IOWA STATE UNIVERSITY
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REPORT OF INSECTICIDE EVALUATION

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Insects Investigated
Soybean Aphid
Japanese Beetle

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Iowa State University
2011 Insecticide Evaluation of Soybean Insects Report

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Funding Sources

Iowa Soybean Association and the soybean checkoff

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Nichino America, Inc.

Syngenta Crop Protection

Introduction to Soybean Aphid

SOYBEAN, *Glycine max* (L.), grown in most of the north central region of the United States has historically used low amounts of insecticide. However, the confirmation of soybean aphid, *Aphis glycines* Matsumura (Hemiptera: Aphididae), in 2000 has drastically changed soybean pest management. Outbreak populations of soybean aphid (i.e., 1,000's per plant) can significantly reduce yield by 40%, and reduce seed size, seed coat quality, pod number and plant height (Ragsdale et al. 2007). Before 2000, less than 0.1% of soybean was treated with insecticides (USDA-NASS). However, soybean aphid management has resulted in a 130-fold increase of insecticide applications in less than a decade (Ragsdale et al. 2011). An estimated 1,400% increase of Iowa soybean acres were treated with a foliar insecticide in 2009 compared to 2000 (Hodgson et al. 2011a). Growers are also increasing the use of insecticidal seed treatments to control early-season establishment of insects on soybean. Approximately 73% of Iowa soybean had an insecticidal seed treatment in 2009 (Hodgson et al. 2011a).

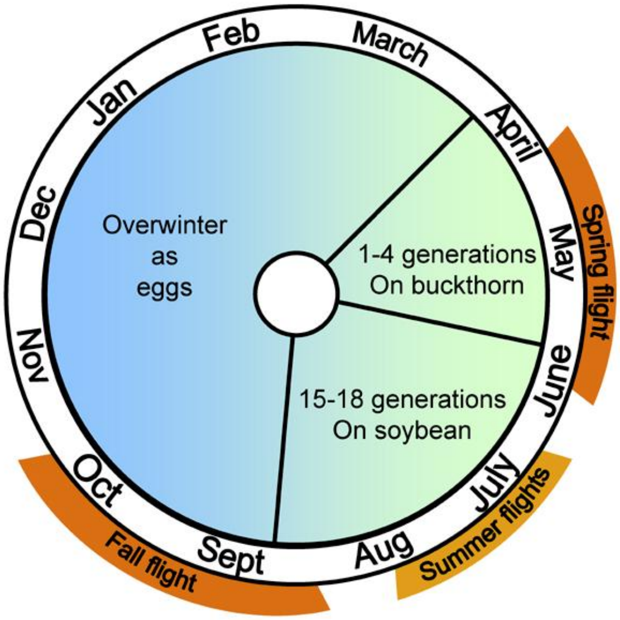
A multistate research effort showed that 650 aphids per plant are needed before economic injury will occur (Ragsdale et al. 2007). An economic threshold of 250 aphids per plant was developed and adopted throughout the north central region (Ragsdale et al. 2007, Hodgson et al. 2011c). The economic threshold should be used from flowering (R1) through seed set (R1-R5.5) to protect yield, reduce control costs, and preserve insecticide efficacy (Hodgson et al. 2011b).

The severity and abundance of soybean aphid in Iowa has fluctuated over the last decade. In 2011, parts of Iowa once again experienced economically significant populations of soybean aphid, especially in the northern half of the state. Some commercial fields were infested in June, which would be considered early compared to most years in Iowa. However, most commercial fields that justified a foliar treatment were sprayed during the first two weeks of August.

Host plant resistance is the newest soybean aphid management tool, and is complementary to existing chemical control. Aphid-resistant varieties have the potential to simultaneously reduce insecticide usage and associated production costs, and preserve natural enemies in soybean (Tilmon et al. 2011). To date, host plant resistant genes for soybean aphid are prefixed with "*Rag*," which is an abbreviation for "Resistant *Aphis glycines*." The *Rag1* gene expresses antibiosis and has been commercially available since 2010. Antibiosis is type of resistance where exposed insects do not live as long or produce as many offspring as they could on susceptible plants.

Soybean Aphid Description. Wingless adults are a typical pear-shape and are 1/16 inch long (Voegtlin et al. 2004). The body is bright yellow-green with dark eyes and black cornicles ("tailpipes" at the end of the abdomen). They have pale legs, antennae and dusky-colored cauda (small appendage on the tip of the abdomen). Winged aphids have a dark head and thorax, and two pairs of clear wings that extend well past the end of the abdomen.

Soybean Aphid Life Cycle. Soybean aphid has a complex life cycle similar to other host-alternating aphids (Ragsdale et al. 2004). In the fall, eggs are laid on buckthorn (*Rhamnus* spp.) to overwinter. Buckthorn is a woody shrub found in shelter belts throughout the north central region. Eggs hatch is synchronized with buckthorn bud burst in the spring. A few asexual wingless generations are produced before winged adults are formed. Spring migrants move to emerging soybean during May and June. There can be 15-18 asexual generations on soybean depending on the temperature (McCornack et al. 2004). During the summer, there is a mixture of wingless and winged adults formed. Aphid crowding, plant quality and the presence of natural enemies may prompt winged aphids to develop. Long distance migration can occur because the aphids move with jet streams. As soybean matures and day length decreases, winged soybean aphids move back to buckthorn to mate and deposit eggs.



Soybean aphids have a host-alternating life cycle that includes soybean and buckthorn.

Soybean Aphid Feeding Damage. As with all aphids, they have a piercing-sucking stylet mouthpart. Nymphs and adults feed on plant sap in the phloem of all aboveground plant parts. Heavily infested plants may be discolored or wilted. Prolonged aphid feeding results in large amounts of cast skins and excreted honeydew on all aboveground plant parts. Honeydew is sugar-rich and sticky, and can promote black sooty mold growth. Severe aphid infestations can cause flower and small pods to abort. The combination of aphids removing plant nutrients and mold-covered leaves can result in up to 40% yield reduction (Ragsdale et al. 2007).

Scouting for Soybean Aphid. Most successful IPM (integrated pest management) programs involve regular sampling of the target pest. This can be especially important for a multigenerational insect with a complex life cycle like soybean aphid. Regular scouting for soybean aphid in July and August is recommended, even if using an insecticidal seed treatment or a host plant resistant variety. Winged aphids are more prevalent and likely to migrate within and between fields during the reproductive soybean period (Hodgson et al. 2005).


Soybean aphids strongly prefer to colonize the newest soybean growth.

Regular sampling throughout the growing season will help producers track trends and improve foliar application timing. Although colonies can be initially patchy, populations can quickly spread throughout the field under favorable weather conditions. Soybean aphid prefers the newest soybean foliage (e.g., expanding trifoliates), and are attracted to late-planted soybean. Scouting every seven to 10 days is ideal to monitor naturally fluctuating populations. Count aphids on 40 plants for every 50 acres of soybean, and be sure to look at different areas of the field. Alternatively, use a binomial sequential sampling plan, *Speed Scouting for Soybean Aphid* (Hodgson et al. 2007). Particular attention should be made to fields during bloom (R1) through seed set (R5.5) (Hodgson et al. 2004).

Materials and Methods

We established plots at three Iowa State University Research Farms (Johnson, Northeast and Northwest) in 2011. A Syngenta soybean variety 05RM310021 was used for all the soybean aphid-susceptible treatments, and a Syngenta soybean variety 07JR801843 was used for the *Rag1*-containing treatments. The two seed types were not genetically related, but were visually similar. There were two controls at each location: an untreated and a “zero aphid” in which a tank-mix of two insecticides (λ-cyhalothrin and chlorpyrifos) was applied every time aphids reached 10 aphids per plant. The control treatments allowed for comparisons of yield protection against soybean aphid.

Johnson Research Farm. The first location was at the Iowa State University Johnson Research Farm in Story County, Iowa. The treatments were arranged in a randomized complete block design with four replications, and soybean was planted in 30-inch rows on 3 June. Each plot was six rows wide and 50 feet long. In total for 2011, we evaluated 10 treatments with products alone or in combination (Table 1).

Northeast Research Farm. The second location was at the Iowa State University Northeast Research Farm in Floyd County, Iowa. The treatments were arranged in a randomized complete block design with four replications, and soybean was planted in 30-inch rows using no-till production practices on 17 May. Each plot was six rows wide and 50 feet long. In total for 2011, we evaluated 24 treatments with products alone or in combination (Table 3).

Northwest Research Farm. The third location was at the Iowa State University Northwest Research Farm in O'Brien County, Iowa. The treatments were arranged in a randomized complete block design with four replications, and soybean was planted in 30-inch rows using no-till production practices on 18 May. Each plot was six rows wide and 50 feet long. In total for 2011, we evaluated 15 treatments with products alone or in combination (Table 5).

Plant Stand. Plant stands were taken at V2 at the Johnson, Northeast, and Northwest Research Farms on 17 June, 7 June, and 15 June, respectively. Two 10-foot sections were randomly selected within each plot, and the number of emerged plants were counted. The average plant stand per 10 feet for each location was 80.9 ± 0.87 (± SEM) plants for the Johnson Research Farm, 93.7 ± 0.37 plants for the Northeast Research Farm, and 90.5 ± 0.34 plants for the Northwest Research Farm.

