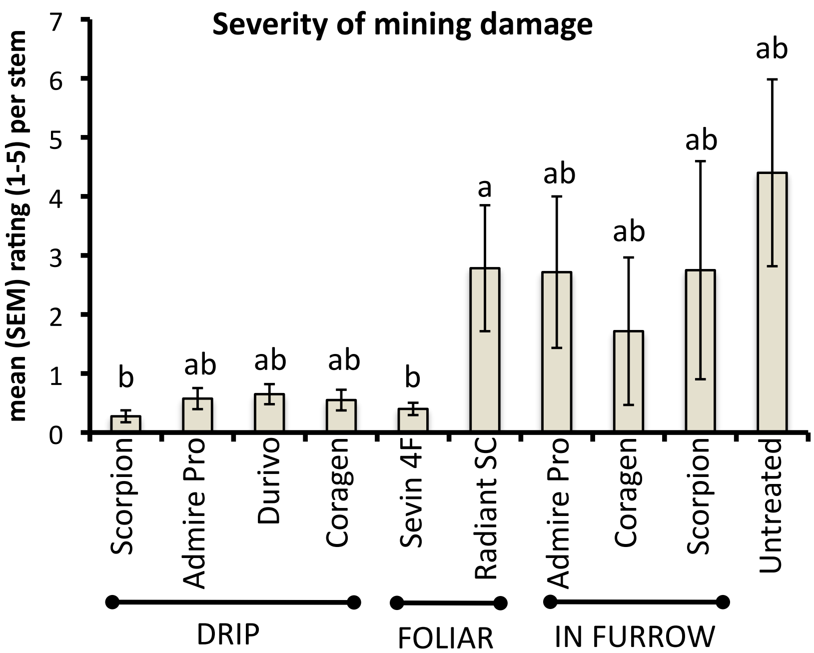


Figure 1. Asparagus miner damage on asparagus stems using a scale of 0-5. (0 - no damage; 5 - severe damage).

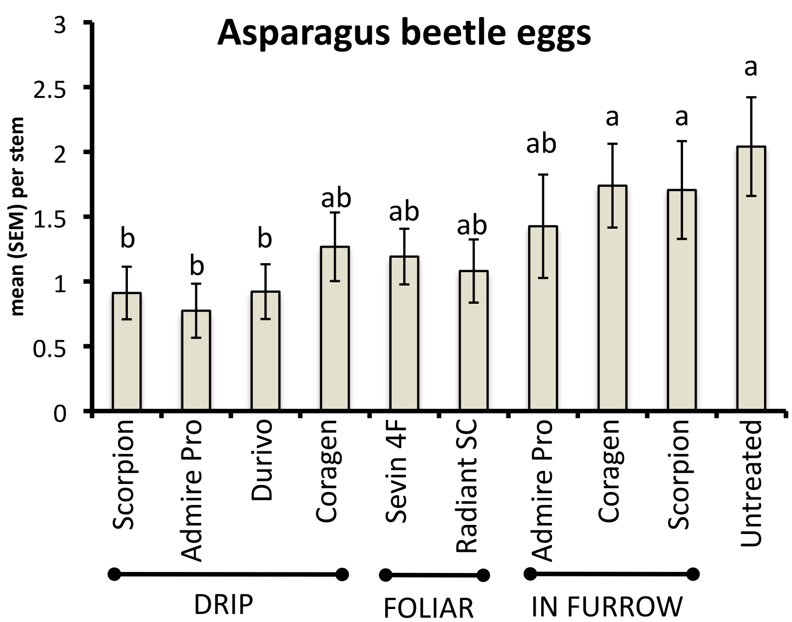


Figure 2. Average asparagus beetle egg abundance in our experimental asparagus plot.

