IOWA STATE UNIVERSITY
Extension and Outreach

# 2019
# REPORT OF INSECTICIDE EVALUATION

Department of Entomology
Ames, Iowa 50011-3140

## Soybean Pest Investigated:
## Soybean Aphid
## Japanese Beetle
## Soybean Gall Midge

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**Project Co-Leaders:**
Greg VanNostrand
Ashley Dean
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**To see a digital copy of the Iowa State University Soybean Insecticide Evaluation Reports from 2009-2019, visit our website:**

***www.ent.iastate.edu/soybeanresearch/content/extension***

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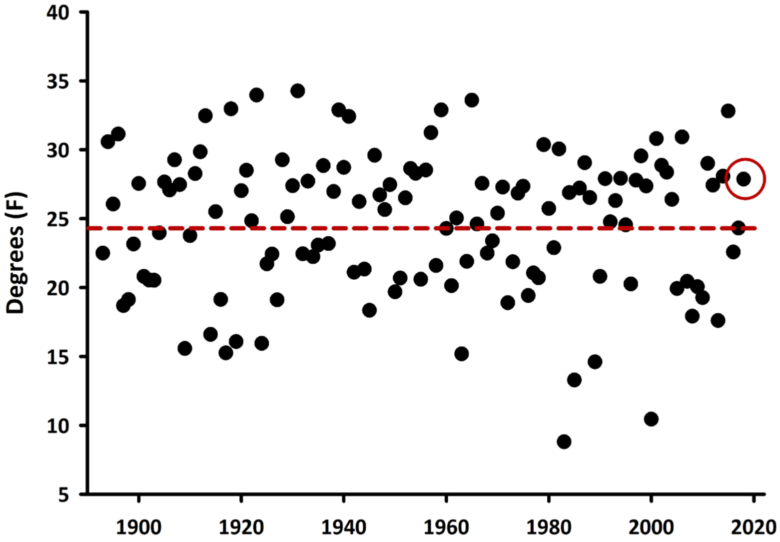
**Special thanks to the Bierbaum Family for letting us use their farm for research!**

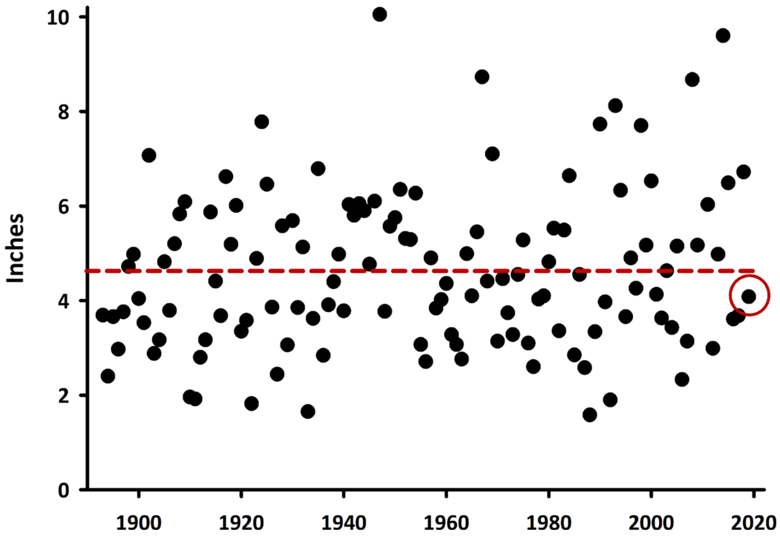
# 2019 Statewide Summary

Initially, the 2018-2019 winter temperatures were relatively warm compared to previous years in Iowa (mean temperature of 28 degrees in December). However, February 2019 was exceptionally cold statewide (mean temperature of 15 degrees). April planting conditions throughout Iowa were cold and wet, and most soybean fields were planted later to accommodate corn.

The most abundant insect statewide was thistle caterpillar. Although noted every year, populations were high and sometimes economic. Other caterpillars were also observed. Soybean aphids arrived to Iowa soybean in July, a few weeks behind normal. Aphid populations were initially patchy and slowly spread within and between fields. In August, some populations grew quickly and exceeded the economic threshold. When foliar applications had sufficient coverage and were applied at the labeled rate, efficacy for soybean aphid was good (i.e., >95% knockdown) throughout Iowa. Other soybean insect pests included Japanese beetle, bean leaf beetle, and soybean gall midge.



*Iowa mean temperature for December from 1893 to 2018. The red line represents the average (24.65°) and the red circle indicates 2018 (27.85°). Data courtesy of the Mesonet, ISU Department of Agronomy, https://mesonet.agron.iastate.edu/.*



*Iowa average monthly liquid precipitation for June from 1893 to 2019. The red line represents the average (4.66") and the red circle indicates 2019 (4.08"). Data courtesy of the Mesonet, ISU Department of Agronomy, https://mesonet.agron.iastate.edu/.*

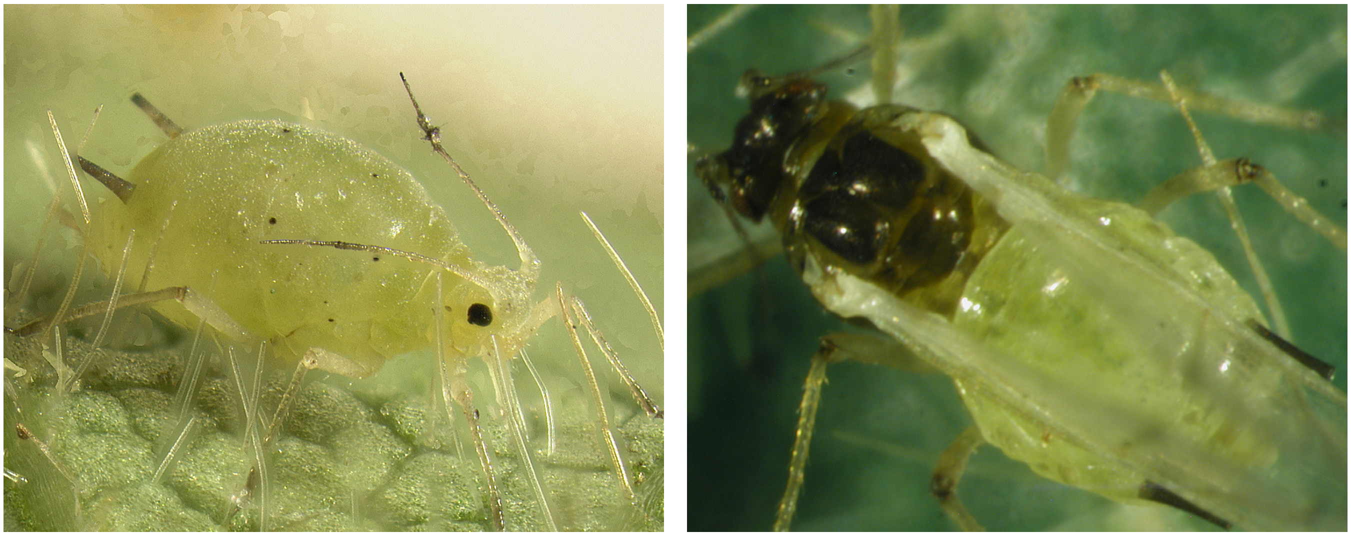
# Soybean Aphid

*Soybean aphid is Iowa's primary soybean insect pest. Photo by Matt Kaiser.*

SOYBEAN APHID, *Aphis glycines* Matsumura (Hemiptera: Aphididae), is an invasive insect from eastern Asia first confirmed on soybean, *Glycine max* L., in the U.S. in 2000 (Ragsdale et al. 2004). Widespread soybean aphid outbreaks in Iowa and the northcentral region were observed in 2003 and 2005, with populations exceeding 1,000 aphids per plant. At this infestation level, 40% yield loss resulted in significantly reduced seed size, seed coat quality, pod number, and plant height (Ragsdale et al. 2007). Soybean aphid proved to be economically important and is now the primary soybean insect pest in Iowa and the northcentral region (Hodgson et al. 2012, Krupke et al. 2017). This pest is more prevalent in northern counties, but can be found throughout the state.