Insecticide Application Techniques. Most of seed did not have a seed treatment, but those treatments containing CruiserMaxx Beans were applied by Syngenta. For all locations, foliar treatments were applied using a backpack sprayer and TeeJet (Springfield, IL) twinjet nozzles (TJ 11002) with 20 gallons of water per acre at 40 pounds of pressure per square inch. Our target for most foliar insecticide treatments was at the economic threshold or if plants reached beginning seed fill (R5).

Estimation of Soybean Aphid Cumulative Aphid Days. Soybean aphids were counted on randomly selected plants within each plot. All aphids (adults, nymphs, and winged aphids) were counted on each whole plant. The number of plants counted ranged from 20 to 3. The number of plants sampled was determined by plant growth stage and by the severity of aphid infestation. Twenty plants were counted in each plot until plants reached reproductive stages, at which point ten plants were sampled in each plot. The number of plants sampled further decreased to 5 and then to 3 per plot as the percentage of plants infested with aphids and the average aphids per plant increased. Summing aphid days accumulated during the growing season provides a measure of the seasonal aphid exposure that a soybean plant experiences, similar to calculating area under the curve. To estimate the total exposure of soybean plants to soybean aphid, we calculated cumulative aphid days (CAD) based on the number of aphids per plant counted on each sampling date. We estimated CAD with the following equation:

$$\sum_{n=1}^{\infty} = \left(\frac{x_{i-1} + x_i}{2} \right) \times t \qquad \text{equation [1]}$$

where x is the mean number of aphids on sample day i, x_{i-1} is the mean number of aphids on the previous sample day, and t is the number of days between samples i - 1 and i. We would expect to see economic loss around 5,000-6,000 CAD (Ragsdale et al. 2007).

Yield Analysis. Yields were determined by weighing grain with a grain hopper which rested on a digital scale sensor custom designed for each of the three harvesters. Yields were corrected to 13% moisture and reported as bushels per acre.

Statistical Analysis. One way analysis of variance (ANOVA) was used to determine treatment effects within each experiment. Means separation for all studies was achieved using a least significant difference (LSD) test with an Student-Newman-Keuls (SNK) pairwise comparison (α = 0.10). All statistical analyses were performed using SAS® software (SAS 2011).

Results and Discussion

There was a range of seasonal aphid pressure at the three locations in 2011. Figure 1 summarizes the timing of first colonization and peak aphid density in the untreated control treatments and *Rag1* treatment. The plots at the Johnson and Northwest Farms were colonized in mid-July, and the Northeast Farm was colonized in early August (Figure 1). The economic threshold was surpassed at the Northeast and Northwest Farms, but the Northeast farm reached the threshold during late seedfill stage (R6). At each location, aphids were suppressed by the treatments with the *Rag1* gene compared to the susceptible, untreated control treatment.

Johnson Research Farm. There was relatively low soybean aphid pressure at this location in 2011. Treatments 9 and 10 had a beginning pod (R3) targeted application and were made on 1 August. Treatments 5, 6, and 8 received a foliar application on 18 August when plants were in the R5 growth stage. Foliar insecticides were applied to the zero aphid plots, or treatment 7, twice (1 August and 18 August) (Table 1). Soybean aphid populations in the untreated control plots averaged 25 ± 15 per plant one day prior to the 18 August application, and later peaked on 2 September at 111 ± 33 aphids per plant (Figure 1a). Soybean aphids reached over 1,800 ± 356 CAD in the untreated control treatment, well below an economically important level (Table 2; Figure 2). The untreated control treatment had significantly more CAD and lower yield compared to all other treatments, but was not significantly different ($P<0.0001$; $F = 6.80$; df = 9, 3) than treatments 3, 6, 8, or 10. (Table 2; Figure 2). Overall, the three *Rag1*-containing treatments had the lowest CAD and yield. There were no significant differences between treatments and yield ($P<0.5021$; $F = 0.97$; df = 9, 3) (Table 2; Figure 3).

Northeast Research Farm. There was moderate soybean aphid pressure at this location in 2011. Treatments 19 and 20 had a beginning pod (R3) targeted application and were made on 26 July. Treatments 6-7, and 9-18 received a foliar application on 16 August when plants were in the R5 growth stage. Foliar insecticides were applied to the zero aphid plots, or treatment 8, twice (26 July and 16 August) (Table 3). Soybean aphid populations in the untreated control plots averaged 50 ± 4 per plant one day prior to the 16 August application, and peaked on 6 September at 435 ± 52 aphids per plant (Figure 1b). The untreated control treatment had more CAD (3,563 ± 1,053) compared to all other insecticide treatments, but was not significantly different ($P<0.0001$; $F = 7.57$; df = 23, 3) than most foliar insecticide treatments (Table 4; Figure 4). Treatments 4, 5, and 8 has significantly less CAD than all other treatments. There was some variability in yield between treatments ($P<0.0001$; $F = 6.28$; df = 23, 3), but the *Rag1*-containing treatments had some of the lowest bushels per acre (Table 4; Figure 5).

Northwest Research Farm. There was heavy soybean aphid pressure at this location in 2011. Treatments 5-7, and 9-15 received a foliar application on 10 August when plants were in the R4 growth stage. Foliar insecticides were applied to the zero aphid plots, or treatment 8, twice (29 July and 10 August (Table 5). Soybean aphid populations in the untreated control plots averaged 263 ± 85 per plant seven days prior to the 10 August application and peaked on 27 August at 870 ± 349 aphids per plant (Figure 1c). Soybean aphid reached over 11,700 ± 3,690 CAD in the untreated control treatment. As expected with high CAD, there were significant treatment differences ($P<0.0001$; $F = 7.39$; df = 14, 3)

(Table 6; Figure 6). Treatment 5 had significantly fewer CAD compared to all other treatments, and all the *Rag1*-containing treatments performed well. The zero aphid control had the highest yield (65.3 ± 1.3), but was not different than the *Rag1*-containing treatments ($P<0.0001$; F = 20.70; df = 14, 3) (Table 6; Figure 7).

Overall Summary. In 2011, seasonal aphid populations between the three locations were highly variable. We included several established insecticides and a few products not yet approved for soybean aphid. Most foliar products were effective at reducing CAD and protecting yield. We did not detect any thriving aphid populations three days after foliar application for any product. At the Northwest Research Farm, where the highest seasonal aphid pressure was accumulated, a single application of a foliar insecticide provided as much yield protection as two applications. In general, the *Rag1*-containing treatments had lower yield, but we attribute the lower yields to the plant genetic potential.

Treatment Recommendations. This large fluctuation between locations within a single growing season is typical population dynamics for Iowa. In the absence of heavy aphid pressure, we do not expect to see a yield difference. Therefore, our recommendation for soybean aphid management is to continue to scout soybean fields and to apply a full rate or a foliar insecticide when populations exceed 250 aphids per plant (see Hodgson et al. 2011b for a more detailed description). One well-timed foliar application applied after aphids exceed the economic threshold will protect yield and increase profits in most situations. Rarely is the economic threshold exceeded twice in a single season and would require multiple applications. We would also strongly encourage growers to incorporate host plant resistance into their seed selection. At this time, we are not recommending insecticidal seed treatments for aphid management because of soybean aphid biology in Iowa. To date, most foliar insecticides are very effective at reducing soybean aphid populations if the coverage is sufficient. Achieving small droplet size to penetrate a closed canopy may be the biggest challenge to managing soybean aphid.

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Table 1. Soybean aphid treatments and rates at the Johnson Research Farm

Treatment	Active Ingredient	Rate	Application
1. Untreated control	-----	-----	-----
2. *Rag1*	-----	-----	-----
3. CruiserMaxx Beans	thiamethoxam	56 g/100 kg seed	ST[1]
4. CruiserMaxx Beans + *Rag1*	thiamethoxam + -----	56 g/100 kg seed ----	ST -----
5. CruiserMaxx Beans + *Rag1* + Warrior II	thiamethoxam + ----- + λ-cyhalothrin	56 g/100 kg seed ----- 1.6 fl oz/ac	ST ----- 18 Aug
6. Warrior II	λ-cyhalothrin	1.6 fl oz/ac	18 Aug
7. Warrior II + Lorsban Advanced	λ-cyhalothrin + chlorpyrifos	1.6 fl oz/ac 16.0 fl oz/ac	1 Aug + 18 Aug
8. Leverage 360[2]	imidacloprid + β-cyfluthrin	2.8 fl oz/ac	18 Aug
9. Leverage 360 @R3[2]	imidacloprid + β-cyfluthrin	2.8 fl oz/ac	1 Aug
10. Leverage 360 + Stratego YLD[2]	imidacloprid + β-cyfluthrin + prothioconazole + trifloxystrobin	2.8 fl oz/ac + 4.0 fl oz/ac	1 Aug

[1] ST (Seed Treatment).

[2] Crop oil and ammonium sulfate were included as adjuvants and formulated at a rate of 1 qt/ac and 1.5 lbs/ac, respectively.