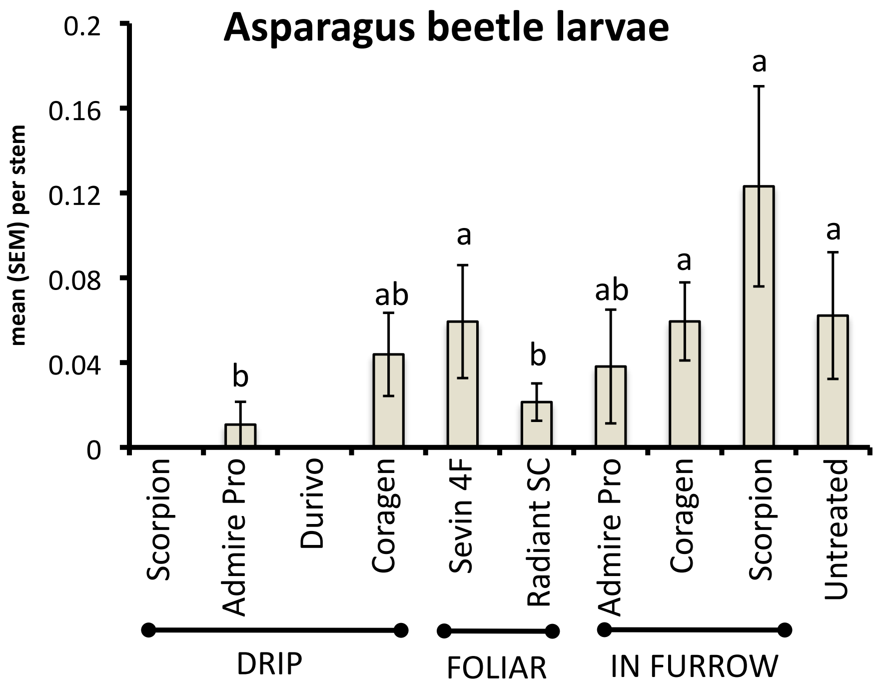


Figure 3. Asparagus beetle larval abundance in our experimental asparagus plot.

Table 1. Treatment list with application modes, rates, and dates for asparagus trial conducted in Hart, MI, summer 2010.

Treatment	Insecticide class	Application mode	Rate	Application dates
Scorpion	neonicotinoid	drip	10.5 fl oz./A	21 June, 4 August
Admire Pro	neonicotinoid	drip	10.5 fl oz./A	21 June, 4 August
Durivo	neonicotinoid + ryanodine receptor modulator	drip	13.0 fl oz./A	21 June, 4 August
Coragen	ryanodine receptor modulator	drip	5.0 fl oz./A	21 June, 4 August
Sevin 4F	carbamate	foliar	2.0 qt./A	12 July, 4 August
Radiant SC	spinetoram	foliar	8.0 fl oz./A	12 July, 4 August
Admire Pro	neonicotinoid	infurrow	10.5 fl oz./A	19 May
Coragen	ryanodine receptor modulator	infurrow	5.0 fl oz./A	19 May

Field 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 to manage thrips 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 in the field, 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. For example, weather conditions in 2010 were favorable for onion thrips development because of the extended periods of hot and dry weather in many parts of the Great Lakes onion growing regions.

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) <u>multiple products have to be used in rotation</u>. 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 and combinations are the most effective, do not exceed maximum application thresholds, and suppress onion thrips numbers the best.

METHODS

Eight insecticide treatments and an untreated check (Figure 1) were tested for onion thrips management in a commercial onion field at Krummery Farms, near Stockbridge, MI. Dry bulb onions (variety 'Sedona') were planted in late April into three-row beds, with 6 in. row spacing and beds spaced apart 25 in. Treatments were replicated four times in a randomized complete block design. Plots were 15 ft. long. The *Movento*/*Radiant*/*Lannate* combination (treatment code 2, Figure 1) involved two applications of each compound; thresholds were only considered when switching to the next chemistry in the rotation. The three treatments containing *HGW86* (treatment codes 3-5) involved applying three compounds in different weekly sequences, with an assessment of thresholds only after each triplicate had been applied (every three weeks). Another treatment involved alternating between *Lannate* and *Radiant* (treatment code 6); again, applications were made for three consecutive weeks before comparing numbers to the threshold. *Lannate* alone (treatment code 7) was applied weekly based on threshold values, with a maximum of four applications. Finally, the two *Requiem* treatments (treatment codes 8 & 9) were applied weekly throughout the season. All but the *Requiem* treatments included the non-ionic surfactant Dyne-Amic to improve penetrability of the insecticide into the onion leaves; the *Movento* treatment used a rate of 0.25% v/v, while the remaining used 0.5% v/v.

Foliar treatments were applied weekly using a single-nozzle hand-held boom at 50 gallons/acre and 40 psi (all but one treatment) or 80 psi (one *Requiem* treatment)(Table 1). Plots were initially sprayed on 2 July when plants had an average of 5.6 leaves and the density of onion thrips averaged 0.8 nymphs/leaf (4.8 nymphs/plant). 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. Subsequent insecticide applications were either based on the threshold of greater than one thrips nymph per leaf or per industry protocol. Additional applications were made on 8, 16, 22, and 29 July and 5 August.

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 11 August.

All onion bulbs in each plot were pulled on 18 August and left in the field to finish drying. The following week, 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 were analyzed using two-way ANOVA (treatment and block) and significant differences were determined with Fisher's Protected LSD test ($p=0.05$).

