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For Minnesota Area I/II Potato Growers Council and Northern Plains Potato Growers Association

Project Title:
Using Insecticides and Host Plant Resistance for Colorado Potato Beetle Control

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Executive Summary

This is a new project. Colorado potato beetles (CPB) are insect pests that can defoliate entire potato plants, resulting in severe yield and quality loss. Chemical control is often the primary method used to manage CPB. However, this pest has developed resistance to several insecticides, and some populations have recently become resistant to imidacloprid (Admire). Growers need effective, economical, and sustainable methods for pest control. We propose to: 1) test experimental insecticide(s) for CPB control.

After we received funding from the MN Area II group, the company we agreed to work with (Nichino America) changed the target pest from CPB to green peach aphids (GPA). We also conducted insecticide trials for GPA in cooperation with Bayer CropScience. Data from both these trials is presented in this report. With regard to testing insecticides against CPB, we are presenting data from trials conducted by Janet Knodel (NDSU Extension Entomologist, co-PI on this grant) in cooperation with various chemical companies.

1) Insecticide Trials – Green Peach Aphid (Prischmann-Voldseth)

Materials and Methods

Location. The experiment was conducted across the Red River from Fargo ND in Glyndon MN (3 mi N of Glyndon, NW ¼ of section 30, township 140N, range 47).

Experiment establishment. The experiment was established within a solid block planting of potatoes (150 x 120 ft). Red Norland seed stock was used as the potato variety. Seed pieces were hand cut and sized to 1.5 to 2 ounces. Seed pieces were treated 2-June 2009 with fungicide (6% Mancozeb dust, 25%) at a rate of 1.0 lb/100wt. Potatoes were planted 3-June using a 2-row shovel opening potato planter. Potato seed pieces were planted in 36-in rows using a within-row seed spacing of 14-in.

Each experimental plot was approximately 15 x 12 ft, and consisted of 4 rows of potatoes with 12-13 plants per row. For the Bayer trial, four replicates of five treatments (see Table 1a for details) were established in a complete random block design, including an untreated control. For the Nichino trial, four replicates of seven treatments (see Table 1b for details) were established, with one untreated control and two standard controls, Warrior® (Syngenta) and Leverage™ 2.7 EC (Bayer Crop Science). Two standards were used because of concerns with insecticide resistance within greenhouse-collected aphid populations used to artificially infest experimental plants.

Weed and disease control. Prior to planting, both herbicides and fertilizer were applied. Acumen™ (Tenkoz Inc.) herbicide (a generic of Prowl®, BASF Ag Products) was applied at a rate of 1 qt/acre along with 10/34/0 plus 10% zinc liquid fertilizer. Herbicides were broadcast applied using T-jet flat fan nozzles at 40 psi pressure. Fertilizers were commercially applied by the cooperating grower and then incorporated to a depth of 4-6in with a field cultivator. Herbicides and fertilizers were applied 29-May.

Potatoes were hilled (cultivated) for the first time on 21-June. At that time less than 5% of the potatoes had emerged. Post-emergent herbicides were applied after hilling (Matrix® DF, 1.0 oz /acre, DuPont; Sencor 4DF 41%, 0.33 lb/acre, Bayer Crop Science). Herbicides were broadcast and applied at a rate of 20 gal/acre total volume using T-jet flat fan nozzles at 40 psi pressure. For additional weed control, potatoes were hilled twice more (5-July and 22-July).

For disease control (predominately early and late blight) Bravo® ZN fungicide (Syngenta) was broadcast on 24-July (2 pt/acre) and 1-August (1 pt/acre). During the growing season no disease was evident.

Green peach aphid (GPA) rearing and inoculation. Early scouting of experimental plots for natural GPA infestation showed that there was not a resident aphid population. Therefore, to ensure enough GPA would be present to conduct insecticide trials, we artificially infested experimental plants using aphids from greenhouse-reared colonies.

GPA colonies were initially established by allowing aphids to naturally infest sentinel potato plants (Red Norland) placed in greenhouses where sugar beets were present. Infested plants were then transferred to mesh cages and populations allowed to build. On 15-July GPA-infested leaves were then moved from greenhouse-grown potatoes to a 6 x 6 x12 ft screen cage placed over two rows of potatoes on the edge of the field plot. GPA were allowed to reproduce and then on 5-Aug, GPA-infested leaves (25-50 aphids per leaf) were transferred to four experimental plants per plot. For each experimental plant, one infested leaf was gently nestled on top of a non-infested leaf located in the middle of the canopy. Both leaves were then covered by a 10 x 12-in mesh Delnet® bag (DelStar Technologies Inc.) in order to restrict aphid movement and prevent aphids from being eaten by predators. Bag location was marked using fluorescent marking tape and flags (Fig. 1a-b). On 10-Aug, experimental plants were reinfested with GPA by placing two infested leaves (50-100 GPA per leaf) from the field rearing cage within the canopy of each experimental plant. However, these leaves were not caged with Delnet bags, and GPA had extremely low establishment.