Table 2. Soybean aphid cumulative exposure and yield at the Johnson Research Farm

Treatment	CAD[1] ± SEM[2]	CAD – LSD[3]	Yield[4] ± SEM	Yield – LSD[5]
1. Untreated control	1806.2 ± 356.3	D	68.1 ± 0.4	A
2. *Rag1*	105.4 ± 35.0	AB	65.4 ± 2.0	A
3. CruiserMaxx Beans	1033.6 ± 244.2	CD	66.1 ± 1.3	A
4. CruiserMaxx Beans + *Rag1*	49.3 ± 18.3	A	64.9 ± 0.8	A
5. CruiserMaxx Beans + *Rag1* + Warrior II	65.9 ± 32.2	A	66.7 ± 0.9	A
6. Warrior II	660.6 ± 404.8	CD	67.3 ± 0.6	A
7. Warrior II + Lorsban Advanced	126.3 ± 77.6	AB	66.0 ± 0.9	A
8. Leverage 360	638.1 ± 372.5	CD	67.1 ± 1.0	A
9. Leverage 360 @R3	290.9 ± 94.3	BC	66.2 ± 0.4	A
10. Leverage 360 + Stratego YLD	505.6 ± 112.8	CD	68.2 ± 1.0	A

[1] CAD (cumulative aphid days), or estimated seasonal exposure of soybean aphid.

[2] SEM (standard error of the mean).

[3] LSD (least significant difference) for CAD (cumulative aphid days); $P<0.0001$; $F = 6.80$; df = 9, 3. Letters represent significant differences ($\alpha = 0.10$).

[4] Yield is reported in bushels per acre.

[5] LSD (least significant difference) for yield; $P<0.5021$; $F = 0.97$; df = 9, 3. Letters represent significant differences ($\alpha = 0.10$).

Table 3. Soybean aphid treatments and rates at the Northeast Research Farm

Treatment	Active Ingredient	Rate	Application
1. Untreated control	-----	-----	-----
2. *Rag1*	-----	-----	-----
3. CruiserMaxx Beans	thiamethoxam	56 g/100 kg seed	ST[1]
4. CruiserMaxx Beans + *Rag1*	thiamethoxam + -----	56 g/100 kg seed ----	ST[1]
5. CruiserMaxx Beans + *Rag1* + Warrior II	thiamethoxam + ----- + λ-cyhalothrin	56 g/100 kg seed ----- 1.6 fl oz/ac	ST[1]
6. Warrior II	λ-cyhalothrin	1.6 fl oz/ac	16 Aug
7. Lorsban Advanced	chlorpyrifos	16.0 fl oz/ac	16 Aug
8. Warrior II + Lorsban Advanced	λ-cyhalothrin + chlorpyrifos	1.6 fl oz/ac 16.0 fl oz/ac	26 Jul + 16 Aug
9. Cobalt Advanced	λ-cyhalothrin + chlorpyrifos	13.0 fl oz/ac	16 Aug
10. Asana XL	esfenvalerate	9.6 fl oz/ac	16 Aug
11. Asana XL + Lannate LV	esfenvalerate + methomyl	8.0 fl oz/ac 8.0 fl oz/ac	16 Aug
12. Hero EC	ζ-cypermethrin + bifenthrin	5.0 fl oz/ac	16 Aug
13. Swagger[2]	bifenthrin + imidacloprid	10.0 fl oz/ac	16 Aug
14. Declare (1.02)	λ-cyhalothrin	1.02 fl oz/ac	16 Aug
15. Declare (1.28)	λ-cyhalothrin	1.28 fl oz/ac	16 Aug
16. Declare + Nufos 4E	λ-cyhalothrin + chlorpyrifos	1.02 fl oz/ac + 4.0 fl oz/ac	16 Aug
17. Leverage 360 (A)[2]	imidacloprid + β-cyfluthrin	2.8 fl oz/ac	16 Aug
18. Leverage 360 (B)[3]	imidacloprid + β-cyfluthrin	2.8 fl oz/ac	16 Aug
19. Leverage 360 @R3[3]	imidacloprid + β-cyfluthrin	2.8 fl oz/ac	26 Jul
20. Leverage 360 + Stratego YLD[3]	imidacloprid + β-cyfluthrin + prothioconazole + trifloxystrobin	2.8 fl oz/ac + 4.0 fl oz/ac	26 Jul

Treatment	Active Ingredient	Rate	Application
21. Transform (0.214)[4]	sulfoxaflor	0.214 fl oz/ac	16 Aug
22. Transform (0.257)[4]	sulfoxaflor	0.257 fl oz/ac	16 Aug
23. Transform (0.357)[4]	sulfoxaflor	0.357 fl oz/ac	16 Aug
24. BAS310I[4]	α-cypermethrin	4.0 fl oz/ac	16 Aug

[1] ST (Seed Treatment).

[2] A non-ionic surfactant was included as an adjuvant and formulated at a rate of 0.25 qt/ac.

[3] Crop oil and ammonium sulfate were included as adjuvants and formulated at a rate of 1 qt/ac and 1.5 lbs/ac, respectively.

[4] Product was not labeled for soybean aphid at the time of this publication.

Table 4. Soybean aphid cumulative exposure and yield at Northeast Research Farm

Treatment	CAD[1] ± SEM[2]	CAD – LSD[3]	Yield[4] ± SEM	Yield – LSD[5]
1. Untreated control	3563.0 ± 1053.3	C	60.1 ± 1.0	BC
2. *Rag1*	639.23 ± 416.7	B	55.8 ± 1.6	A
3. CruiserMaxx Beans	782.8 ± 247.5	BC	61.3 ± 2.7	CDE
4. CruiserMaxx Beans + *Rag1*	109.5 ± 46.9	A	60.2 ± 1.3	BCD
5. CruiserMaxx Beans + *Rag1* + Warrior II	74.8 ± 39.3	A	56.7 ± 3.0	AB
6. Warrior II	267.8 ± 30.0	B	67.2 ± 0.8	E
7. Lorsban Advanced	782.1 ± 81.8	BC	63.7 ± 0.6	CDE
8. Warrior II + Lorsban Advanced	55.9 ± 25.9	A	63.1 ± 1.0	CDE
9. Cobalt Advanced	1649.0 ± 865.1	BC	66.1 ± 1.1	DE
10. Asana XL	1256.2 ± 641.8	BC	65.2 ± 1.3	CDE
11. Asana XL + Lannate	521.4 ± 80.8	B	64.6 ± 2.0	CDE
12. Hero	669.2 ± 107.3	BC	66.1 ± 1.3	E
13. Swagger	952.5 ± 193.1	BC	66.2 ± 0.8	E
14. Declare (1.02)	977.6 ± 318.8	BC	66.2 ± 1.2	E
15. Declare (1.28)	1087.2 ± 257.1	BC	64.3 ± 0.2	CDE
16. Declare + Nufos 4E	663.4 ± 137.8	BC	64.6 ± 0.9	CDE
17. Leverage 360 (A)	1807.0 ± 531.0	BC	62.8 ± 2.1	CDE
18. Leverage 360 (B)	1147.0 ± 346.5	BC	62.9 ± 2.0	CDE
19. Leverage 360 @R3	2171.2 ± 1237.3	BC	64.3 ± 1.1	CDE
20. Leverage 360 + Stratego YLD	832.2 ± 185.3	BC	65.4 ± 1.3	CDE

Treatment	CAD[1] ± SEM[2]	CAD – LSD[3]	Yield[4] ± SEM	Yield – LSD[5]
21. Transform (0.214)	1671.1 ± 496.1	BC	66.1 ± 0.4	E
22. Transform (0.257)	1555.4 ± 300.0	BC	66.6 ± 1.3	E
23. Transform (0.357)	954.5 ± 133.5	BC	66.1 ± 0.4	E
24. BAS310I	1637.8 ± 616.0	BC	64.3 ± 0.8	CDE

[1] CAD (cumulative aphid days), or estimated seasonal exposure of soybean aphid.

[2] SEM (standard error of the mean).

[3] LSD (least significant difference) for CAD (cumulative aphid days); P<0.0001; F = 7.57; df = 23, 3. Letters represent significant differences (α = 0.10).

[4] Yield is reported in bushels per acre.

[5] LSD (least significant difference) for yield; P<0.0001; F = 6.28; df = 23 3. Letters represent significant differences (α = 0.10).

Table 5. Soybean aphid treatments and rates at the Northwest Research Farm

Treatment	Active Ingredient	Rate	Application
1. Untreated control	-----	-----	-----
2. *Rag1*	-----	-----	-----
3. CruiserMaxx Beans	thiamethoxam	56g/100 kg seed	ST[1]
4. CruiserMaxx Beans + *Rag1*	thiamethoxam + -----	56g/100 kg seed ----	ST -----
5. CruiserMaxx Beans + *Rag1* + Warrior II	thiamethoxam + ----- + λ-cyhalothrin	56g/100 kg seed ----- 1.6 fl oz/ac	ST ----- 10 Aug
6. Warrior II (A)	λ-cyhalothrin	1.6 fl oz/ac	10 Aug
7. Warrior II (B)	chlorpyrifos	1.6 fl oz/ac	10 Aug
8. Warrior II + Lorsban Advanced	λ-cyhalothrin + chlorpyrifos	1.6 fl oz/ac 16.0 fl oz/ac	29 Jul + 10 Aug
9. Cobalt Advanced	λ-cyhalothrin + chlorpyrifos	13.0 fl oz/ac	10 Aug
10. Endigo ZC	λ-cyhalothrin + thiamethoxam	4.5 fl oz/ac	10 Aug
11. Voliam Xpress[2]	λ-cyhalothrin + chlorantraniliprole	6.5 fl oz/ac	10 Aug
12. Agrimek SC (2.0)[2]	abamectin	2.0 fl oz/ac	10 Aug
13. Agrimek SC (2.5) [2]	abamectin	2.5 fl oz/ac	10 Aug
14. Agri-flex SC (7.0)[2,3]	abamectin + thiamethoxam	7.0 fl oz/ac	10 Aug
15. Agri-flex SC (8.5)[2,3]	abamectin + thiamethoxam	8.5 fl oz/ac	10 Aug

[1] ST (Seed Treatment).