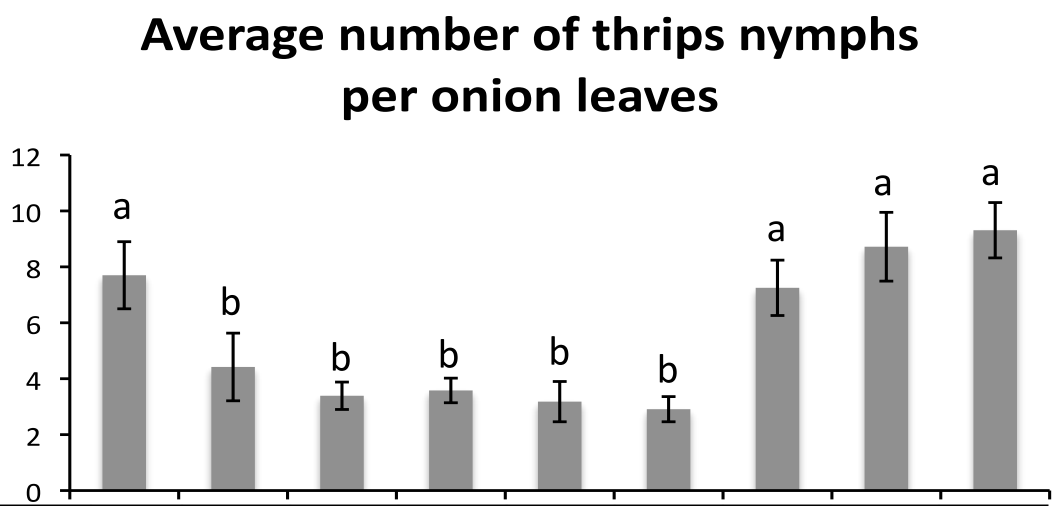
RESULTS

This summer was especially hot and dry, leading to extremely high thrips pressure. By late July, thrips numbers were climbing steadily in all treatments, with some reaching up to 20+ nymphs per leaf by early August (Figure 2). As a result, only one of our treatment combinations (treatment code 6, Figure 1) suppressed thrips nymph numbers to below threshold, following week 3. Unfortunately, numbers climbed back up in this treatment after week 4, requiring us to restart the application of insecticides. The alternation of *Lannate* and *Radiant* led to the numerically lowest average value for thrips, but it was not significantly different from other treatments that also contained these two compounds in alternation with either *HGW86* or *Movento*. *Lannate* alone and *Requiem* treatments (at both low and high pressure) failed to provide adequate control and numbers did not differ from the untreated check.

Due to the heavy thrips pressure, most of the onion foliage in the untreated and in some insecticide treated plots was completely devastated by mid-August. On 11 August, all plots were visually rated 7 or lower (mean = 2.7), which is well below the commercially acceptable standard (8 or above). Harvest data also reflected the heavy thrips pressure:

none of the bulbs were large enough to be classified as jumbo and overall yield was low (avg. of 164,622 bulbs/acre or 213 cwt/acre). The weight or number of bulbs harvested in each size category was not different among treatments. Our stand count was very uniform, supported by the lack of significant differences in the number of bulbs harvested per plot.

Different letters above bars denote statistically significant differences among treatments.



Week 1	-	Movento	Lannate	HGW86 (low rate)	HGW86 (high rate)	Lannate	Lannate	Requiem (low psi)	Requiem (high psi)
Week 2	-	Movento	HGW86 (low rate)	Lannate	Lannate	Radiant	Lannate	Requiem (low psi)	Requiem (high psi)
Week 3	-	Radiant	Radiant	Radiant	Radiant	Lannate	Lannate	Requiem (low psi)	Requiem (high psi)
Week 4	-	Radiant	Lannate	HGW86 (low rate)	HGW86 (high rate)	-	Lannate	Requiem (low psi)	Requiem (high psi)
Week 5	-	Lannate	HGW86 (low rate)	Lannate	Lannate	Radiant	-	Requiem (low psi)	Requiem (high psi)
Week 6	-	Lannate	Radiant	Radiant	Radiant	Lannate	-	Requiem (low psi)	Requiem (high psi)
Treatment code	1	2	3	4	5	6	7	8	9

Figure 1. Seasonal mean number of thrips nymphs per onion leaf in an insecticide field-trial at Stockbridge, MI, summer 2010. Treatment combinations and sequence of applications are provided below; see Table 1 for product rates used.

Table 1. Seasonal mean number of thrips nymphs per onion leaf in an insecticide field-trial at Stockbridge, MI, summer 2010.