GPA counts and chemical application. On 13-Aug, prior to spraying, the Delnet bags were removed and aphid densities assessed. Fig. 2a shows pre-treatment GPA densities on one infested leaf with has 7 leaflets. Aphids were counted on 5 leaflets per infested leaf (from leaves initially covered with Delnets), beginning at the terminal end of the leaf (Fig. 2a-b). After pre-counts were taken, the target pesticides were applied using a CO^2 backpack sprayer. Silwet L-77 was used as the non-ionic surfactant. Pesticides were applied using a T-jet flat fan nozzle at 40 psi with a total application rate of 20 gal/acre. For the Bayer trial, GPA densities were assessed on 14-Aug, 16-Aug, 18-Aug, 21-Aug, 26-Aug, and 3-Sept with data presented as mean aphids per leaflet (Table 2a). For the Nichino trial, GPA densities were assessed on 21-Aug, 24-Aug, 31-Aug, and 7-Sept with data presented as mean aphids per leaflet (Table 2b). Potatoes then began senescing and GPA densities were not assessed further.

Colorado potato beetle (CPB) control and assessment. CPB were present throughout the plots, and needed to be controlled in order to prevent experimental plants from being defoliated. We decided not to use Admire Pro at planting to control CPB because we were concerned there might be non-target effects on GPA densities. Therefore, on 7-Aug, once defoliation by the beetles reached ~5%, Novodor FC® insecticide (Valent BioSciences; 3 qt/acre) was applied to all plots using a CO^2 backpack sprayer with T-jet flat fan nozzles at 40 psi. Novodor is a biological insecticide (*Bacillus thuringiensis, tenebrionis* strain) that is host specific to Coleoptera, including CPB. For the Nichino trial, percent CPB defoliation was quantitatively assessed on 18-Aug and qualitatively assessed on 24-Aug.

Potato yield. For the Bayer trial, yield data was gathered from each of the four experimental plants per plot (*i.e.* the plants that were infested with GPA).On 24 Oct, potatoes in individual hillswere hand dug using a 4-tined potato fork. Potatoes from each plant were weighed on site using a portable electronic balance. Yield data is presented in Table 3 (in ounces per plant).

Statistical analysis. Treatment averages were used if there was any missing data (*e.g.* if a leaflet was damaged / dead). Aphid count data was square root transformed and analyzed using analysis of variance (ANOVA) in Systat 12 (Systat Inc. 2007). Tukey's Honest Significant Difference was used as a posthoc test. The same statistical methods were used to analyze potato yield data, although the data did not need to be transformed. Non-transformed data are presented in Tables 2a-b and 3.

Results and Discussion

Artificial aphid infestation of experimental plants was successful, although initial aphid densities were higher than threshold levels when chemicals were applied (in some cases over 100 aphids per leaflet).

Bayer trial. Aphid populations were not significantly different between treatments at the beginning of the experiment (Table 2a). GPA densities decreased dramatically after chemicals were applied in all treatments. The decrease in GPA densities in the untreated control was likely due to dispersal after Delnets were removed. Dispersal could have contributed to lower aphid densities in non-control plots, although dead aphids were observed on leaves, and the only chemical treatment that did not have significantly lower GPA aphid densities 1 day post-treatment (PT) was #2 (Movento-70) . In addition, 3, 5, 7, and 13 days PT GPA densities in all Movento treatments were close to zero and significantly lower than GPA densities in the untreated control. By 21 days PT, GPA densities in the control treatment had fallen and were not significantly different than those in the chemical treatments, with the exception of #2 (Movento-70), where GPA densities were still significantly lower than those in the control. Overall, it appeared that all Movento treatments were effective at reducing GPA populations.

Mean yield per experimental potato plant was lowest in treatment #3 (Movento-88; 45.88 ± 3.84 ounces per plant) and highest in treatment #4 (Movento + Provado; 55.25 ± 2.67 ounces per plant). However, there was no significant impact of chemical treatment on potato yield per experimental plant (Table 3).