[2] Product was not labeled for soybean aphid at the time of this publication.

[3] A non-ionic surfactant was included as an adjuvant and formulated at a rate of 0.25 qt/ac.

Table 6. Soybean aphid cumulative exposure and yield at Northwest Research Farm

Treatment	CAD[1] ± SEM[2]	CAD – LSD[3]	Yield[4] ± SEM	Yield – LSD[5]
1. Untreated control	18896.0 ± 4420.8	E	56.8 ± 0.6	A
2. *Rag1*	1546.0 ± 776.1	C	65.0 ± 1.5	C
3. CruiserMaxx Beans	19738.9 ± 3785.9	E	57.1 ± 1.7	A
4. CruiserMaxx Beans + *Rag1*	399.8 ± 136.0	B	64.8 ± 0.7	C
5. CruiserMaxx Beans + *Rag1* + Warrior II	55.2 ± 11.5	A	64.8 ± 1.8	C
6. Warrior II (A)	4342.8 ± 1931.1	D	62.8 ± 0.8	BC
7. Warrior II (B)	2957.6 ± 948.9	CD	62.6 ± 1.1	BC
8. Warrior II + Lorsban Advanced	394.5 ± 91.5	B	65.3 ± 1.3	C
9. Cobalt Advanced	2407.1 ± 262.0	CD	62.3 ± 0.3	BC
10. Endigo ZC	4424.9 ± 1391.3	D	62.5 ± 0.6	BC
11. Voliam Xpress	4111.2 ± 551.1	D	62.2 ± 0.4	BC
12. Agrimek SC (2.0)	20253.4 ± 6930.2	E	58.7 ± 2.3	AB
13. Agrimek SC (2.5)	18978.0 ± 7045.3	E	57.3 ± 1.0	A
14. Agri-flex SC (7.0)	7399.7 ± 1732.5	DE	62.1 ± 0.8	BC
15. Agri-flex SC (8.5)	4606.8 ± 1220.1	D	61.1 ± 1.4	BC

[1] CAD (cumulative aphid days), or estimated seasonal exposure of soybean aphid.

[2] SEM (standard error of the mean).

[3] LSD (least significant difference) for CAD (cumulative aphid days); $P<0.0001$; F = 20.70; df = 14, 3. Letters represent significant differences ($\alpha = 0.10$).

[4] Yield is reported in bushels per acre.

[5] LSD (least significant difference) for yield; $P<0.0001$; F = 7.39; df = 14, 3. Letters represent significant differences ($\alpha = 0.10$).

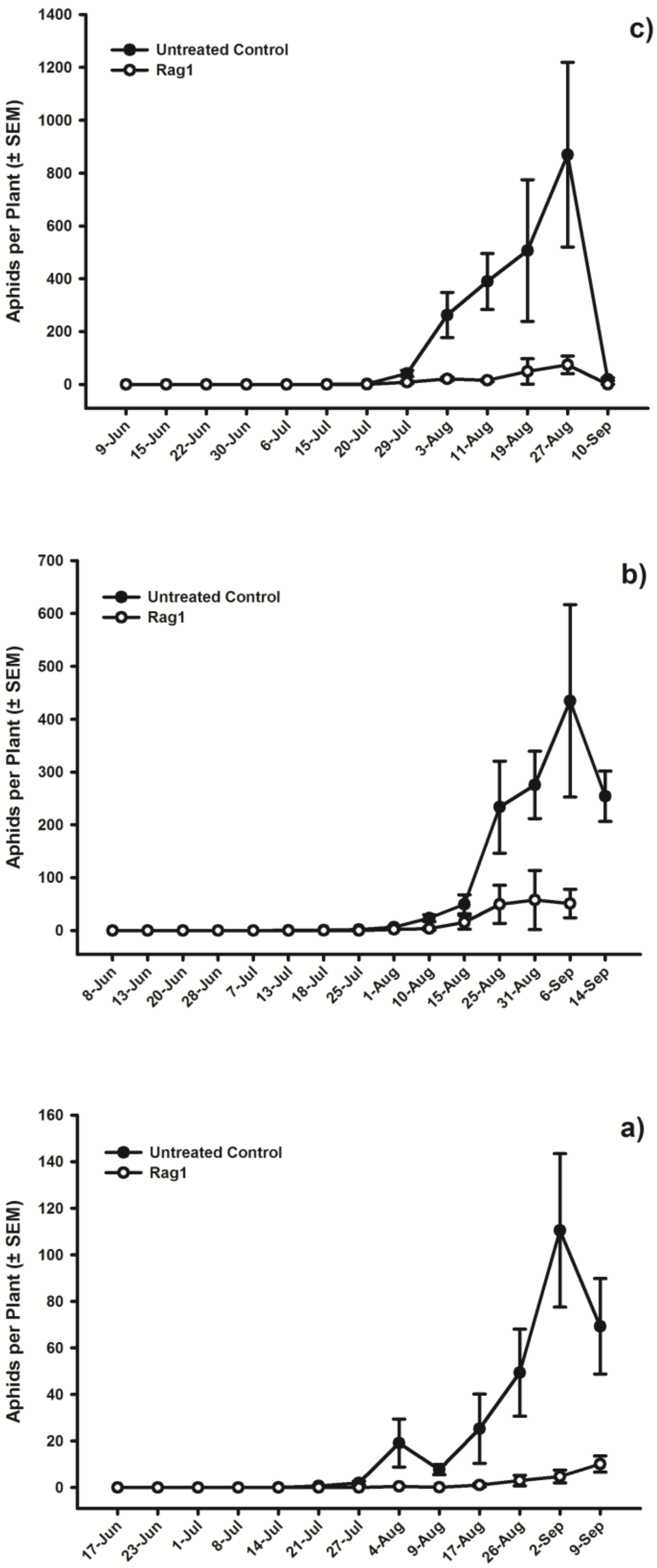

Figure 1. Mean number of soybean aphids in the untreated control and *Rag1* treatments at the a) Johnson, b) Northeast, and c) Northwest Farms.