Treatment code	Treatments	Rate	Seasonal mean # thrips nymphs/leaf
1	Untreated		7.7a
2	Movento Radiant Lannate LV	5 fl oz./acre 8 fl oz./acre 3 pts./acre	4.4 b
3	Lannate LV HGW86 10 OD Radiant	3 pts./acre 13.5 fl oz./acre 8 fl oz./acre	3.4 b
4	HGW86 10 OD Lannate LV Radiant	13.5 fl oz./acre 3 pts./acre 8 fl oz./acre	3.6 b
5	HGW86 10 OD Lannate LV Radiant	20.5 fl oz./acre 3 pts./acre 8 fl oz./acre	3.2 b
6	Lannate LV Radiant	3 pts./acre 8 fl oz./acre	2.9 b
7	Lannate LV	3 pts./acre	7.3a
8	Requiem 25EC	2 qts./acre (40 psi)	8.7a
9	Requiem 25EC	2 qts./acre (80 psi)	9.3a

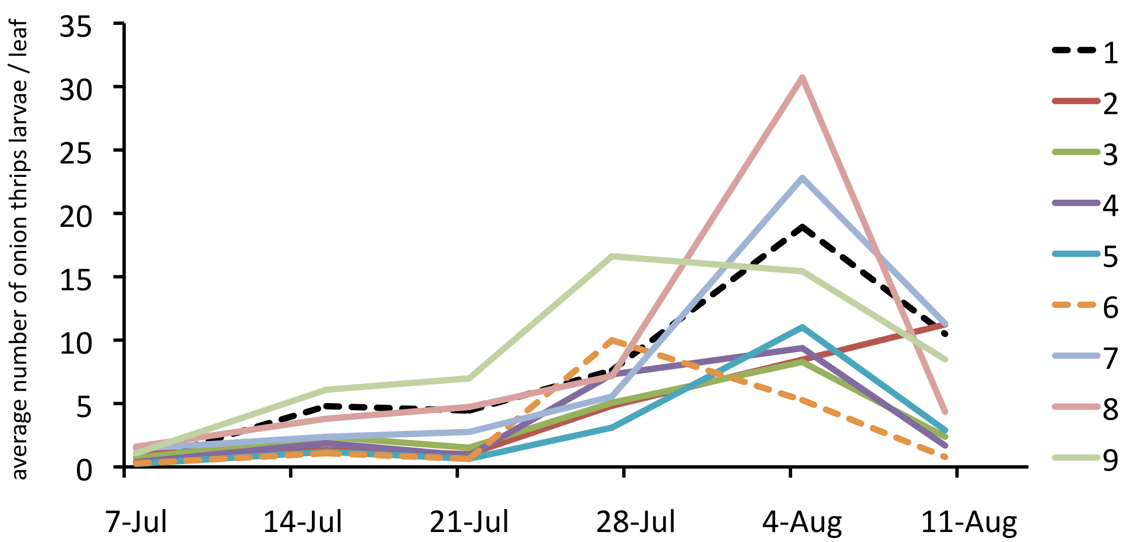


Figure 2. Mean number of onion thrips nymphs per onion leaf from an insecticide field-trial in Stockbridge, MI in 2010.

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

Twenty-seven 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 13 May 2010. Treatments were replicated four times in a randomized complete block design. Plots were 40 ft. long and three rows wide with untreated guard rows bordering each plot.

Admire Pro, *Platinum 75SG*, and *Regent 4SC* treatments were applied as in-furrow sprays at planting, using a single-nozzle hand-held boom (30 gallons/acre and 30 psi). Seed treatments (*HGW86 60 FS* treatments, *Titan 60 SL*, *Admire Pro*, and *Cruiser Max*) were applied by mixing seed pieces for each row with the corresponding amount of product in a small plastic bag and shaking until seed pieces were thoroughly coated. Foliar treatments were first applied at greater than 50% Colorado potato beetle egg hatch on 17 June. Based on the economic threshold of more than one large larva per plant, only the *Agri-Flex 1.55 SC* treatment required an additional first generation spray, applied on 1 July. Post-spray counts of Colorado potato beetle adults, small larvae (1^{st} and 2^{nd} instars), and large larvae (3^{rd} and 4^{th} instars) of four randomly selected plants form the middle row of each plot were made 5 or 6 days after each foliar application. The numbers of small larvae, large larvae and adults were transformed (log + 0.1) prior to analysis. Multivariate analysis of variance was used for data analysis, with block and date as random factors and insecticide treatment as fixed factor. Ad-hoc *Tukey* means comparison was used to compare treatment means when the overall model was significant ($P < 0.01$).

Plots were visually rated for defoliation weekly by estimating total defoliation per plot. Percent defoliation values were arcsine transformed prior to analysis, and an analysis of variance was done with block and date as random factors and insecticide treatment as fixed factor in the model. Ad-hoc *Tukey* means comparison was used to compare treatment means when the overall model was significant ($P < 0.05$). On 14 September, the middle row of each plot was harvested mechanically and the tubers were weighed. Data were analyzed using analysis of variance with treatment as fixed and block as random factor in the model and significant treatment differences were determined with *Tukey* post-hoc means separation test ($P < 0.05$).