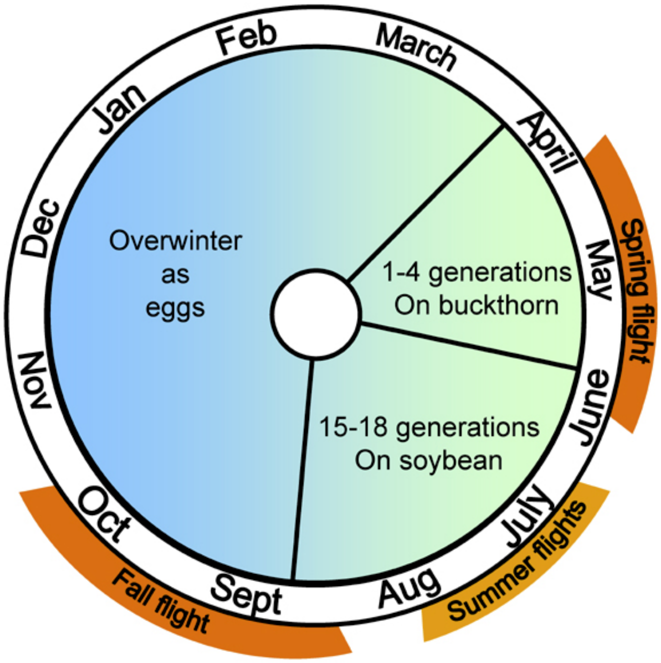
There were only occasional insect pest issues in midwestern soybean before 2000, which resulted in less than 1% of fields being treated with insecticides (USDA-NASS). The injury potential of soybean aphid resulted in a 130-fold increase of insecticide applications in less than ten years (Ragsdale et al. 2011). Since 1996, the average soybean seed costs (not including pesticidal seed treatments) for the U.S. Heartland have increased from \$20 to \$58 per acre, while yield is more slowly increasing from 45 to 52 bushels per acre (USDA-NASS). Seed treatments are widely adopted and increasing in cost annually. Fifteen years after the discovery of soybean aphid on soybean, farmers have drastically changed management practices to protect yield.

**Description.** Wingless soybean aphid adults have a typical pear-shaped body and are 1/16 inches long (Voegtlin et al. 2004). The body is bright yellow-green with red eyes and black cornicles (i.e., "tailpipes" at the end of the abdomen). They have pale legs and antennae, and a dusky-colored cauda (i.e., small appendage on the tip of the abdomen). Soybean aphid nymphs look similar to adults except smaller in size and a reduced cauda. Winged soybean aphids have a dark head and thorax, and two pairs of clear wings that extend well past the end of the abdomen.



*Wingless soybean aphid (left photo by Claudio Gratton) and winged soybean aphid (right photo by Rob Venette).*

**Life Cycle.** Soybean aphid has a complex life cycle similar to other host-alternating aphid species (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. Egg hatch is synchronized with buckthorn bud burst in the spring. A few asexual wingless generations are produced before winged adults are formed on buckthorn. 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 in the summer. Long distance migration can occur because the aphids move with jet streams. As soybean matures, and temperature and day length decreases, winged soybean aphids move back to buckthorn, where mating and egg deposition occurs.



*Soybean aphid has a host-alternating life cycle that includes soybean and buckthorn.*

**Feeding Injury.** As with all aphids, soybean aphids have a piercing-sucking mouthpart. Nymphs and adults feed on plant sap in the phloem of all leaves and stems. Heavily infested plants may become 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).

*Sooty mold (top) on leaves can negatively impact soybean yield. Photo by Brian McCornack.*

**Seasonal Exposure.** Estimating soybean aphid pressure over the entire growing season provides a measure of the seasonal aphid exposure that a soybean field experiences, similar to calculating area under the curve or heat units for plant development. To estimate the total exposure of soybean plants to soybean aphid, we calculate 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 injury around 5,000–6,000 CAD (Ragsdale et al. 2007).

**Management.** A multi-state research effort showed that over a wide range of growing conditions, 650 aphids per plant are needed before economic injury (i.e., bushels per acre being reduced) will occur (Ragsdale et al. 2007). A conservative economic threshold of 250 aphids per plant was developed for the north central region to minimize yield loss (Ragsdale et al. 2007, Hodgson et al. 2012). The economic threshold should be used from R1–R5.5 (i.e., flowering through seed set) to protect yield, reduce control costs, and preserve insecticide efficacy (Hodgson et al. 2012). This threshold remains consistent regardless of fluctuating input costs and market values (Koch et al. 2016). Our program validates the economic threshold annually (See 2009-2019 reports; ***www.ent.iastate.edu/soybeanresearch/content/extension***) and showed spraying at R6 (i.e., full seed set) did not produce a yield response (Hodgson and VanNostrand 2013, 2017).

Most IPM (integrated pest management) programs involve regular sampling of the pest. This can be especially important for a multigenerational insect with a complex life cycle like soybean aphid (Hodgson et al. 2012). Regular scouting for soybean aphid in July and August, or at least from R1–R5.5 (i.e., bloom through seed set), is recommended (Hodgson et al. 2004) even if the plants have an insecticidal seed treatment. Winged aphids are more prevalent and likely to migrate within and between fields during the reproductive soybean period (Hodgson et al. 2005). Regular sampling will help farmers and crop consultants track population trends and improve foliar application timing.

The severity and abundance of soybean aphid in Iowa fluctuates. Although colonies can be initially patchy, populations can quickly spread throughout the field under favorable weather conditions. Soybean aphid prefers the newest soybean foliage. Plants covered with honeydew or sooty mold indicate soybean aphids have been there for a long time and yield loss has likely occurred. 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,*** to make faster treatment decisions (Hodgson et al. 2007; blank forms can be found here: ***http://bit.ly/2fJbbdr***).

Host plant resistance is a new tool to manage soybean aphid and complementary to foliar insecticides. 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). Host plant resistant genes for soybean aphid are prefixed with "***Rag***" which is an abbreviation for "Resistant to ***Aphis glycines***." The ***Rag1*** gene expresses antibiosis, a type of resistance where exposed insects do not live as long or produce as many offspring as they could on susceptible plants. The ***Rag1*** gene does not cause yield drag but it is not always included into high-yielding seed genetics (Kim and Diers 2009). Additional ***Rag*** genes have been discovered and pyramids with two or more ***Rag*** genes have been developed. McCarville et al. (2014) showed ***Rag1*** or ***Rag2*** varieties significantly reduced the seasonal exposure of soybean aphid, and a pyramid of ***Rag1+2*** offered nearly full yield protection without the need for foliar insecticides in a wide geographic region.

**Management Recommendations.** Population fluctuations between locations and years is typical soybean aphid dynamics for Iowa. Our recommendation for soybean aphid management in Iowa is to:

- Strongly consider using host plant resistance if soybean aphid populations are persistent and the seed agronomic traits are appropriate for the area. The use of a pyramided gene will result in lower seasonal accumulation and reduce the need for foliar insecticides.

- Plant early if the field is in an area with persistent soybean aphid populations.

- Scout for soybean aphid, especially during R1–R5, and use a foliar insecticide if aphids exceed the economic threshold of 250 per plant.

- Use a product labeled for soybean aphid; most well-timed applications of foliar insecticides will provide yield protection if applied at the economic threshold and coverage is sufficient.

- Evaluate foliar insecticide efficacy three days after application to ensure soybean aphid populations were sufficiently reduced.

- Understand that late-season accumulation of aphids (i.e., after R5) may not impact yield like it does in early reproductive growth; a foliar insecticide applied after seed set may not be an economically profitable choice.


*Use high volume and pressure to create small droplets that make contact with soybean aphids in the lower canopy. Photo by Erin Hodgson.*


*Look for surviving aphids 3-4 days after an application to assess insecticide efficacy. Photo by Thelma Heidel-Baker.*

## Methods and Materials

**Plot Establishment.** We established plots at the ISU Northwest Research Farm in O'Brien County, Iowa in 2019. Syngenta NK S24-K2 brand soybean was used. Seeds did not have a pesticidal seed treatment unless specifically stated. The treatments were arranged in a randomized complete block design with four replications, and soybean was planted in 30-inch rows using standard production practices on 16 May 2019. Each plot was eight rows wide and 44 feet long. In total, we evaluated 27 treatments that included products alone or in combination (Table 1).

**Sampling Protocol.** Soybean aphids were counted on randomly selected plants within each plot. All aphids (adults, nymphs, and winged adults) were counted on whole plants from early vegetative stages through maturity (Figure 1). The number of plants counted per plot ranged from 20 to 3, and was determined by plant growth stage and by the severity of aphid infestation (Hodgson et al. 2005). Twenty plants were counted in each plot during the vegetative growth. At R2 (i.e., full bloom), ten plants were sampled in each plot. The number of plants sampled further decreased to 5 and then to 3 per plot as plants matured from R3–R5 (i.e., pod fill to seed fill). The CAD for each treatment was estimated for each location (Table 2; Figure 2).