Nichino trial. Aphid populations were not significantly different between treatments at the beginning of the experiment. Post-treatment (PT) aphid densities were assessed after four days instead of three due to inclement weather. GPA densities decreased dramatically after chemicals were applied in all treatments. The decrease in GPA densities in the untreated control was likely due to dispersal after Delnets were removed. Dispersal could have contributed to lower aphid densities in non-control plots, although dead aphids were observed on leaves. In addition, even though GPA densities in the untreated control declined, four and seven days PT GPA densities in all NNI-0101 treatments and the Leverage treatment were close to zero and significantly lower than GPA densities in the untreated control and Warrior treatment. Applying Warrior appeared to flare GPA densities. Seven days PT, GPA densities in the untreated control were significantly lower than the Warrior treatment. Fourteen and 21 days PT, GPA densities in all treatments were significantly lower than the Warrior treatment. Overall, it appeared that Leverage and all the NNI-0101 treatments were effective at reducing GPA populations.

On 18-Aug, mean percent CPB defoliation was below 3% in all plots (1-N25, 2.9 ± 0.6; 2-N37.5, 2.3 ± 0.3; 3-N50, 1.7 ± 0.3; 4-N37.5 WDG, 1.9 ± 0.4; 5-Warrior, 2.4 ± 0.4; 6-Leverage, 1.9 ± 0.2; 7-untreated, 2.9 ± 0.4; refer to Table 1 for treatment details). On 24-Aug, percent CPB defoliation was uniform in all plots and ranged from 5-8%.

Table 1a. Bayer GPA trial: details of experimental treatment applications.

#	Product	Formulation	Rate (g ai/ha)	Product (oz/ac)	Application timing	Type of application
1	Untreated control	n/a	n/a	n/a	n/a	n/a
2	MOVENTO 240 SC + NIS	240 + 100	70, 0.25% v/v	4, 0.25% v/v	At detection	Foliar
3	MOVENTO 240 SC + NIS	240 + 100	88, 0.25% v/v	5, 0.25% v/v	At detection	Foliar
4	MOVENTO 240 SC + PROVADO + NIS	240 + 192 + 100	56.2 + 53.3, 0.25% v/v	3, 3.8, 0.25% v/v	At detection	Foliar
5	MOVENTO 240 SC + LEVERAGE + NIS	240 + 324 + 100	56.2 + 90, 0.25% v/v	3, 3.8, 0.25% v/v	At detection	Foliar

= Treatment code
NIS = non-ionic surfactant (see methods for details)

Table 1b. Nichino GPA trial: details of experimental treatment applications.

#	Product	Product	Product (oz/ac)	Application timing	Type of application
1	NNI-0101 20SC + NIS	25 g ai / ha	1.59 fl oz 0.5% v/v	At detection	Foliar
2	NNI-0101 20SC + NIS	37.5 g ai / ha	2.39 fl oz 0.5% v/v	At detection	Foliar
3	NNI-0101 20SC + NIS	50 g ai / ha	3.19 fl oz 0.5% v/v	At detection	Foliar
4	NNI-0101 20WDG + NIS	37.5 g ai / ha	2.68 oz 0.5% v/v	At detection	Foliar
5	Standard = Warrior	22.4 g ai / ha	2.56 fl oz / acre	At detection	Foliar
6	Standard = Leverage 2.7 EC	90.0 g ai / ha	3.8 fl oz / acre	At detection	Foliar
7	Untreated control	n/a	n/a	n/a	n/a

= Treatment code
NIS = non-ionic surfactant

Table 2a. Bayer GPA trial: effect of experimental treatments on green peach aphid densities.

#	Product	Green peach aphids / leaflet						
		Aug 13[1]	**Aug 14**	**Aug 16**	**Aug 18**	**Aug 21**	**Aug 26**	**Sept 3**
1	Untreated control	49.6 ± 9.7 a	23.4 ± 7.4 a	5.4 ± 3.0 a	4.5 ± 2.5 a	3.8 ± 1.8 a	2.1 ± 0.9 a	0.3 ± 0.1 a
2	MOVENTO 240 SC (70)	44.5 ± 4.9 a	13.3 ± 2.9 ab	.04 ± .02 b	.01 ± .01 b	.02 ± .01 b	.01 ± .01 b	0 ± 0 b
3	MOVENTO 240 SC (88)	45.7 ± 5.8 a	7.6 ± 2.4 bc	.14 ± .06 b	0.5 ± 0.5 b	0.2 ± 0.2 b	0 ± 0 b	.05 ± .03 ab
4	MOVENTO 240 SC + PROVADO	45.1 ± 9.7 a	3.5 ± 2.4 c	0.9 ± 0.8 b	0.8 ± 0.6 b	0.5 ± 0.4 b	.03 ± .02 b	.05 ± .03 ab
5	MOVENTO 240 SC + LEVERAGE	60.6 ± 9.9 a	0.9 ± 0.6 c	.09 ± .09 b	.09 ± .06 b	.09 ± .09 b	.03 ± .02 b	.08 ± .05 ab
P-value		0.67	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.06

Means (± standard error of the mean) followed by the same letter are not significantly different ($P > 0.05$), Tukey's HSD test. **#** = Treatment code. [1] = pre-treatment densities

Table 2b. Nichino GPA trial: effect of experimental treatments on green peach aphid densities.