RESULTS
All treatments significantly reduced the numbers of small larvae, large larvae, and adults on plants compared to the untreated plots (Table 1). Beetle pressure was higher in 2010 than in 2009, but comparing to previous years, insect pressure was low overall. Nevertheless, the untreated plots had significantly greater defoliation compared to all other treatments ($F = 11.46$; $df = 27, 446$; $P < 0.01$). The seasonal defoliation average was 13% in untreated plots, compared to less than 2% for all other treatments (there were no statistically significant differences between insecticide treatments). Growing conditions were favorable this season, with dry, hot weather leading to rapid plant growth, likely outpacing the impacts of Colorado potato beetle feeding damage. Overall average yield was 33,211.7 lb/A, with no significant differences between any of the treatments ($F = 0.72$; $df = 27, 110$; $P = 0.8285$).

While neonicotinoid insecticides are still providing sufficient Colorado potato beetle control for Michigan farmers, it is reassuring to see other chemical classes also providing adequate control (i.e.: *Coragen*, *Regent*, *Agri-Mek*, and *Rimon*). *Regent* is currently registered for use in potato for wire-worm control. *Rimon* is only effective when applied to larvae that still need to grow and molt since this product contains a hormone that inhibits development to the next growing stage.

With the slow increase in neonicotinoid resistance seen in Michigan (see the section below for more details on this), it remains important to have effective non-neonicotinoid compounds available for second generation control and/or for future use if neonicotinoid resistance becomes a significant problem.

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

Treatment	Insecticide class	Application mode	Rate	Adult[1]	Small Larva[1]	Large Larva[1]
Untreated				0.7 a	1.4 a	4.8 a
Admire Pro	neonicotinoid	seed treatment	9.4 g ai/100 kg	0.0 b	0.0 b	0.1 b
Cruiser Max	neonicotinoid	seed treatment	4.7 g ai/100 kg	0.0 b	0.0 b	0.0 b
HGW86 60 FS	cyantraniliprole	seed treatment	9.0 g ai/100 kg	0.0 b	0.2 b	0.1 b
HGW86 60 FS + Titan 60 SL	cyantraniliprole + lambdacyahalothrin	seed treatment	6.8 g ai/100 kg +6.3 g ai/100 kg	0.1 b	0.0 b	0.0 b
HGW86 60 FS + Titan 60 SL	cyantraniliprole + lambdacyahalothrin	seed treatment	9.0 g ai/100 kg +6.3 g ai/100 kg	0.0 b	0.0 b	0.0 b
HGW86 60 FS + Titan 60 SL	cyantraniliprole + lambdacyahalothrin	seed treatment	6.8 g ai/100 kg +3.1 g ai/100 kg	0.1 b	0.3 b	0.0 b
HGW86 60 FS + Admire Pro	cyantraniliprole + neonicotinoid	seed treatment	6.8 g ai/100 kg +9.4 g ai/100 kg	0.0 b	0.0 b	0.0 b
HGW86 60 FS + Admire Pro	cyantraniliprole + neonicotinoid	seed treatment	9.0 g ai/100 kg +9.4 g ai/100 kg	0.0 b	0.1 b	0.2 b
Titan 60 SL	lambdacyhalothrin	seed treatment	6.3 g ai/100 kg	0.0 b	0.2 b	0.1 b
HGW86 10 OD	cyantraniliprole	foliar	3.4 fl oz/A	0.0 b	0.3 b	0.0 b
HGW86 10 OD	cyantraniliprole	foliar	6.8 fl oz/A	0.0 b	0.1 b	0.0 b
HGW86 10 OD	cyantraniliprole	foliar	10.1 fl oz/A	0.0 b	0.3 b	0.0 b
HGW86 10 OD	cyantraniliprole	foliar	13.5 fl oz/A	0.1 b	0.0 b	0.0 b
Coragen 1.67 SC	ryanodine receptor modulator	foliar	7 fl oz/A	0.0 b	0.0 b	0.1 b
Voliam Flexi 40 WG	neonicotinoid + ryanodine receptor modulator	foliar	4 oz/A	0.1 b	0.1 b	0.0 b
Agri-Flex 1.55 SC	neonicotinoid + chloride channel activator	foliar	0.79 fl oz/A	0.01 b	0.3 b	0.1 b
Voliam Xpress 1.25 ZC	pyrethroid + ryanodine receptor modulator	foliar	7 fl oz/A	0.1 b	0.4 b	0.7 b
Endigo 2.06 ZC	pyrethroid + neonicotinoid	foliar	4 fl oz/A	0.0 b	0.1 b	0.1 b
Leverage 360	pyrethroid + neonicotinoid	foliar	2.8 fl oz/A	0.1 b	0.4 b	0.4 b
Leverage 2.7	pyrethroid + neonicotinoid	foliar	3.8 fl oz/A	0.0 b	0.1 b	0.4 b
Agri-Mek 0.15 EC	chloride channel activator	foliar	16 fl oz/A	0.0 b	0.0 b	0.1 b
Rimon 0.83EC	growth inhibitor	foliar	12 fl oz/A	0.1 b	0.1 b	0.1 b
Scorpion 35 SL	neonicotinoid	foliar	3.0 fl oz/A	0.1 b	0.2 b	0.2 b
Scorpion 35 SL Radiant SC	neonicotinoid + spinetoram	foliar (alternated weekly)	3.0 fl oz/A 8.0 fl oz/A	0.0 b	0.1 b	0.0 b
Admire Pro	neonicotinoid	infurrow	8.7 fl oz/A	0.1 b	0.0 b	0.0 b
Platinum 75 SG	neonicotinoid	infurrow	2.67 oz/A	0.1 b	0.0 b	0.0 b
Regent 4 SC	chloride channel modulator	infurrow	3.2 fl oz/A	0.0 b	0.5 b	0.1 b