**Insecticide Applications.** Most of the seed used in 2019 did not have a pesticidal seed treatment, except for those treatments with Cruiser 5FS and CruiserMaxx Vibrance FS (Table 1). All seed treatments were applied by Syngenta. Foliar treatments were applied using a custom sprayer and TeeJet (Springfield, IL) flat fan nozzles (XR8002) with 20 gallons of water per acre at 30 pounds of pressure per square inch. Our target spray application is made at the economic threshold or at R5.5 if the threshold is not met.

**Yield.** Each plot was harvested using a small plot combine. Plants were harvested on 15 October. Yields were determined by weighing grain with a hopper which rested on a digital scale sensor custom designed for the combine. Yields were corrected to 13% moisture and reported in bushels per acre (Table 2; Figure 3).

**Statistical Analysis.** A one-way analysis of variance (ANOVA) was used to determine CAD and yield treatment effects within each experiment. Mean separation for all treatments were achieved using a least significant differences (LSD) test (alpha = 0.10). All statistical analyses were performed using SAS® software (SAS 9.4).

## Results and Conclusions

The plots were initially colonized by soybean aphid in July, with exponential growth in August (Figure 1). There were a few other soybean insect pests present (e.g., Japanese beetle, colaspis beetles, thistle caterpillar, and stink bugs), but economic populations were not evident. Natural enemies, such as beetles, flies, lacewings and wasps, were present throughout the reproductive stages, but did not significantly impact aphid populations. The threshold was met on 15 August and plots were sprayed on 16 August (Table 1). Plants were at R5 (beginning seed set) at the time of the foliar application. Soybean aphid populations peaked on 5 September (Figure 1). In the untreated control treatments, aphid populations reached 1,783.33 per plant ± 376.14 (± standard error of the mean).

There were some significant differences among CAD treatments, ranging from 2,372-36,827 (Table 2; Figure 2). Most of the CAD was accrued in late August and September after full seed set. Treatment 1 (untreated control) had the most CAD and had significantly more aphids than all other treatments. Treatments 5, 6, and 10 had generally more CAD than most other foliar insecticidal treatments; it is unknown if the aphids on the farm or within plots were pyrethroid resistant. As demonstrated in previous efficacy evaluations, when aphids peak after full seed set, yield losses are not as dramatic. Although treatment 1 (untreated control) had numerically less yield than all other treatments, there was much overlap between treatments (Table 2, Figure 3).

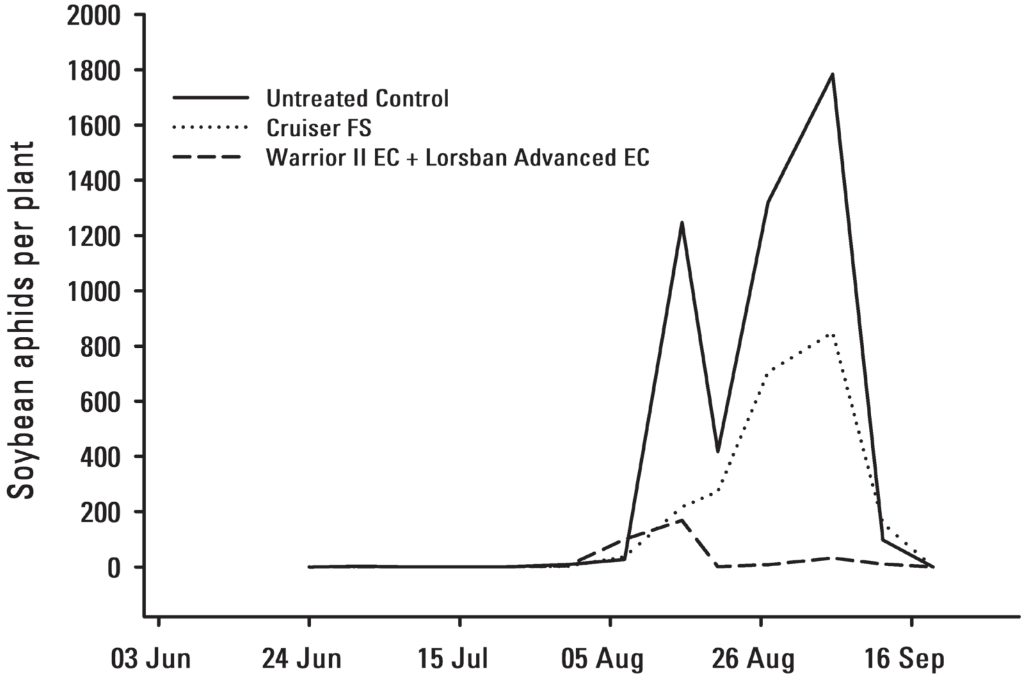


**Figure 1. Mean number of aphids per plant in 2019 at the Northwest Research Farm.**

## Table 1. List of treatments and rates for soybean aphid at the Northwest Research Farm in 2019

| Treatment and Formulation | Group[a] | Active Ingredient(s)[b] | Rate[c] | Timing |
|---|---|---|---|---|
| 1. Untreated Control | ----- | ----- | ----- | ----- |
| 2. Lorsban Advanced EC | 1B | chlorpyrifos | 16.0 fl oz | 16 Aug |
| 3. Dimethoate 4E | 1B | dimethoate | 16.0 fl oz | 16 Aug |
| 4. Warrior II CS | 3A | lambda-cyhalothrin | 1.92 fl oz | 16 Aug |
| 5. Hero EC | 3A | zeta-cypermethrin + bifenthrin | 5.0 fl oz | 16 Aug |
| 6. Brigade EC (A) | 3A | bifenthrin | 3.2 fl oz | 16 Aug |
| 7. Brigade EC (B) | 3A | bifenthrin | 4.8 fl oz | 16 Aug |
| 8. UPL Lambda (A) | 3A | lambda-cyhalothrin | 0.92 fl oz | 16 Aug |
| 9. UPL Lambda (B) | 3A | lambda-cyhalothrin | 0.96 fl oz | 16 Aug |
| 10. Lambda-Cy EC | 3A | lambda-cyhalothrin | 0.92 fl oz | 16 Aug |
| 11. Cruiser 5FS | 4A | thiamethoxam (ST) | 0.0756 mg ai/seed | ----- |
| 12. CruiserMaxx Vibrance FS | 4A | thiamethoxam (ST) | 0.0945 mg ai/seed | ----- |
| 13. Transform WG (A) | 4C | sulfoxaflor | 0.542 oz | 16 Aug |
| 14. Transform WG (B) | 4C | sulfoxaflor | 0.8 oz | 16 Aug |
| 15. Pyrifluquinazon (A) | 9B | pyrifluquinazon | 0.8 fl oz | 16 Aug |
| 16. Pyrifluquinazon (B) | 9B | pyrifluquinazon | 1.2 fl oz | 16 Aug |
| 17. Pyrifluquinazon (C) | 9B | pyrifluquinazon | 1.6 fl oz | 16 Aug |
| 18. Sefina DC | 9D | afidopyropen | 3.0 fl oz | 16 Aug |
| 19. Warrior II CS and<br>Lorsban Advanced EC | 3A<br>1B | lambda-cyhalothrin<br>chlorpyrifos | 1.92 fl oz<br>16.0 fl oz | 16 Aug |
| 20. Stallion SC | 3A + 1B | zeta-cypermethrin + chlorpyrifos | 11.75 fl oz | 16 Aug |
| 21. Cobalt Advanced EC | 3A + 1B | lambda-cyhalothrin + chlorpyrifos | 16.0 fl oz | 16 Aug |
| 22. Cruiser 5FS and<br>Warrior II CS | 4A<br>3A | thiamethoxam (ST)<br>lambda-cyhalothrin | 0.0756 mg ai/seed<br>1.92 fl oz | -----<br>16 Aug |
| 23. CruiserMaxx Vibrance FS and<br>Warrior II CS | 4A<br>3A | thiamethoxam (ST)<br>lambda-cyhalothrin | 0.0945 mg ai/seed<br>1.92 fl oz | -----<br>16 Aug |
| 24. Brigadier SC | 3A + 4A | bifenthrin + imidacloprid | 5.1 fl oz | 16 Aug |
| 25. Endigo ZCX (A) | 3A + 4A | lambda-cyhalothrin + thiamethoxam | 3.5 fl oz | 16 Aug |
| 26. Endigo ZCX (B) | 3A + 4A | lambda-cyhalothrin + thiamethoxam | 4.5 fl oz | 16 Aug |
| 27. Sefina DC and<br>Priaxor CS | 9D<br>7 + 11[d] | afidopryropen<br>fluxapyroxad + pyraclostrobin | 3.0 fl oz<br>4.0 fl oz | 16 Aug |

[a] Insecticide group according to the Insecticide Resistance Action Committee (*http://www.irac-online.org/*);
[b] Does not contain a fungicidal/insecticidal seed treatment (ST) unless noted; [c] per acre unless noted; and
[d] Fungicide group according to the Fungicide Resistance Action Committee (*https://www.frac.info/*).