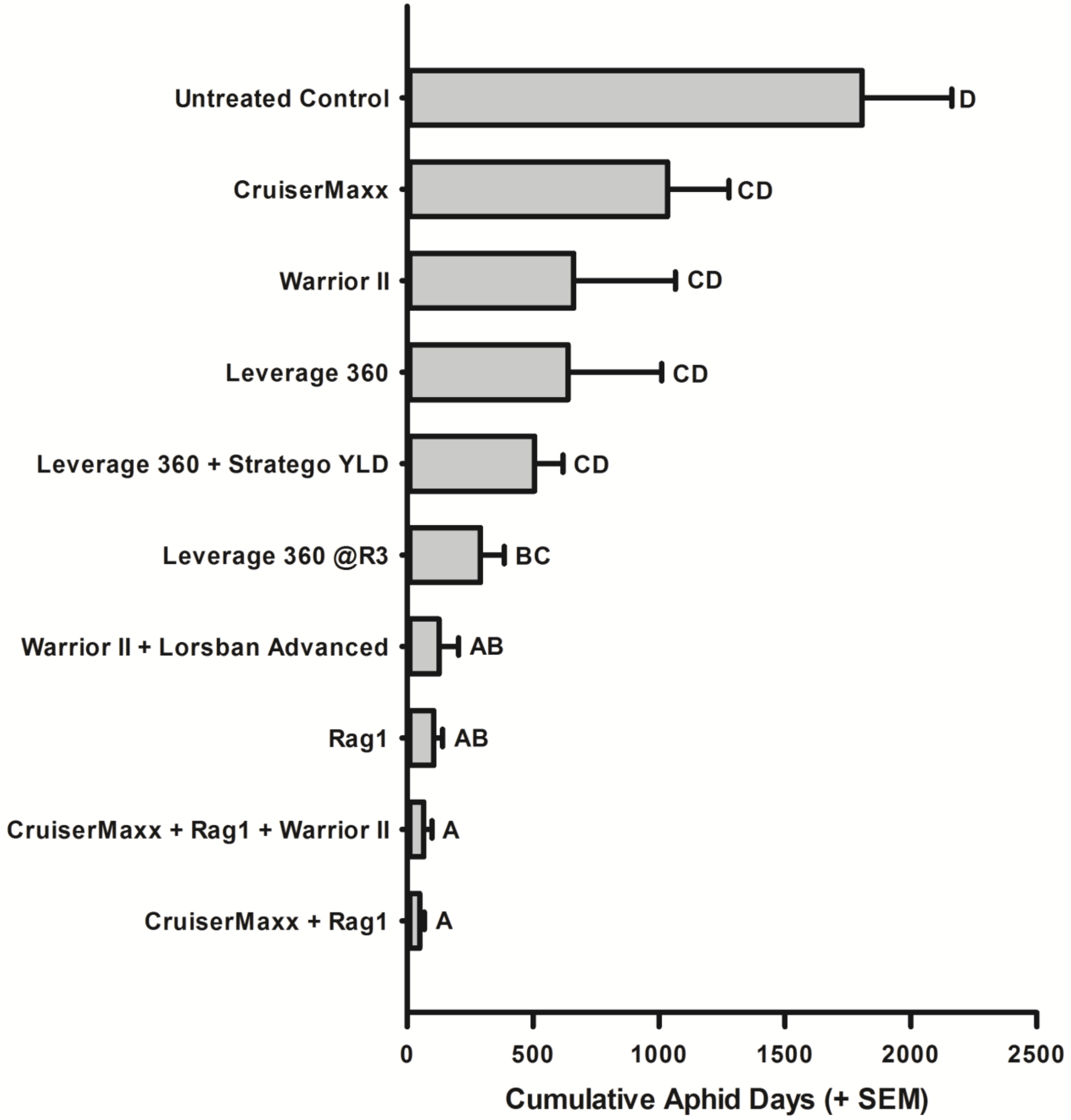

Figure 2. Mean separation of treatments (+ standard error of the mean) on cumulative aphid days at the Johnson Research Farm. Rates and dates of application are only given if the same product was applied at different rates or times. Means with a unique letter are significantly different (α= 0.10; P<0.0001; F = 6.80; df = 9, 3).

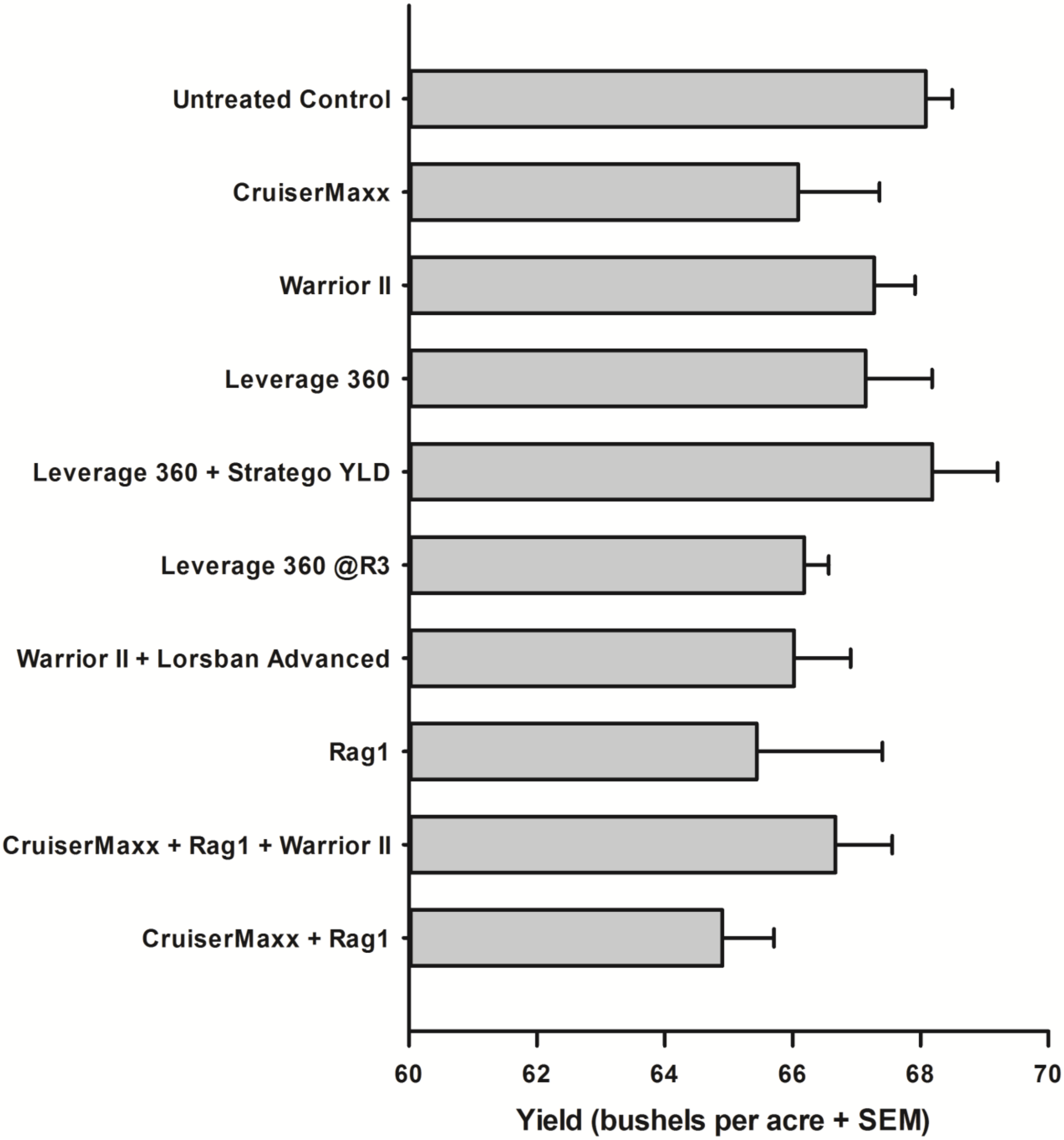

Figure 3. Mean separation of soybean aphid treatments (+ standard error of the mean) on yield at the Johnson Research Farm. Rates and dates of application are only given if the same product was applied at different rates or times. There were no significant treatment differences (α= 0.10; P<0.5021; F = 0.97; df = 9, 3).

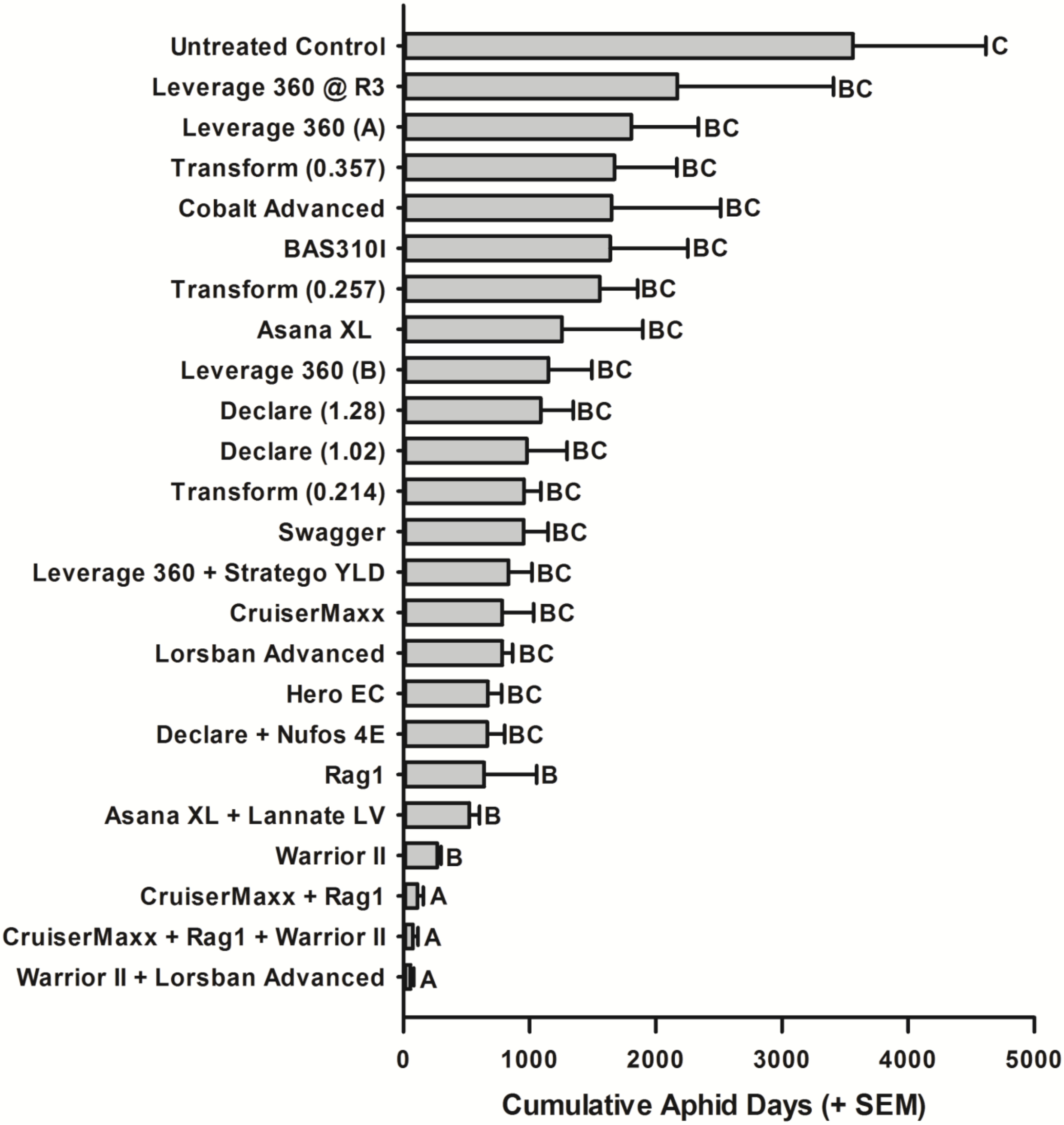

Figure 4. Mean separation of treatments (+ standard error of the mean) on cumulative aphid days at the Northeast Research Farm. Rates and dates of application are only given if the same product was applied at different rates or times. Means with a unique letter are significantly different ($\alpha = 0.10$; $P<0.0001$; $F = 7.57$; $df = 23, 3$).