[1] Different letters within a column denote statistically significant differences among treatments.

Susceptibility of Colorado potato beetle populations to imidacloprid and thiamethoxam

Imidacloprid (*Admire Pro*) and thiamethoxam (*Platinum*, *Actara*) continue to be the most common means of Colorado potato beetle control. Today, greater than 75% of the 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 strong 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, 15 Colorado potato beetle populations (10 Michigan populations and 5 populations collected in other states) were bioassayed with imidacloprid and/or thiamethoxam.

METHODS

During 2010, 10 Colorado potato beetle populations were collected from 4 Michigan counties (Mecosta, Montcalm, St. Joseph, and Tuscola). Cooperators also provided a population from New York and two each from Maine and Virginia. One laboratory strain was also tested (Table 1).

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. A range of five to nine concentrations was selected for each population, depending on the number of available beetles and known resistance history for each population. In each bioassay, 20-30 adults were treated with each concentration (nine to 10 beetles per dish and two to three 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 imidacloprid LD_{50} value (dose lethal to 50% of the beetles) for the susceptible laboratory strain was 0.208 µg/beetle (Table 2), statistically higher than in previous years. The LD_{50} values from the field for imidacloprid ranged from 1.573 µg/beetle (Sackett Ranch field VG) to 12.738 µg/beetle (Tuscola) for Michigan populations (Figure 1). However, the St. Joseph sample had 100% mortality at the lowest dose tested (0.3 µg/beetle); since all doses tested caused 100% mortality, the analysis was unable to calculate an LD_{50} value, but clearly this is the most susceptible population tested. On the other hand, the Tuscola population showed almost no response to all doses tested, resulting in a projected LD_{50} value of 12.738 µg/beetle, but lacked confidence limits, a very high value for the Midwest. The imidacloprid LD_{50} values from the out-of-state populations ranged from 0.104 µg/beetle (Painter, VA) to 20.428 (Jamesport, NY).

LD_{50} values were generally higher this year, with all but one population (Fryeburg, ME) having significantly higher values than the susceptible laboratory strain. One possible cause for the elevated values was a change in methodology from previous years. In 2010, we did not put beetles in cold-storage prior to testing, whereas in previous years, populations were subjected to a week or more of cold-storage (11±1°C). Instead, beetles were maintained at room temperature and fed daily until bioassays were conducted. Regardless, as in 2009, all Michigan imidacloprid LD_{50} values were significantly higher than the susceptible comparison. In 2010, 60% of the Michigan samples were greater than 10-fold resistant to imidacloprid, compared to 85% in 2009 and 90% in 2008.

The thiamethoxam LD_{50} value for the susceptible laboratory strain was 0.112 µg/beetle (Table 1), also statistically higher than in previous years. LD_{50} values for thiamethoxam in Michigan ranged from 0.152 µg/beetle (St. Joseph) to 3.248 µg/beetle (Montcalm), and from 0.134 µg/beetle (Bridgewater, ME) to 1.152 µg/beetle (Jamesport, NY) for out-of-state populations (Figure 1). Unlike the past two years, where no Michigan populations showed greater than 10-fold resistance to thiamethoxam, two populations tested (Montcalm and Tuscola) were more than 10-fold resistant to thiamethoxam. The 3.248 µg/beetle value from Montcalm is particularly high, representing the highest field thiamethoxam value we've recorded.