## Table 2. Soybean aphid density and yield for soybean aphid treatments at the Northwest Research Farm in 2019

| Treatment and Formulation | CAD ± SEM[a] | CAD - LSD[b] | Yield ± SEM[c] | Yield - LSD[d] |
|---|---:|---|---:|---|
| 1. Untreated Control | 36,827.74 ± 7,228.56 | G | 52.63 ± 1.73 | H |
| 2. Lorsban Advanced EC | 5,760.34 ± 766.40 | ABC | 59.53 ± 1.79 | BCDE |
| 3. Dimethoate 4E | 5,320.97 ± 1,347.39 | ABC | 58.08 ± 2.17 | DEFG |
| 4. Warrior II CS | 17,287.58 ± 3,337.26 | EF | 55.25 ± 1.38 | GH |
| 5. Hero EC | 19,743.35 ± 7,568.03 | F | 54.43 ± 1.94 | H |
| 6. Brigade EC (A) | 20,240.54 ± 9,441.44 | F | 61.38 ± 0.70 | ABCD |
| 7. Brigade EC (B) | 5,007.24 ± 872.65 | ABC | 63.43 ± 0.99 | A |
| 8. UPL Lambda (A) | 8,476.13 ± 920.36 | ABCD | 60.15 ± 1.72 | ABCD |
| 9. UPL Lambda (B) | 11,782.27 ± 3,405.58 | CDE | 52.93 ± 3.14 | H |
| 10. Lambda-Cy EC | 17,186.71 ± 5,377.30 | EF | 53.53 ± 3.00 | H |
| 11. Cruiser 5FS | 16,983.81 ± 2,845.73 | EF | 58.93 ± 2.04 | CDEF |
| 12. CruiserMaxx Vibrance FS | 11,103.59 ± 778.21 | BCDE | 59.18 ± 1.03 | CDE |
| 13. Transform WG (A) | 6,089.26 ± 1,224.42 | ABC | 62.10 ± 1.18 | ABC |
| 14. Transform WG (B) | 3,282.44 ± 905.30 | AB | 59.15 ± 0.85 | CDE |
| 15. Pyrifluquinazon (A) | 8,851.28 ± 1,822.64 | ABCD | 55.43 ± 2.61 | FGH |
| 16. Pyrifluquinazon (B) | 10,307.50 ± 2,362.58 | BCDE | 55.40 ± 2.13 | FGH |
| 17. Pyrifluquinazon (C) | 14,283.49 ± 1,729.98 | DEF | 55.93 ± 1.72 | EFGH |
| 18. Sefina DC | 5,570.71 ± 968.47 | ABC | 60.95 ± 1.90 | ABCD |
| 19. Warrior II CS and Lorsban Advanced EC | 2,372.33 ± 579.22 | A | 58.23 ± 1.58 | DEFG |
| 20. Stallion SC | 7,517.73 ± 2,815.22 | ABCD | 58.43 ± 1.98 | DEFG |
| 21. Cobalt Advanced EC | 3,975.81 ± 1,492.00 | ABC | 59.70 ± 1.24 | BCD |
| 22. Cruiser 5FS and Warrior II CS | 8,141.55 ± 1,596.03 | ABCD | 63.13 ± 1.23 | AB |
| 23. CruiserMaxx Vibrance FS and Warrior II CS | 3,984.38 ± 791.71 | ABC | 63.73 ± 0.34 | A |
| 24. Brigadier SC | 4,691.71 ± 1,214.30 | ABC | 59.43 ± 1.47 | CDE |
| 25. Endigo ZCX (A) | 3,587.27 ± 639.99 | AB | 60.75 ± 1.17 | ABCD |
| 26. Endigo ZCX (B) | 4,675.85 ± 808.21 | ABC | 60.98 ± 2.26 | ABCD |
| 27. Sefina DC and Priaxor CS | 6,625.17 ± 1,654.79 | ABCD | 60.28 ± 1.18 | ABCD |

[a] CAD (cumulative aphid days) is the estimated seasonal exposure of soybean aphid ± the standard error of the mean; [b] LSD (least significant difference) of CAD at alpha = 0.10 ($P<0.0001$; $F = 5.19$; df = 26, 3); [c] yield is reported in bushels per acre ± the standard error of the mean; and [d] LSD of yield at alpha = 0.10 ($P<0.0001$; $F = 4.30$; df = 26, 3).

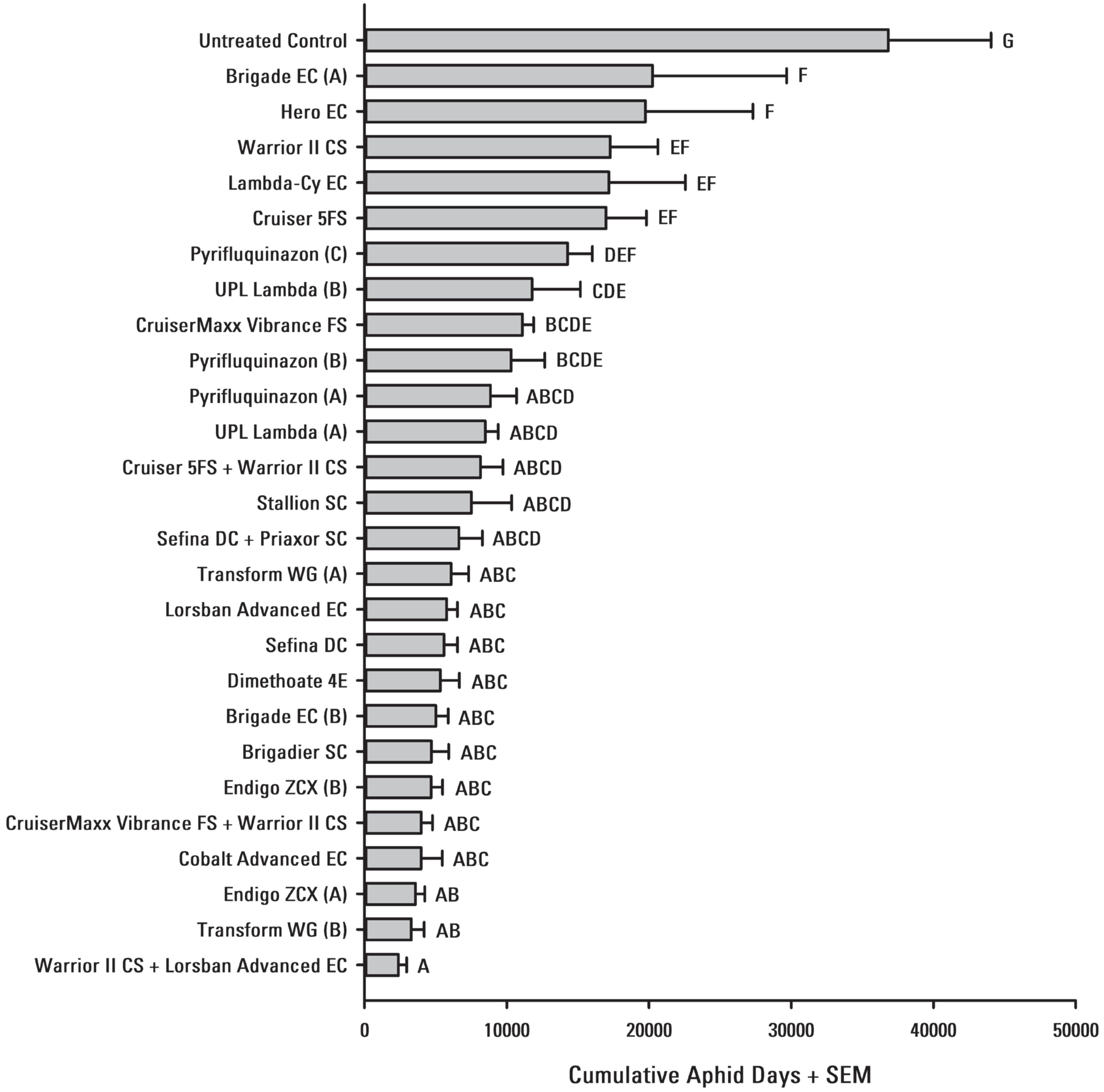


**Figure 2. Mean separation of cumulative aphid days + standard error of the mean treatments at the Northwest Research Farm in 2019. See Table 1 for a full list of treatments and rates. Means with a unique letter are significantly different at alpha = 0.10 (P<0.0001; F = 5.19; df = 26, 3).**