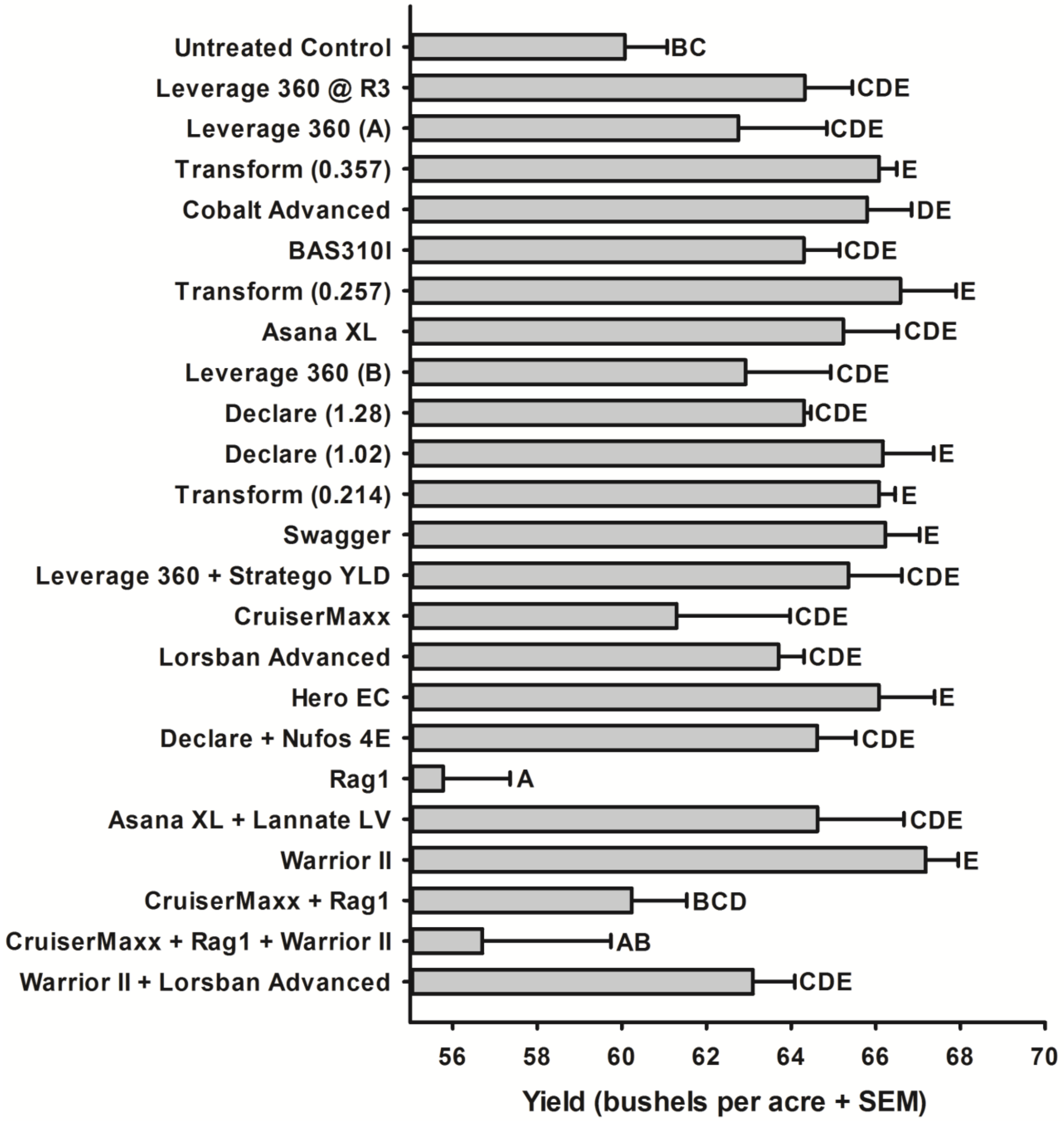

Figure 5. Mean separation of soybean aphid treatments (+ standard error of the mean) on yield at the Northeast Research Farm. Rates and dates of application are only given if the same product was applied at different rates or times. Means with a unique letter are significantly different (α= 0.10; P<0.0001; F = 6.28; df = 23, 3).

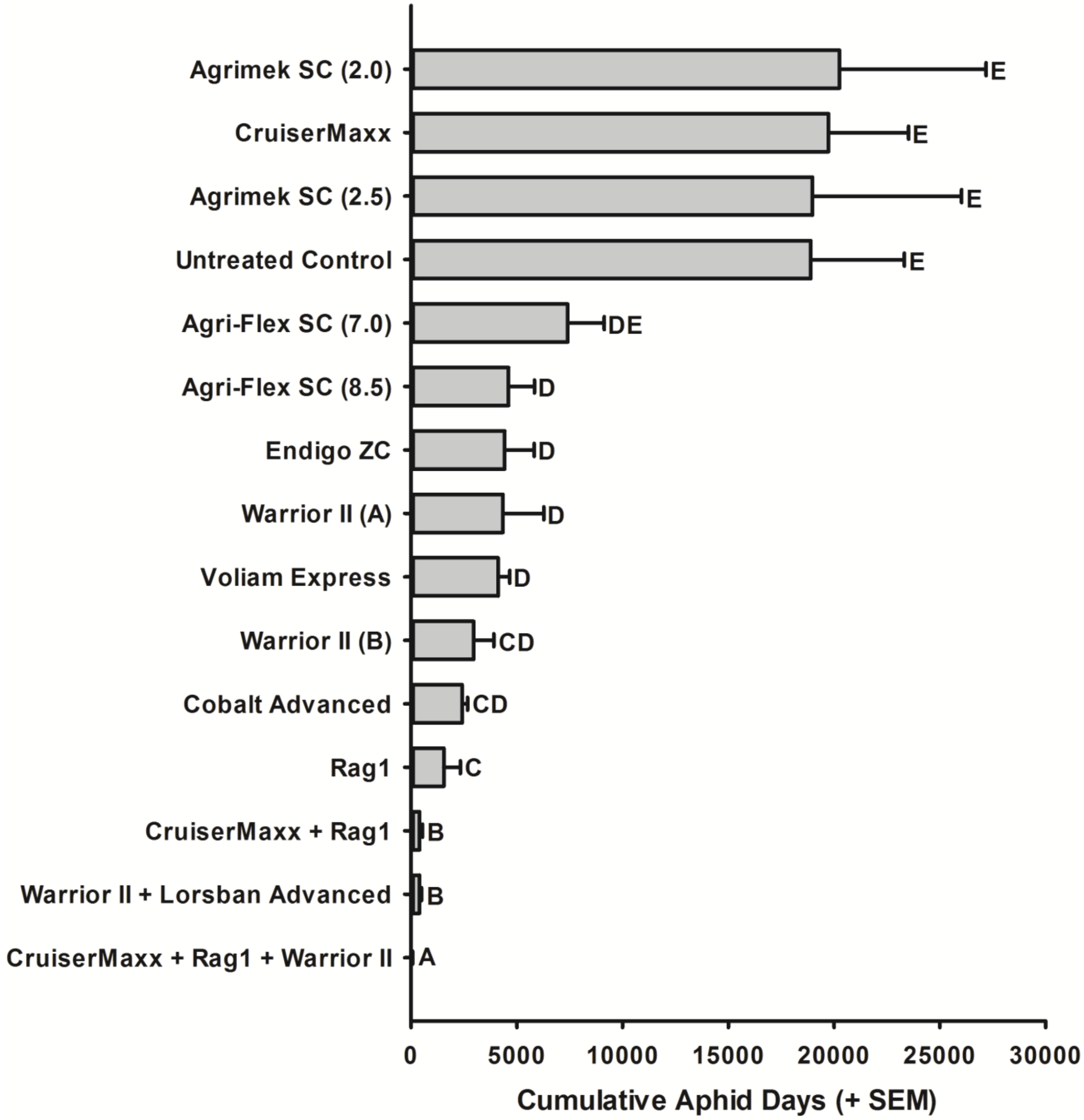

Figure 6. Mean separation of treatments (+ standard error of the mean) on cumulative aphid days at the Northwest Research Farm. Rates and dates of application are only given if the same product was applied at different rates or times. Means with a unique letter are significantly different (α= 0.10; P<0.0001; F = 20.70; df = 14, 3).