Thiamethoxam resistance remains uncommon and has probably been delayed by the more prevalent use of imidacloprid in the field. However, now that some Michigan sites are showing greater than 10-fold resistance to thiamethoxam, it will be important to monitor thiamethoxam resistance even closer, even more important to avoid multiple applications of neonicotinoids in a single growing season, and essential to alternate with other chemical classes for Colorado potato beetle control.

Table 1. Colorado potato beetle populations tested for susceptibility to imidacloprid and thiamethoxam in 2010.

Michigan populations
Montcalm Farm Summer adults were collected on 14 July 2010 from untreated potatoes at the Michigan State University Montcalm Potato Research Farm, Entrican, MI.
Paul Main Farm Summer adults were collected by Mark Otto, Argi-Business Consultants, Inc. from commercial potato fields in Mecosta County.
Field H6 (old field number HB-Hen) Adults were collected just north of Lakeview on 12 July 2010; adults were migrating from volunteer potatoes in field H5 (old field number HB-NS) corn. Field H6 is NW of Paul Main's field H4 (old field number HB-S [Shurlow]) that had a very high summer adult LD50 value a few years ago.
Field R13 Adults were collected in Rodney on 12 July 2010; adults were migrating from volunteer potatoes in field R1 corn.
Sackett Potatoes Summer adults were collected by Mark Otto, Argi-Business Consultants, Inc. from commercial potato fields in Mecosta and Montcalm Counties.
Field 14 Adults were collected from Home farm trap rows, Mecosta County on 12 July 2010.
Field 132 Adults were collected from northeast of Remus, Mecosta County (same population as fields 101-107) on 12 July 2010; adults were migrating from potato volunteers in fields 135-136 corn.
Fields 152-153 Adults were collected in Montcalm County on 17 July 2010. Overwintered adults migrated from field 150-151; food control early from Admire Pro, but should have sprayed 1^{st} generation larvae earlier.
Sackett Ranch Field VG1-2-7 Summer adults were collected on 12 July 2010 from a commercial potato field in southeast Edmore, Montcalm County; adults migrated in from potato volunteers from field VG3-4 corn. There has been no beetle pressure in this area for years and years.
St. Joseph Summer adults were collected by Karl Ritchie, Walther Farms on 13 July 2010 from a commercial potato field in St. Joseph County.
Sturgis Summer adults were collected in August from a commercial potato field near Sturgis, St. Joseph County.
Tuscola Summer adults were collected on 20 July 2010 from a commercial potato field in Tuscola County.
Out-of-state populations
Bridgewater, Maine Overwintered adults were collected in June 2010 by Andrei Alyokhin, University of Maine, from a commercial potato field near Bridgewater, ME.
Fryeburg, Maine Overwintered adults were collected on 2 June 2010 by Andrei Alyokhin, University of Maine, from a commercial potato field near Fryeburg, ME.
Jamesport, New York Overwintered adults were collected on 2 June 2010 by Sandra Menasha, Cornell Cooperative Extension, from a commercial potato field in Suffolk County, NY.
New Church, Virginia Overwintered adults were collected on 13 May 2010 by Tom Kuhar, Virginia Polytechnic Institute and State Universiy, from a commercial potato field near New Church, VA.
Painter, Virginia Summer adults were collected on 14 June 2010 by Tom Kuhar, Virginia Polytechnic Institute and State Universiy, from a commercial potato field 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		
Montcalm	1.909	1.530 – 2.789
Paul Main H6	4.394	2.966 – 10.234
Paul Main R13	2.495	*
Sackett Potatoes 14	2.998	1.810 – 468.790
Sackett Potatoes 132	3.137	2.459 – 4.549
Sackett Potatoes 152-153	3.141	1.625 – 12.937
Sackett Ranch VG1-2-7	1.573	1.324 – 1.898
St. Joseph	N/A	[lowest dose (0.3) had 100% mortality]
Sturgis	0.275	0.241 – 0.312
Tuscola	12.738	*
Out-of-state populations		
Bridgewater, Maine	0.428	0.136 – 0.647
Fryeburg, Maine	3.523	2.832 – 4.668
Jamesport, New York	20.428	*
Painter, Virginia	0.104	0.081 – 0.132
Laboratory strain		
New Jersey	0.208	0.166 – 0.288
THIAMETHOXAM		
Michigan populations		
Montcalm	3.248	1.552 – 411.562
Paul Main H6	0.872	0.753 – 1.014
Paul Main R13	0.671	0.321 – 262.123
Sackett Potatoes 14	0.960	0.670 – 4.686
Sackett Potatoes 132	0.859	0.498 – 2.478
Sackett Potatoes 152-153	0.691	0.608 – 0.780
Sackett Ranch VG1-2-7	0.773	0.687 – 0.871
St. Joseph	0.152	0.122 – 0.180
Sturgis	0.253	0.174 – 0.347
Tuscola	1.304	1.038 – 1.956
Out-of-state populations		
Bridgewater, Maine	0.134	0.087 – 0.177
Fryeburg, Maine	0.730	0.324 – 1.281
Jamesport, New York	1.152	1.011 – 1.324
New Church, Virginia	0.884	*
Laboratory strain		
New Jersey	0.112	0.098 – 0.130