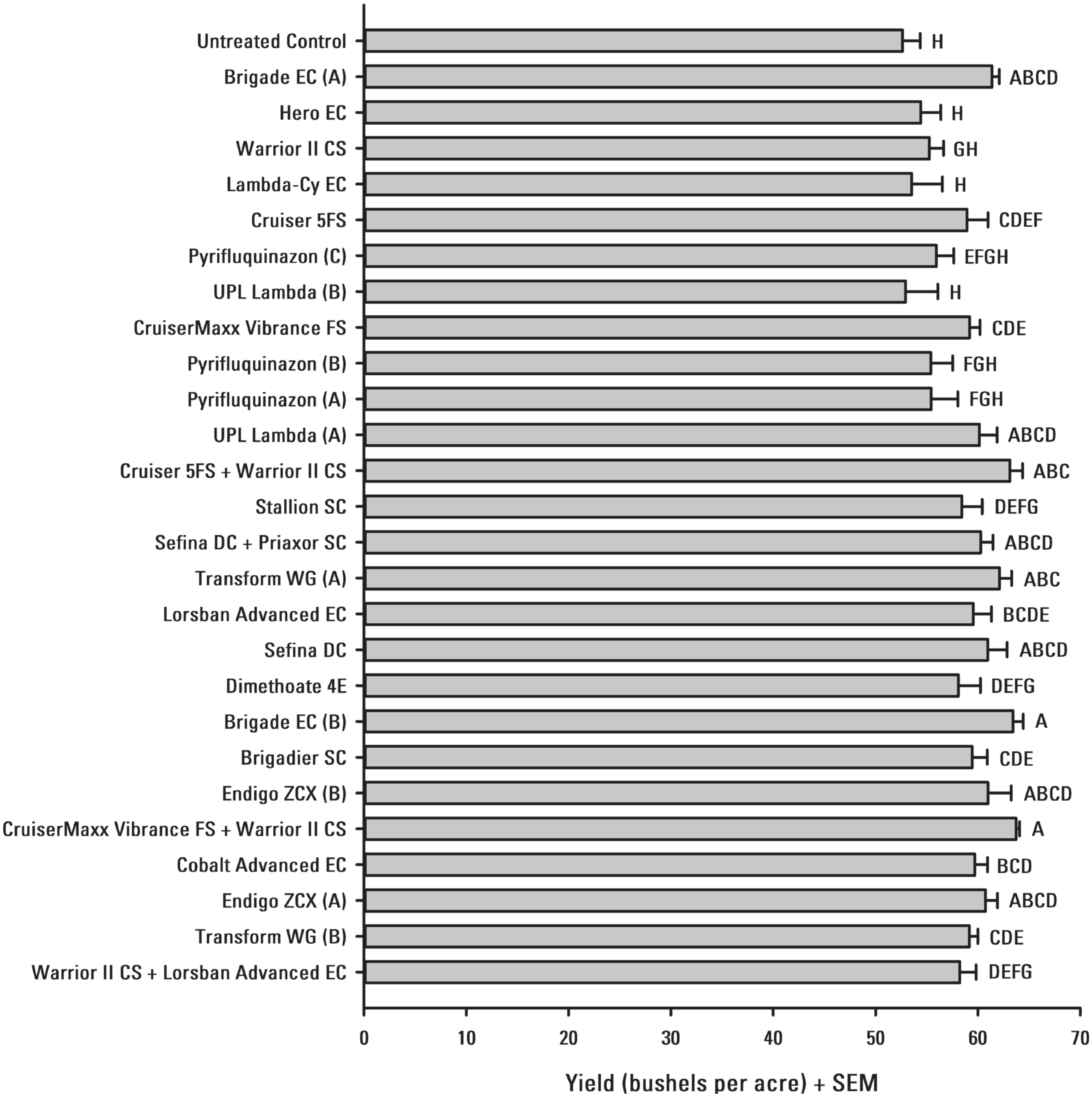


**Figure 3. Mean separation of yield + standard error the mean for soybean aphid treatments at the Northwest Research Farm in 2019. See Table 1 for a full list of treatments and rates. Means with a unique letter are significantly different at alpha = 0.10 (P=0.0001; F = 4.30; df = 26, 3).**

# Japanese Beetle

*There are many insects easily confused with Japanese beetles - make sure to confirm the identification. Photo by Dorothy E. Pugh.*

JAPANESE BEETLE, ***Popillia japonica*** Newman (Coleoptera: Scarabaeidae), is an invasive insect from Asia first confirmed in the United States in 1916. This beetle is a significant insect pest of turfgrass and ornamental, horticultural and agricultural plants in the eastern United States. The pest status of Japanese beetle is due in part to its generalist nature, feeding on more than 300 plant species, as well as the ability to form large aggregations. As larvae, Japanese beetles are destructive to turfgrass roots, including lawns, golf courses, and athletic fields. Adults feed mainly on leaves between the veins and leave a characteristic skeletonized appearance. The significance of this invasive species in the Midwestern United States is increasing, with first detection in Iowa in 1994. A thorough literature review for Japanese beetle was recently published (Shanovich et al. 2019).

**Description.** Newly deposited eggs are laid singly and can be generally found at a depth of up to 4 inches. Most often, eggs are white and spherical with a diameter of 1/16 inch. Larvae go through three instars and are C-shaped white grubs with a yellowish-brown head. Larvae have chewing mouthparts and three pairs of thoracic legs. The bodies of the larvae are covered with brown hairs concentrated on the dorsal (top) side and at the tip of the abdomen. The ventral (bottom) side of the last abdominal segment bears two diagnostic V-shaped rows of six or seven spine-like hairs, which may be used to distinguish larvae from other scarab species. Adult Japanese beetles have brightly colored metallic-green bodies with coppery-bronze elytra (forewings). Along the sides of the body are tufts of white setae (hair) and two spots of white setae on the back end. Their bodies are oval in shape, about 5/16 inches long and ¼ inches wide. The females are generally larger than the males.

*Key life stages of Japanese beetle, including larva, left (Photo by David Cappaert) and adult, right (Photo by Theresa Cira).*

**Life Cycle.** Throughout most of its range in the United States, Japanese beetle has one generation per year. In the Midwest, adults begin emerging from the soil in mid-to-late June to early July (Hodgson 2018), with females probably emerging a few days earlier than males. Emerging females carry an average of 20 mature eggs and are thought to release a sex pheromone to attract males. Throughout their adult lifespan of 4 to 6 weeks, females will continually alternate between feeding, mating, and ovipositing eggs. They will enter the soil a dozen or more times, laying up to 60 individual eggs. Sites with short grass cover along with high soil moisture, moderate soil texture, low organic matter content, and sunlight are preferred by females for oviposition, although eggs may also be laid within crop fields, with soybean seemingly preferred to corn. In addition, reduced-tillage systems promote higher egg densities.

Eggs typically hatch within 10-14 days and development to third instars requires about 4 weeks. The larvae feed on plant roots and decaying vegetation wherever they hatch, due to their limited mobility through the soil. Third instars will feed into October and begin to move deeper into the soil profile, typically up to 6 inches below the soil surface, for overwintering. Diapause ends the following spring when soil temperatures in the upper 6 inches exceed 50°F, and grubs begin to move back upward in the soil profile to continue feeding for another 4 to 8 weeks before pupating. The pupal stage lasts 7-17 days and the newly-molted adults remain in the soil for 2-14 days prior to emergence.