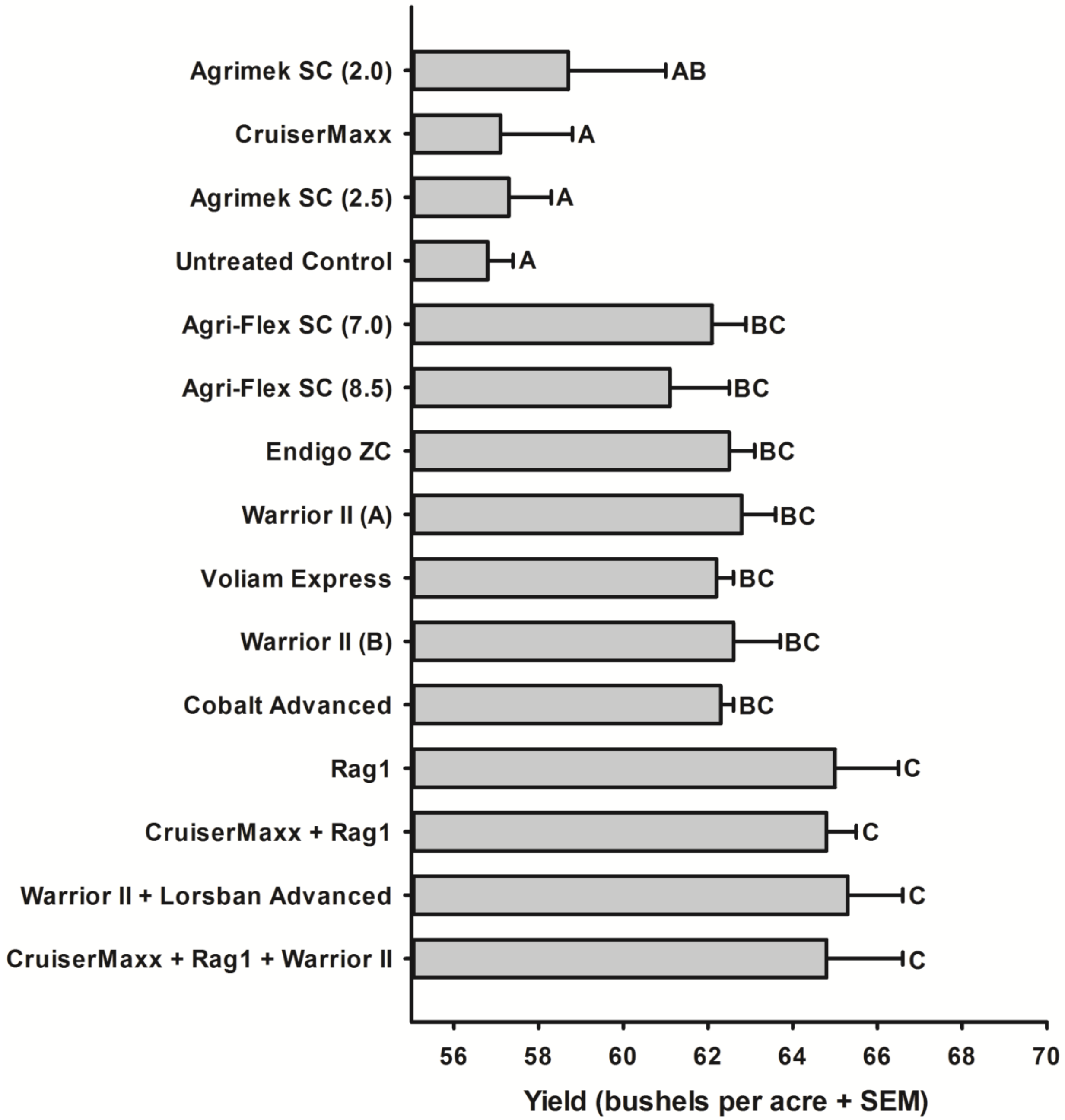

Figure 7. Mean separation of soybean aphid treatments (+ standard error of the mean) on yield at the Northwest Research Farm. Rates and dates of application are only given if the same product was applied at different rates or times. Means with a unique letter are significantly different (α= 0.10; P<0.0001; F = 7.39; df = 14, 3).

Introduction to Japanese Beetle

JAPANESE BEETLE, *Popillia japonica* Newman (Coleoptera: Scarabaeidae), is an introduced pest originating from Japan and has been present in Iowa since 1994. Beetles are slowly spreading from eastern Iowa and are confirmed in 56 out of 99 counties (Hodgson et al. 2011). Japanese beetle adults will feed on approximately 300 plant species including corn, soybean, ornamentals, trees, and shrubs (USDA-APHIS 2004). Their plant damage in Iowa has been erratic and generally confined to urban areas. However, significant adult feeding in soybean and corn was detected in 2011, and so we developed a small efficacy evaluation for the most common foliar insecticides.

Japanese Beetle Description. Adults are ½ inch long and oval in shape with a metallic green head and copper forewings (USDA-APHIS 2004). There are six white tufts of hair along each side of the abdomen and the antennae are clubbed. The adults are distinctive, but can be confused with several look-alike beetles that can be found in soybean and urban areas (e.g., false Japanese beetles, masked chafers, bumble flower beetle, etc.) (Cranshaw 2007, Hodgson and Alston 2006). Larvae are white grubs with a brown head and three pairs of thoracic legs. Larvae are 1 inch long when fully developed, but are always found in a c-shape (Cranshaw 2007).

Japanese beetles are metallic green and bronze. Photo by David Cappaert.

Japanese Beetle Life Cycle. Japanese beetles have one generation per year. Males emerge a few days before females in late May or early June (Cook and Gray 2004). Adults emerge from grass in late June and immediately begin to feed on low-lying plants such as roses and shrubs. Adults eventually move up on trees and field crop foliage to feed and mate. Mated females move back to grass in August and September to lay small egg masses in soil cavities. To be a suitable egg-laying site, an area must have moderate to high soil moisture, moderate soil texture, sunlight, and short grass cover (Potter and Held 2002). Females prefer to lay eggs in grasses, however, they may also lay eggs within field crops with sufficient soil moisture. Cultivation may also be an important factor in determining a site's suitability for

Japanese beetle females. Higher adult Japanese beetle densities are found in no-till or reduced-till soybean and larvae have been found to be 10-fold more abundant in weedy nursery fields compared with cultivated fields (Szendrei and Isaacs 2006). The eggs hatch into small grubs that feed on roots underground until late September when the temperature cools. The almost fully-grown grubs burrow down in the soil and remain inactive all winter. In the early spring, grubs become active again and feed until turning into resting pupae. The pupae hatch into adults and emerge from the soil.

Japanese Beetle Damage. Japanese beetles release a strong aggregation pheromone, and are commonly seen feeding and mating in clusters. Adults are also highly mobile and move frequently in the summer (Cook and Gray 2004, Hodgson and Alston 2006). Adults are skeletonizers in soybean and can cause severe defoliation. Adults prefer to feed on the upper leaf surface. Heavily defoliated leaves look scorched or bronze in color.

Materials and Methods

Johnson Research Farm. We established plots at the Iowa State University Johnson Research Farm in Story County, Iowa. The treatments were arranged in a randomized complete block design with four replications, and soybean was planted in 30-inch rows on 3 June. A Pioneer Hi-Bred Roundup Ready soybean variety 92Y20 was used for all treatments. Each plot was four rows wide and 30 feet long with 10-foot alleys separating rows of treatments. The plots were located in the northeast corner of a 4.3 acre field with a six-row border to edge of the field to the East and a 4-row border to the edge of the field to the north. In total for 2011, we evaluated 6 treatments with products alone or in combination (Table 7). The experiment included an untreated control to allow for comparisons of yield protection against Japanese beetle.

Application Techniques. All foliar insecticide treatments were made on 2 August. All applications were made using a backpack sprayer and TeeJet (Springfield, IL) twinjet nozzles (TJ 11002) with 20 gallons of water per acre at 40 pounds of pressure per square inch.

Japanese Beetle Scouting. Adults tend to aggregate and are highly mobile, and therefore economic thresholds are not typically based on beetle abundance (e.g. through sweep netting or density of beetles per plant). We estimated percent defoliation for each plot by visual approximation. In addition, we estimated the number of beetles by taking 10 sweeps per plot.

Yield Analysis. Yields were determined by weighing grain with a grain hopper which rested on a digital scale sensor custom designed for the harvester. Plots were harvested on 17 October and yields were corrected to 13% moisture and reported as bushels per acre.

Results and Discussion

Weekly sampling started on 27 July and continued until 26 August (Figure 8). On the first sample, percent defoliation ranged from 5-15%, and beetle abundance ranged from 12-27 beetles per sweep (Figure 9). Although the treatment threshold of 20% after bloom was not reached, foliar insecticides were applied on 2 August. Foliar insecticides reduced Japanese beetle densities to less than ten per sweep while the untreated control was over 18 per sweep. However, within seven days, there were no differences between foliar treatments and the untreated control. Beetles continued to feed past pod fill, but percent defoliation never exceeded 20%.

Yield comparisons indicated a significant difference between treatments ($P<0.0001$; $F = 1.74$; $df = 3, 8$) (Figure 9). But the foliar insecticides did not significantly differ from the untreated control. These data support the currently established economic threshold for Japanese beetle, and that applying a foliar insecticide was not cost-effective decision.