#	Product	Green peach aphids / leaflet				
		Aug 17[1]	**Aug 21**	**Aug 24**	**Aug 31**	**Sept 7**
1	NNI-0101 25	99.8 ± 6.7 a	1.2 ± 0.6 a	0 ± 0 a	0.03 ± 0.02 a	0.03 ± 0.02 a
2	NNI-0101 37.5	102.5 ± 8.6 a	0.1 ± 0.1 a	0.01 ± 0.01 a	0 ± 0 a	0 ± 0 a
3	NNI-0101 50	124.0 ± 8.0 a	1.1 ± 0.4 a	0.03 ± 0.03 a	0 ± 0 a	0 ± 0 a
4	NNI-0101 37.5 WDG	108.3 ± 10.2 a	1.0 ± 0.5 a	0.2 ± 0.1 a	0.01 ± 0.01 a	0.01 ± 0.01 a
5	Warrior	99.6 ± 7.1 a	25.2 ± 3.3 b	14.0 ± 1.8 b	2.8 ± 0.4 b	0.5 ± 0.2 b
6	Leverage	109.5 ± 9.0 a	0.05 ± 0.03 a	0.01 ± 0.01 a	0.3 ± 0.1 a	0.01 ± 0.01 a
7	Untreated control	119.5 ± 7.9 a	20.3 ± 2.4 b	9.7 ± 1.8 c	0.3 ± 0.1 a	0 ± 0 a
	P-value	0.101	< 0.001	< 0.001	< 0.001	< 0.001

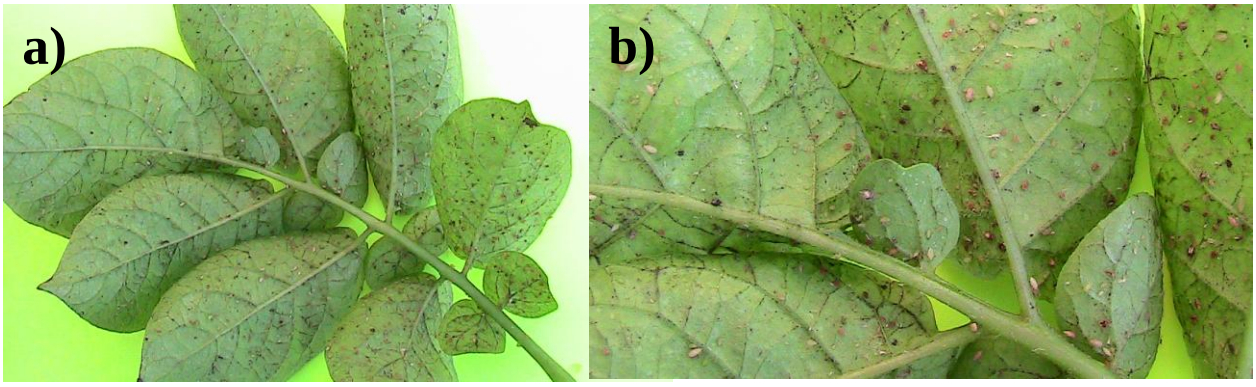
Means followed by the same letter are not significantly different ($P > 0.05$), Tukey's HSD test. **#** = Treatment code. [1] = pre-treatment densities

Table 3. Bayer GPA trial: effect of experimental treatments on potato yield.

#	Product	Yield / experimental plant (oz.)
1	Untreated control	53.75 ± 2.71 a
2	MOVENTO 240 SC (70)	52.69 ± 2.58 a
3	MOVENTO 240 SC (88)	45.88 ± 3.84 a
4	MOVENTO 240 SC + PROVADO	55.25 ± 2.67 a
5	MOVENTO 240 SC + LEVERAGE	46.38 ± 2.88 a
	P-value	0.08
Means (± standard error of the mean) followed by the same letter are not significantly different ($P > 0.05$), Tukey's HSD test. # = Treatment code		

Fig. 1a-b. Green peach aphid infestation technique.

Fig. 2a-b. Pre-treatment green peach aphid densities per leaf.



2) Insecticide Trials – Colorado Potato Beetles (Knodel, Beauzay, Prischmann-Voldseth)

Materials and Methods

The experiment was conducted across the Red River from Fargo ND in Glyndon MN (3 mi N of Glyndon, NW ¼ of section 30, township 140N, range 47).