**Feeding Injury.** Japanese beetle adults feed on the interveinal tissue of soybean leaves, leaving the veins intact and creating a characteristic skeletonized appearance. Defoliation by Japanese beetle in soybean can be field-wide but is typically concentrated along field edges, and feeding-induced plant volatiles are thought to promote aggregations. Aggregations of adults often worry farmers, because defoliation appears severe; however, adults are highly mobile and likely do not feed in one place for long. Additionally, beetles have a top-down feeding pattern (upper canopy defoliated first) but generally do not destroy the entire leaf surface. Therefore, when estimating defoliation, the entire canopy, not just upper or injured leaves, must be considered.

*Estimating defoliation is a more accurate way to make treatment decisions. Photo by Mark Licht.*

**Management.** The severity and abundance of Japanese beetle in Iowa fluctuates. When scouting for Japanese beetle in field crops, it is crucial to obtain a representative field sample as they have been found to aggregate in higher numbers along the field edges, particularly on downwind sides. This will be important to determine whether border treatment will suffice or if whole-field treatment is warranted. Scouting can be difficult due to their high mobility. Flight activity is greatest during clear weather when the temperature is between 84 and 95°F, relative humidity is above 60%, and wind speed is below 12.43 mph; these conditions would subsequently be optimal for adult feeding activity. Also, since adults are highly mobile, reinfestations are common after insecticide applications and should not be assumed to be resistant to insecticides.

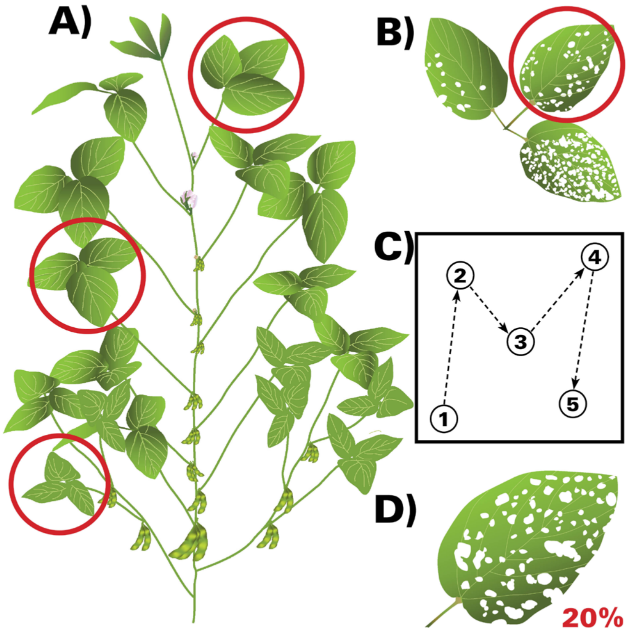
Scouting for Japanese beetle adults in soybean involves estimating percent defoliation across the entire field, because infestations may be concentrated. In addition, it is critical to sample the entire plant, not just the top of the canopy where beetles tend to aggregate. In doing so, estimations can be made for the level of defoliation for the entire canopy of the field. If an application is needed, many foliar insecticides are labeled for use on adult Japanese beetle, and some soil insecticides and low-rate neonicotinoid seed treatments are labeled for white grubs in field crops. Also, if Japanese beetle pressure is high and pollination is incomplete, consider whether reinfestations are severe enough to warrant additional insecticide applications.

## Methods and Materials

**Plot Establishment.** We established plots at two locations in 2019. The first location was at the ISU Northeast Research Farm in Floyd County, Iowa. Pioneer 23A32X brand soybean was used for all the treatments and was planted in 30-inch rows using no-till production practices on 18 May 2019. Plots were six rows wide and 60 feet long. The second location was at the ISU Johnson Research Farm in Story County, Iowa. Pioneer P27A17X brand soybean was used for all the treatments and was planted in 30-inch rows using standard production practices on 4 June 2019. Plots were six rows wide and 50 feet long. Treatments at both locations were arranged in a randomized complete block design with four replications. In total we evaluated 7 treatments at each location (Tables 3, 5).

**Sampling Protocol.** We sampled for Japanese beetle four times at both locations (2 pre-spray and 2 post-spray). Percent defoliation was estimated for 10 random plants in each plot on each sample date using the method outlined below. Briefly, we chose three trifoliates at random from the top, middle, and bottom of each plant. We discarded the leaflets with the most and least defoliation on each trifoliate and estimated percent defoliation for the remaining leaflet. We took 10 sweeps from the center four rows of each plot and recorded the number of Japanese beetles present (Figures 4, 5). Other defoliating insects were recorded from sweep net samples but are not reported here.

1. Walk at least 30 feet into the field.
2. Take a trifoliate from the top, middle and bottom of a randomly-selected plant (A).
3. From each trifoliate, remove the leaflet with most defoliation and the leaflet with the least defoliation. Keep the remaining leaflet (B).
4. Stop at 9 more randomly-selected plants at least 10-20 steps apart and repeat #2-3.
5. Move to four more areas in the field (C), repeat #2-4 each time to collect 50 total leaflets (10 leaflets from 5 areas).
6. Estimate the percent defoliation of each leaflet (D) and calculate the average for the entire field. Refer to a defoliation guide to gauge your estimates.
7. Consider a foliar insecticide to protect yield if the average defoliation is above 30% for vegetative soybean and above 20% for reproductive soybean AND insects are still present.



Graphic adapted from McMechan 2017 (http://bit.ly/2Po3nja).

*Estimating insect defoliation in soybean (Shanovich et al. 2019).*

**Insecticide Applications.** Foliar treatments were applied after the second sample date using a backpack sprayer with 20 gallons of water per acre at 40 pounds of pressure per square inch. At the ISU Northeast Research Farm, a non-ionic surfactant was included at 0.25% v/v for all treatments and applications were made on 6 August 2019. Applications were made at the ISU Johnson Research Farm on 5 August 2019. See Tables 3 and 5 for full treatment details.

**Yield.** Each plot was harvested using a small plot combine. The middle four rows of each treatment were harvested on 16 October 2019 and 17 October 2019 at the ISU Northeast Research Farm and ISU Johnson Research Farm, respectively. Yields were determined by weighing grain with a hopper which rested on a digital scale sensor custom designed for each combine. Yields were corrected to 13% moisture and reported in bushels per acre (Tables 4, 6).

**Statistical Analysis.** A one-way analysis of variance (ANOVA) was used to determine the effect of treatment on beetle densities at the first sampling date after insecticide application, percent defoliation at the final sampling date, and yield at harvest at each location. A least significant differences (LSD) test was used to achieve mean separation for all treatments (alpha = 0.05). All statistical analyses were performed using SAS® software (SAS 9.4).

## Results and Conclusions

Plots were established in locations that had high populations of Japanese beetles to test insecticidal efficacy. There were a few other defoliating insect pests present (e.g., bean leaf beetle, thistle caterpillar, and green cloverworm) as well as other pests (e.g., soybean aphid and stink bugs), but economic populations were not evident. Japanese beetle populations peaked on 1 August at the ISU Northeast Research Farm and 2 August at the ISU Johnson Research Farm (Figures 4, 5). In the untreated control treatments, beetle populations reached 9.75 ± 2.10 (± standard error of the mean) and 11.00 ± 3.16 per 10 sweeps at the ISU Northeast Research Farm and ISU Johnson Research Farm, respectively. The untreated control and Transform had higher beetle numbers than all other treatments at both locations (Tables 4, 6; Figures 4, 5). All treatments had beetle numbers and defoliation well below levels that would translate to measurable yield losses, and no significant differences in yield were observed among treatments at either location (Tables 4, 6).

## Table 3. List of treatments and rates for Japanese beetle at the Northeast Research Farm in 2019

| Treatment and Formulation | Group[a] | Active Ingredient(s)[b] | Rate[c] | Timing |
|---|---|---|---|---|
| 1. Untreated Control | ----- | ----- | ----- | ----- |
| 2. Transform WG | 4C | sulfoxaflor | 1.06 oz | 6 Aug |
| 3. Brigade EC (A) | 3A | bifenthrin | 3.2 fl oz | 6 Aug |
| 4. Brigade EC (B) | 3A | bifenthrin | 4.8 fl oz | 6 Aug |
| 5. Brigade EC (C) | 3A | bifenthrin | 6.4 fl oz | 6 Aug |
| 6. Warrior II CS | 3A | lambda-cyhalothrin | 1.6 fl oz | 6 Aug |
| 7. Cobalt Advanced EW | 3A + 1B | lambda-cyhalothrin + chlorpyrifos | 16.0 fl oz | 6 Aug |

[a] Insecticide group according to the Insecticide Resistance Action Committee (*http://www.irac-online.org/*); [b] Does not contain a fungicidal/insecticidal seed treatment (ST) unless noted; and [c] per acre unless noted.