Treatment Recommendations. The treatment threshold for Japanese beetles in soybean is 30% defoliation before bloom and 20% defoliation after bloom (R1) through seed set (R6) (Cook and Gray 2004). The most important time to scout in soybean is from full bloom (R1) through full seed set (R6). Scouts tend to greatly over-estimate the percent defoliation caused by Japanese beetle, and foliar insecticides can be applied before economic thresholds are reached.

In this evaluation, Japanese beetle was easily detected. Some of the plants had extensive defoliation, but overall estimates were below the treatment threshold of 20%. The plots near the field edge had more obvious damage compared to interior plots. In this evaluation, using a foliar insecticide did not significantly improve yield protection. Therefore, we highly recommend scouting entire commercial fields to assess overall defoliation, as field edges will result in an over-estimate of damage. If only the field edges exceed treatment thresholds, consider making border application, if practical, to reduce application costs.

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Table 7. Japanese beetle treatments and rates at the Johnson Research Farm

Treatment	Active Ingredient	Rate
1. Untreated control	-----	-----
2. Warrior II	λ-cyhalothrin	1.6 fl oz/ac
3. Lorsban Advanced	chlorpyrifos	16.0 fl oz/ac
4. Centric	thiamethoxam	2.5 fl oz/ac
5. Warrior II + Lorsban Advanced	λ-cyhalothrin + chlorpyrifos	1.6 fl oz/ac 16.0 fl oz/ac
6. Endigo ZC	λ-cyhalothrin + thiamethoxam	4.0 fl oz/ac

Table 8. Japanese beetle density and yield at the Johnson Research Farm

Treatment	Mean[1] ± SEM[2]	Yield[3] ± SEM	Yield – LSD[4]
1. Untreated control	15.5 ± 4.2	60.9 ± 2.5	A
2. Warrior II	20.3 ± 7.7	55.4 ± 1.1	B
3. Lorsban Advanced	19.5 ± 5.2	56.2 ± 3.3	AB
4. Centric	27.5 ± 8.5	56.8 ± 2.6	AB
5. Warrior II + Lorsban Advanced	13.5 ± 2.3	56.5 ± 0.3	AB
6. Endigo ZC	12.0 ± 5.6	59.3 ± 2.4	AB

[1] Mean number of beetles prior to foliar applications.

[2] SEM (standard error of the mean).

[3] Yield is reported in bushels per acre.

[4] LSD (least significant difference) for yield; $P<0.0001$; $F = 1.74$; df = 8, 3. Letters represent significant differences ($\alpha = 0.10$).

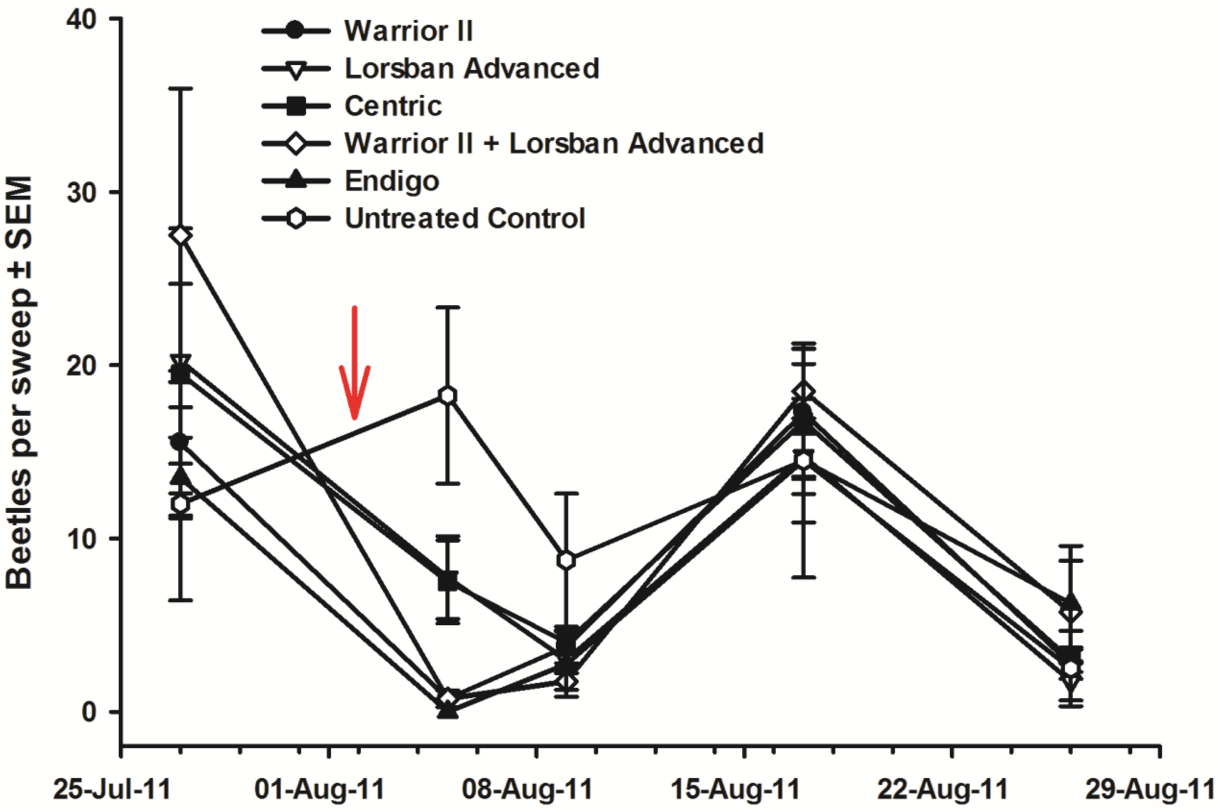

Figure 8. Japanese beetle populations (± standard error of the mean) at the Johnson Research Farm. Arrow indicates timing of foliar applications.

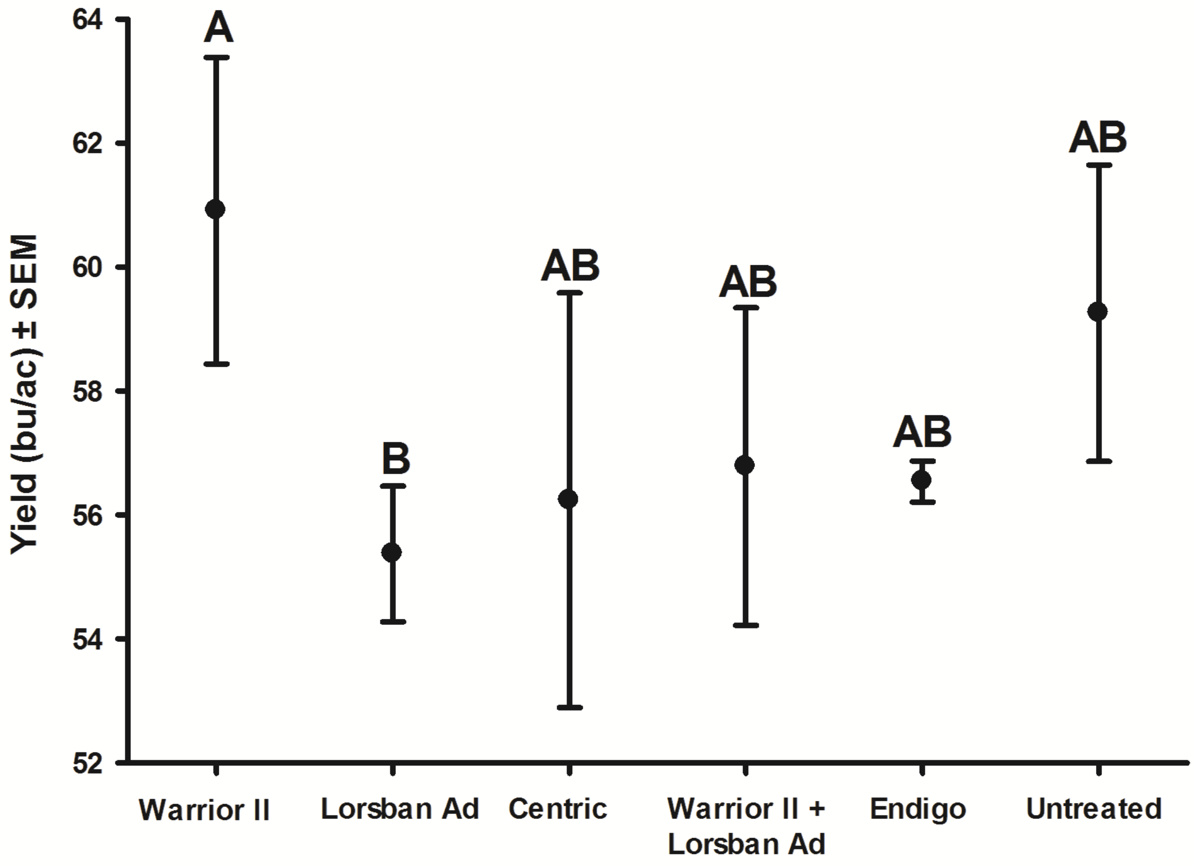

Figure 9. Mean separation of Japanese beetle treatments (± standard error of the mean) on yield at the Johnson Research Farm. Means with a unique letter are significantly different ($\alpha = 0.10$; $P<0.0001$; $F = 1.74$; df = 8, 3).