Red Norland seed stock was used as the potato variety. Seed pieces were hand cut and sized to 1.5 to 2 ounces. Seed pieces were treated 2 June 2009 with fungicide (6% Mancozeb dust, 25%) at a rate of 1.0 lb/100wt. Potatoes were planted 3 June using a 2-row shovel opening potato planter. Rows were hilled when needed and kept free of weeds by herbicides, cultivation and hand-weeding. On 29 May, PPI herbicide (Prowl at 1qt/acre) plus fertilizer (10-34-0 + 10% zinc) was applied at 5 gal/acre. On 21 June 21, Matrix was applied 10 fl oz/acre plus Sencor @ 0.33 lb/acre. On 13 and 20 Sept, Bravo Zinc fungicide was applied at 1 pt/acre, and then at 1.5 pt/acre.

Plots were 30 ft long and consisted of 4 rows per plot with two guard rows between plots. Row spacing was 36 inches and potatoes were planted 14 inches apart within the rows. Plant population was approximately 19,360 plants/acre. Blocks (replications) were separated by 10-foot alleys. Four replicates of eight treatments were established in a complete random block design:

1) Untreated check
2) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a
3) Rimon at 9 fl oz/a
4) Temprano at 8 fl oz/a
5) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a + 2nd app of Rimon at 2 fl oz/a (7-10 DAT)
6) Coragen at 3.5 fl oz/a (low label rate)
7) Coragen at 5 fl oz/a (high label rate)
8) Admire Pro at 0.35 oz/cwt (seed treatment standard)

Rimon is a growth regulator with long residual activity. Temprano has a quick knock down and some residual activity. Coragen has a quick knockdown and good residual, but is not effective against the egg stage of CPB. All foliar insecticide treatments were mixed just prior to application. Foliar treatments were applied with a CO_2 sprayer and 12-foot boom with T-Jet 80015 nozzles at 40 psi and an application volume of 20 GPA. Admire Pro was applied as a seed treatment at planting.

The pre-spray CPB count was conducted on the morning of 13 July. All foliar insecticide applications were made on the afternoon of 13 July. The second application of Rimon at 2 fl oz/a was applied to Treatment 6 on 21 July. Weekly counts were conducted on 20 July (7 DAT), 27 July (14 DAT), 3 Aug (21 DAT) and 10 Aug (28 DAT). Counts were made by counting the numbers of egg masses, small larvae, large larvae and adults on 10 plants in the center two rows of each plot. Defoliation ratings were made at 7, 14, 21, and 28 DAT. Defoliation was visually estimated and recorded as the percent of leaf tissue consumed for the entire plot. Plots were harvested on 28 Oct. Analysis of variance for CPB count data, defoliation data and yield was conducted using PROC GLM in SAS statistical software. Treatment means were compared using Fisher's Protected LSD ($P \leq 0.05$).

Mating CPB adults and egg masses were first noted in the trial during the first week of July. This was about two weeks later than in previous years due to much below normal temperatures in June. CPB numbers built up rapidly throughout the trial, but feeding activity was

slow. This also was likely due to unseasonably cool temperatures during July and early August. Pre-spray count data on July 13 (Table 4) suggested that CPB was fairly well distributed in the trial (with the exception of the Admire seed treatment, which had low CPB densities). The presence of all life stages within the trial indicated that the time was right to apply the foliar insecticide treatments. After this date, adult and egg mass counts were generally too low to be statistically meaningful. No phytotoxicity was observed for any treatment.

Most of the damage was caused by larvae, especially large larvae, and therefore we will focus on the larval life stages. Prior to applications of foliar chemicals (13 July), there were no significant differences in densities of large larvae (LL) between foliar chemical treatments, although densities of small larvae (SL) ranged from a mean of 3.33 to 8.00 (Figs. 1-2; Table 4). On 20 July, after foliar chemicals were applied, SL and LL densities were significantly higher in the untreated control compared to all chemical treatments, including the Admire Pro seed piece treatment (Figs. 1-2; Table 5). On 27 July, densities of LL were still significantly higher in the untreated control compared to all chemical treatments. However, on 27 July, there were no significant differences in densities of SL between the untreated control and any of the chemical treatments, with the exception of treatment 3 (Rimon), which had significantly higher densities of SL (Figs. 1-2; Table 6). By 3 Aug, virtually all of the SL in all treatments had grown into the LL group. On 3 Aug, LL densities in treatment 4 (Temprano), were significantly higher than the other treatments. All other chemical treatments, with the exception of #3 (Rimon), had significantly lower LL densities compared to the untreated control (Figs. 1-2; Table 7). By 10 Aug, LL densities had dropped in all treatments, although densities in treatment #4 (Temprano) were still significantly higher than those in all other treatments (Figs. 1-2; Table 8).