## Table 4. List of beetle density, percent defoliation, and yield for treatments for Japanese beetle at the Northeast Research Farm in 2019

| Treatment and Formulation | Beetles ± SEM[a] | Beetles - LSD[b] | Defoliation ± SEM[c] | Defoliation - LSD[d] | Yield ± SEM[e] | Yield - LSD[f] |
|---|---|---|---|---|---|---|
| 1. Untreated Control | 9.75 ± 2.10 | A | 1.73 ± 0.43 | A | 63.63 ± 2.10 | A |
| 2. Transform WG | 6.00 ± 2.04 | B | 2.09 ± 0.98 | A | 64.38 ± 2.49 | A |
| 3. Brigade EC (A) | 0.00 ± 0.00 | C | 4.19 ± 1.70 | A | 67.18 ± 2.63 | A |
| 4. Brigade EC (B) | 0.00 ± 0.00 | C | 3.48 ± 1.46 | A | 67.09 ± 0.81 | A |
| 5. Brigade EC (C) | 0.00 ± 0.00 | C | 3.77 ± 1.64 | A | 68.88 ± 0.93 | A |
| 6. Warrior II CS | 0.00 ± 0.00 | C | 1.21 ± 0.13 | A | 64.40 ± 1.86 | A |
| 7. Cobalt Advanced EW | 0.00 ± 0.00 | C | 2.88 ± 0.66 | A | 65.56 ± 1.91 | A |

[a] Beetles is the number of beetles two days after treatment ± the standard error of the mean (SEM); [b] LSD (least significant difference) of beetles at alpha = 0.05 ($P<0.0001$; F = 11.24; df = 6, 18); [c] Defoliation is the percent defoliation at the final sampling date ± SEM; [d] LSD of defoliation at alpha = 0.05 (P = 0.51; F = 0.91; df = 6, 18); [e] Yield is reported in bushels per acre ± SEM; and [f] LSD of yield at alpha = 0.05 (P=0.45; F = 1.01; df = 6, 18).

## Table 5. List of treatments and rates for Japanese beetle at the Johnson Research Farm in 2019

| Treatment and Formulation | Group[a] | Active Ingredient(s)[b] | Rate[c] | Timing |
|---|---|---|---|---|
| 1. Untreated Control | ----- | ----- | ----- | ----- |
| 2. Transform WG | 4C | sulfoxaflor | 1.06 oz | 6 Aug |
| 3. Brigade EC (A) | 3A | bifenthrin | 3.2 fl oz | 6 Aug |
| 4. Brigade EC (B) | 3A | bifenthrin | 4.8 fl oz | 6 Aug |
| 5. Brigade EC (C) | 3A | bifenthrin | 6.4 fl oz | 6 Aug |
| 6. Warrior II CS | 3A | lambda-cyhalothrin | 1.6 fl oz | 6 Aug |
| 7. Cobalt Advanced EW | 3A + 1B | lambda-cyhalothrin + chlorpyrifos | 16.0 fl oz | 6 Aug |

[a] Insecticide group according to the Insecticide Resistance Action Committee (*http://www.irac-online.org/*); [b] Does not contain a fungicidal/insecticidal seed treatment (ST) unless noted; and [c] per acre unless noted.

## Table 6. List of beetle density, percent defoliation, and yield for treatments for Japanese beetle at the Johnson Research Farm in 2019

| Treatment and Formulation | Beetles ± SEM[a] | Beetles - LSD[b] | Defoliation ± SEM[c] | Defoliation - LSD[d] | Yield ± SEM[e] | Yield - LSD[f] |
|---|---|---|---|---|---|---|
| 1. Untreated Control | 11.00 ± 3.16 | B | 1.65 ± 0.37 | C | 62.89 ± 4.33 | A |
| 2. Transform WG | 16.75 ± 2.69 | A | 4.27 ± 1.00 | AB | 65.20 ± 3.76 | A |
| 3. Brigade EC (A) | 4.75 ± 1.60 | C | 5.43 ± 0.91 | A | 69.86 ± 2.69 | A |
| 4. Brigade EC (B) | 3.50 ± 0.87 | C | 2.67 ± 0.92 | BC | 69.56 ± 1.69 | A |
| 5. Brigade EC (C) | 1.75 ± 0.63 | C | 1.26 ± 0.34 | C | 68.05 ± 1.25 | A |
| 6. Warrior II CS | 4.00 ± 0.41 | C | 2.59 ± 1.15 | BC | 64.73 ± 3.55 | A |
| 7. Cobalt Advanced EW | 4.00 ± 1.08 | C | 2.37 ± 0.51 | BC | 69.80 ± 1.57 | A |

[a] Beetles is the number of beetles three days after treatment ± the standard error of the mean (SEM); [b] LSD (least significant difference) of beetles at alpha = 0.05 (P = 0.0002; F = 8.24; df = 6, 18); [c] Defoliation is the percent defoliation at the final sampling date ± SEM; [d] LSD of defoliation at alpha = 0.05 (P = 0.02; F = 3.26; df = 6, 18); [e] Yield is reported in bushels per acre ± SEM; and [f] LSD of yield at alpha = 0.05 (P=0.34; F = 1.23; df = 6, 18).

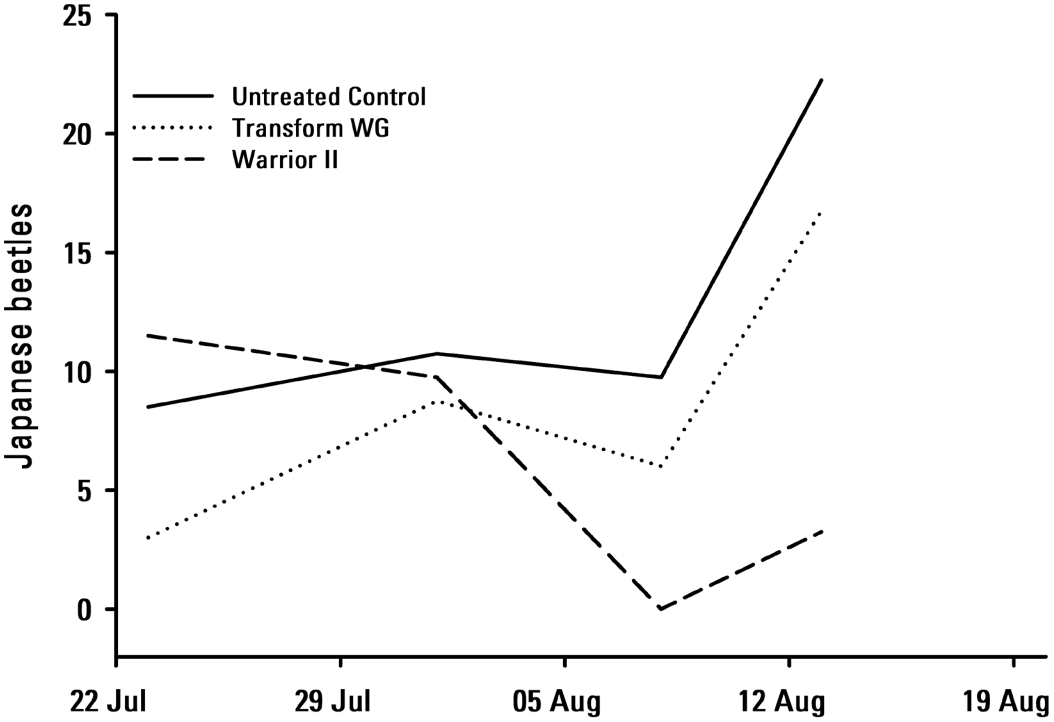


Figure 4. Mean number of beetles per 10 sweeps at the Northeast Research Farm.