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

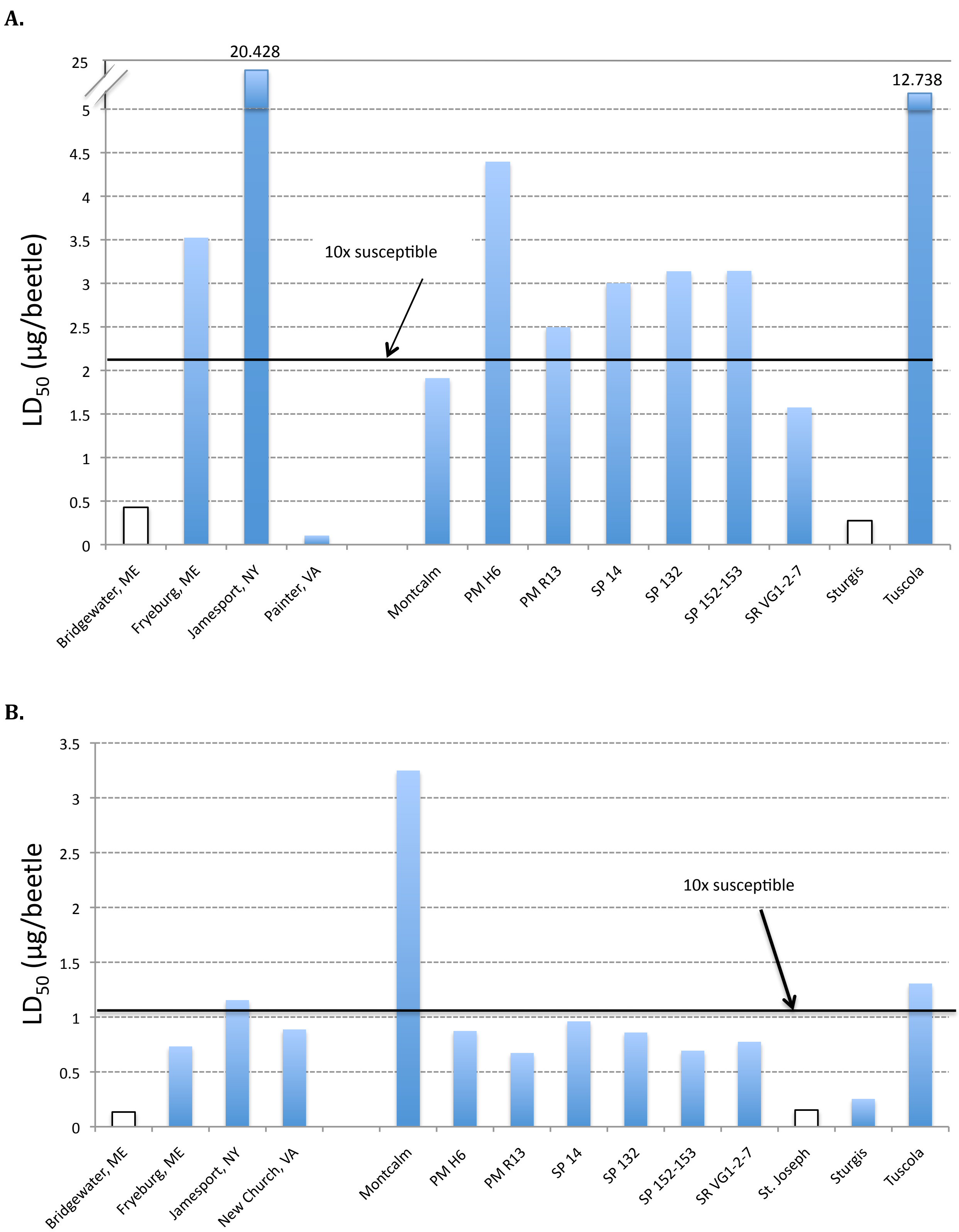


Figure 1. Susceptibility of field populations of Colorado potato beetle to imidacloprid (A) and thiamethoxam (B). Dark bars represent populations that had significantly greater LD_{50} values compared to the susceptible strain.