Overall, the Admire Pro seed treatment provided excellent control of CPB throughout the growing season. Foliar insecticide treatments that provided comparable control of CPB included #5 [Rimon at 9 fl oz/a + Temprano at 8 fl oz/a + 2nd app of Rimon at 2 fl oz/a (7-10 DAT)] and #7 (Coragen at 5 fl oz/a).

For yield, a season-long moisture gradient existed in about ½ of the trial. This had a significant impact on yield for several plots. Treatment 8 was not impacted by excessive moisture, but all other treatments had at least two plots that were. This is reflected by the high CV (46%) for yield. A log transformation was performed on yield data to try and lower the variability within treatments, even though the raw data satisfied the assumption of homogeneity of variance. Significance for raw yield data and transformed yield data are presented in Table 9. The CPB life stage count data and percent defoliation data give a better indication of insecticide activity than does yield data.

Fig. 1. Mean densities of small CPB larvae per plant (Series #'s correspond to treatments).

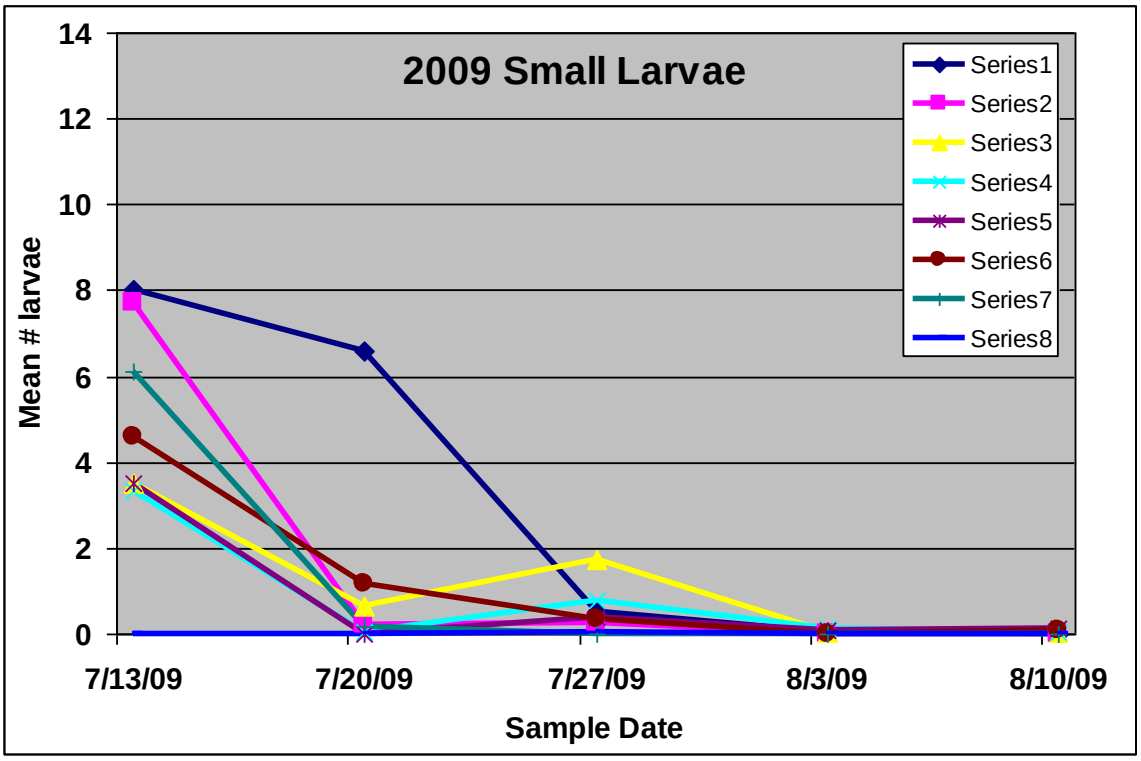


Fig. 2. Mean densities of large CPB larvae per plant (Series #'s correspond to treatments).

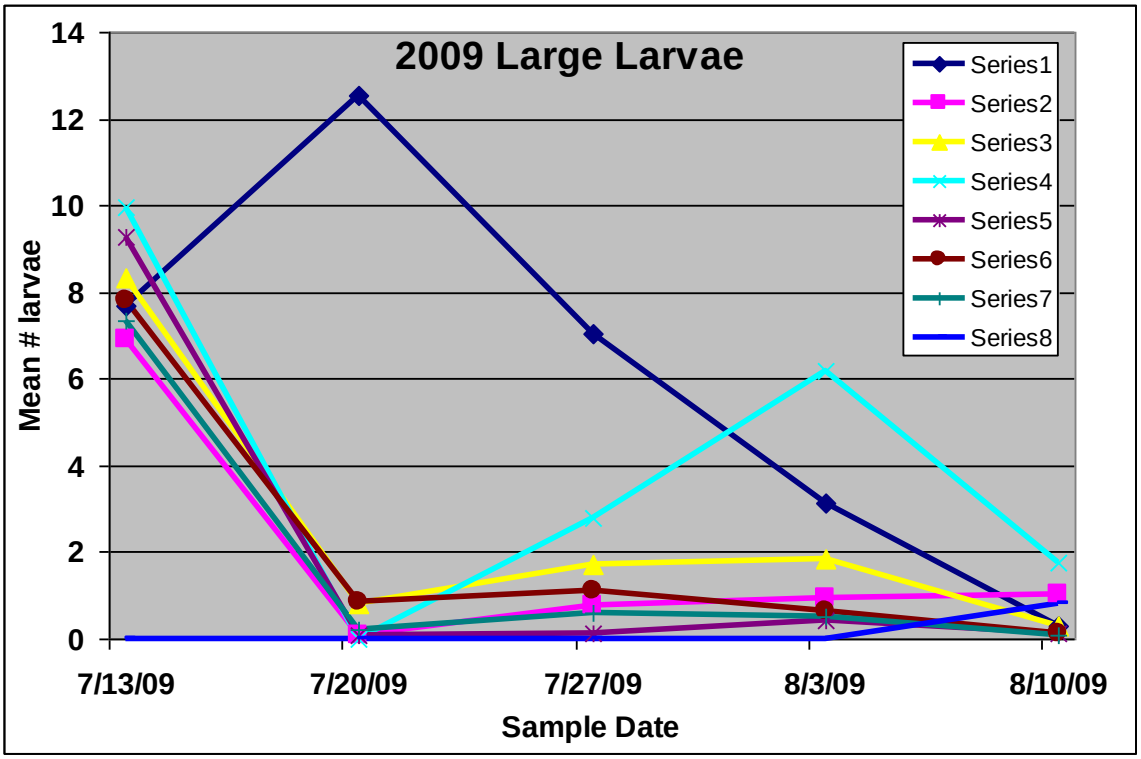


Table 4. Mean CPB life stage counts for 13 July (pre-foliar spray count date).

Treatment	Egg masses/plant	Small larvae/plant	Large larvae/plant	Adults/plant	% Defoliation /plot
1) Untreated check	0.23 abc	8.00 a	7.70 a	0.18 b	---
2) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a	0.15 bc	7.73 a	6.90 a	0.10 b	---
3) Rimon at 9 fl oz/a	0.40 a	3.53 bc	8.33 a	0.18 b	---
4) Temprano at 8 fl oz/a	0.28 abc	3.33 bc	9.98 a	0.40 a	---
5) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a + 2nd app of Rimon at 2 fl oz/a (7-10 DAT)	0.28 abc	3.50 bc	9.28 a	0.10 b	---
6) Coragen at 3.5 fl oz/a	0.35 ab	4.58 ab	7.80 a	0.05 b	---
7) Coragen at 5 fl oz/a	0.33 ab	6.10 ab	7.35 a	0.05 b	---
8) Admire Pro at 0.35 oz/cwt (seed treatment standard)	0.05 c	0 c	0 b	0.15 b	---
***P*-value**	**0.125**	**0.001**	**0.004**	**0.012**	**---**

Means within a column with the same letter are not significantly different (Fisher's Protected LSD, $P \leq 0.05$).

Table 5. Mean CPB life stage counts and percent defoliation for 20 July (7 DAT).

Treatment	Egg masses/plant	Small larvae/plant	Large larvae/plant	Adults/plant	% Defoliation /plot
1) Untreated check	0 b	6.58 a	12.53 a	0 b	18 a
2) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a	0.10 a	0.23 b	0.08 b	0.10 ab	5 b
3) Rimon at 9 fl oz/a	0.03 ab	0.65 b	0.80 b	0.08 ab	5 b
4) Temprano at 8 fl oz/a	0.05 ab	0.05 b	0 b	0.08 ab	5 b
5) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a + 2nd app of Rimon at 2 fl oz/a (7-10 DAT)	0.03 ab	0 b	0.10 b	0 b	5 b
6) Coragen at 3.5 fl oz/a	0.08 ab	1.18 b	0.85 b	0.08 ab	5 b
7) Coragen at 5 fl oz/a	0.05 ab	0.18 b	0.23 b	0.13 ab	5 b
8) Admire Pro at 0.35 oz/cwt (seed treatment standard)	0 b	0 b	0 b	0.23 a	5 b
***P*-value**	**0.264**	**<0.001**	**<0.001**	**0.099**	**0.003**

Means within a column with the same letter are not significantly different (Fisher's Protected LSD, $P \leq 0.05$).

Table 6. Mean CPB life stage counts and percent defoliation for 27 July (14 DAT).

Treatment	Egg masses/plant	Small larvae/plant	Large larvae/plant	Adults/plant	% Defoliation /plot
1) Untreated check	0 b	0.53 b	7.05 a	0.05 a	30 a
2) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a	0.05 ab	0.28 b	0.78 cd	0.08 a	5 b
3) Rimon at 9 fl oz/a	0 b	1.75 a	1.70 bc	0 a	5 b
4) Temprano at 8 fl oz/a	0 b	0.78 b	2.80 b	0 a	5 b
5) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a + 2nd app of Rimon at 2 fl oz/a (7-10 DAT)	0.03 ab	0.38 b	0.13 d	0.03 a	5 b
6) Coragen at 3.5 fl oz/a	0.03 ab	0.33 b	1.13 cd	0.08 a	5 b
7) Coragen at 5 fl oz/a	0 b	0 b	0.58 cd	0.03 a	5 b
8) Admire Pro at 0.35 oz/cwt (seed treatment standard)	0.08 a	0.05 b	0 d	0.08 a	5 b
***P*-value**	**0.323**	**0.006**	**<0.001**	**0.572**	**0.104**

Means within a column with the same letter are not significantly different (Fisher's Protected LSD, $P \leq 0.05$).

Table 7. Mean CPB life stage counts and percent defoliation for 3 August (21 DAT).

Treatment	Egg masses/plant	Small larvae/plant	Large larvae/plant	Adults/plant	% Defoliation /plot
1) Untreated check	0 b	0.05 a	3.15 b	1.08 a	59 a
2) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a	0.03 a	0 a	0.95 cd	0.05 bc	5 b
3) Rimon at 9 fl oz/a	0 b	0.03 a	1.85 bc	0.10 bc	5 b
4) Temprano at 8 fl oz/a	0 b	0.15 a	6.20 a	0.18 bc	5 b
5) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a + 2nd app of Rimon at 2 fl oz/a (7-10 DAT)	0 b	0.10 a	0.43 d	0.03 c	5 b
6) Coragen at 3.5 fl oz/a	0 b	0 a	0.63 cd	0.33 b	5 b
7) Coragen at 5 fl oz/a	0 b	0 a	0.53 cd	0.18 bc	5 b
8) Admire Pro at 0.35 oz/cwt (seed treatment standard)	0 b	0 a	0 d	0.13 bc	5 b
***P*-value**	**0.431**	**0.652**	**<0.001**	**<0.001**	**<0.001**

Means within a column with the same letter are not significantly different (Fisher's Protected LSD, $P \leq 0.05$).

Table 8. Mean CPB life stage counts and percent defoliation for 10 August (28 DAT).

Treatment	Egg masses/plant	Small larvae/plant	Large larvae/plant	Adults/plant	% Defoliation /plot
1) Untreated check	0 a	0 a	0.28 cd	5.50 a	54 a
2) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a	0 a	0 a	1.03 b	1.35 bc	5 b
3) Rimon at 9 fl oz/a	0 a	0 a	0.28 cd	0.48 d	5 b
4) Temprano at 8 fl oz/a	0 a	0.03 a	1.78 a	0.23 d	5 b
5) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a + 2nd app of Rimon at 2 fl oz/a (7-10 DAT)	0 a	0.13 a	0.15 d	0.83 bcd	5 b
6) Coragen at 3.5 fl oz/a	0 a	0.10 a	0.15 d	1.65 b	5 b
7) Coragen at 5 fl oz/a	0 a	0 a	0.10 d	0.78 cd	5 b
8) Admire Pro at 0.35 oz/cwt (seed treatment standard)	0 a	0 a	0.83 bc	0.18 d	5 b
***P*-value**	**n/a**	**0.478**	**<0.001**	**<0.001**	**<0.001**

Means within a column with the same letter are not significantly different (Fisher's Protected LSD, $P \leq 0.05$).

Table 9. Mean yields.

Treatment	Yield (cwt/acre)
1) Untreated check	87.0 b
2) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a	152.1 b
3) Rimon at 9 fl oz/a	145.4 b
4) Temprano at 8 fl oz/a	185.7 ab
5) Rimon at 9 fl oz/a + Temprano at 8 fl oz/a + 2nd app of Rimon at 2 fl oz/a (7-10 DAT)	120.6 b
6) Coragen at 3.5 fl oz/a	110.4 b
7) Coragen at 5 fl oz/a	120.5 b
8) Admire Pro at 0.35 oz/cwt (seed treatment standard)	290.9 a
LSD	**110.49**
CV	**49.6%**

Means within a column with the same letter are not significantly different (Fisher's Protected LSD, $P \leq 0.05$