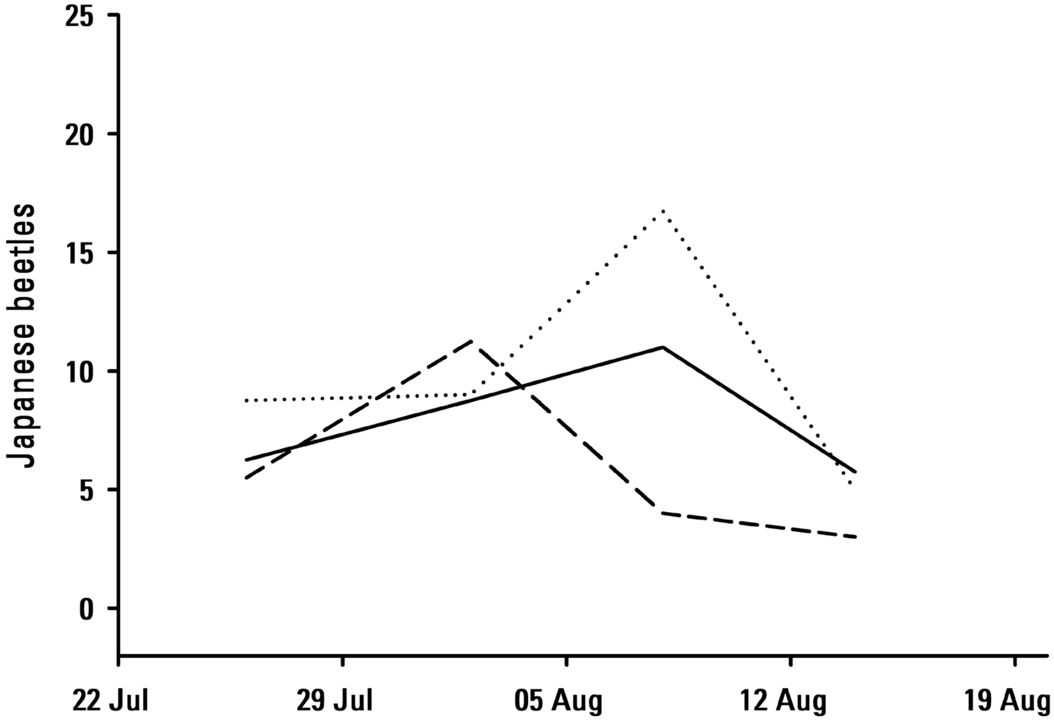
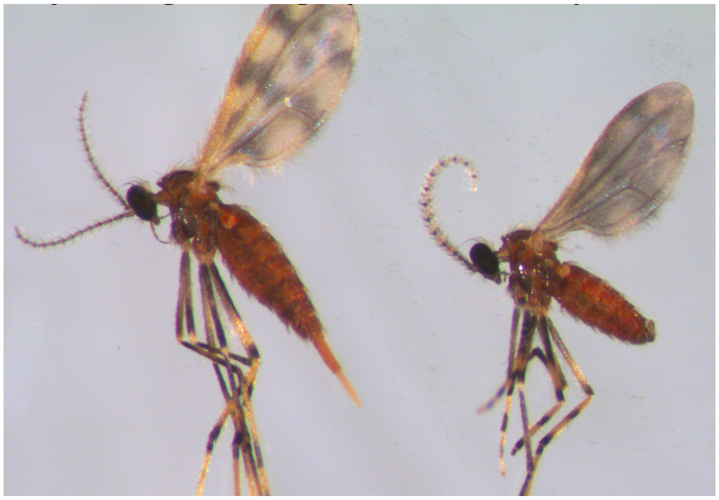


Figure 5. Mean number of beetles per 10 sweeps at the Johnson Research Farm.

# Soybean Gall Midge

SOYBEAN GALL MIDGE, ***Resseliella maxima*** Gagné (Diptera: Cecidomyiidae), is a new pest recently confirmed on soybean, ***Glycine max*** L., in the U.S. Notable populations and economic loss was observed in the northcentral region in 2018 and 2019 (i.e., Iowa, Minnesota, Missouri, Nebraska, South Dakota).

**Description.** Adults have orange abdomens and antenna with alternating dark and light bands. The females are generally larger (¼-inches long) than the males. Wings are mottled with yellow and black scales reinforced by light and dark ground color. The legs are long, dangling from the body, and have alternating dark and light bands. Larvae have few external features. First and second instars are pale, and third instars are orange.



*Soybean gall midge female (left) and male (right). Photo by Mitchell Helton.*

**Life Cycle.** Much is unknown about the biology and life cycle of soybean gall midge. Eggs are deposited on the plant and larvae feed on the inside of the stem near the soil line. Infested areas begin to discolor and sometimes an enlargement, or gall, forms. The gall becomes brittle, often causing plant lodging and complete yield loss.

*A range of larval development on infested soybean. Photo by Mitchell Helton.*

## Methods and Materials

**Plot Establishment.** We established plots at two locations in 2019. Syngenta NK S24-K2 brand soybean was used for all treatments without a seed treatment. Asgrow AG30X9 was used for treatments with a pesticidal seed treatments. The first location was at the ISU 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 4 June 2019. Each plot was four rows wide and 30 feet long. In total, we evaluated 14 treatments (Table 7). The second location was at a commercial farm near Griswold, Iowa in Cass County. The treatments were arranged in a randomized complete block design with four replications, and soybean was planted in 30-inch rows using standard production practices on 15 May 2019. Each plot was four rows wide and 30 feet long. In total, we evaluated 14 treatments (Table 9).

Plant populations were estimated at both locations, on 9 July and 11 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 linear feet was 41.43 ± 0.57 (± SEM) plants at the ISU Northeast Research Farm and 58.74 ± 0.63 plants at the Griswold Farm.

**Sampling Protocol.** Soybean gall midge injury was evaluated using a visual rating system. All plots were evaluated for larval injury from July through September and assessed on a 5-point scale (1 being the best and 5 being the worst). Injury was rated based on a percentage of plants showing injury symptoms caused by soybean gall midge infestations. An injury rating of 1 would be approximately 0 percent of plants showing injury from soybean gall midge injury, and a 5 would be approximately 100 percent of plants showing injury. Final injury ratings were taken on 10 September 2019 and treatments were given a final mean injury rating from all replications.

Adult soybean gall midge emergence was monitored. Emergence cages were placed over the soil to track adult emergence for timing foliar insecticide application. It was determined that the overwintering generation of soybean gall midge adults emerged from last year's soybean fields. Emergence cages were moved throughout the season as new generations emerged. Cages were placed over soybeans identified to be infested with soybean gall midge larvae. All subsequent generations of soybean gall midge emerged from this year's soybean fields. All emergence cages were verified at least twice per week for adult captures.

**Insecticide Applications.** Rates for all insecticides are summarized in Tables 7 and 9. For the Northwest Research Farm, foliar treatments were applied using a custom sprayer and TeeJet (Springfield, IL) flat fan nozzles (XR8002) with 20 gallons of water per acre at 30 pounds of pressure per square inch. For the Griswold Farm, first foliar treatments were applied using a custom sprayer and TeeJet turbo nozzles (TT11002) with 25 gallons of water per acre at 35 pounds of pressure per square inch. Second foliar treatments were applied using a backpack sprayer and TeeJet turbo nozzles (TT11002) with 20 gallons of water per acre at 40 pounds of pressure per square inch.

**Yield.** Each plot was harvested using a small plot combine. Yield was taken from the center two rows. The plots at the ISU Northwest Research Farm were harvested on 25 October and the plots at the commercial farm were harvested on 14 October. Yields were determined by weighing grain with a hopper which rested on a digital scale sensor custom designed for each of the combines. Yields were corrected to 13% moisture and reported in bushels per acre (Tables 8, 10; Figures 7, 9).

**Statistical Analysis.** A one-way analysis of variance (ANOVA) was used to determine yield treatment effects within each experiment. Mean separation for all treatments were achieved using a least significant differences (LSD) test (alpha = 0.05). All statistical analyses were performed using SAS® software (SAS 9.4).

## Results and Conclusions

Adult soybean gall midge emergence began mid-June and midge-infested plants were found shortly after. Adult emergence was almost completely continuous throughout the summer, with three generations of adults being observed. There were a few other soybean insect pests present (e.g., soybean aphid, Japanese beetle, and thistle caterpillar), at both locations but economic populations were not evident. First adult detection foliar sprays were made on 26 June at the ISU Northwest Research Farm and 3 July at the commercial farm. Injury was more severe at the Griswold Farm, with a mean injury rating of 4.14 ± 0.28 compared to a rating of 1.0 at the Northwest Research Farm (Figures 6, 8). Yield was not impacted by soybean gall midge at the Northwest Farm (Figure 7).Yields at the Griswold Farm were greatly impacted, ranging from 4.3 ± 1.02 to 43.9 ± 12.2 bushels per acre (Figure 9). When soybean gall midge pressure was heavy, insecticides evaluated in 2019 did not provide complete yield protection.

## Table 7. List of treatments and rates for soybean gall midge at the Northwest Research Farm in 2019

| Treatment and Formulation | Group[a] | Active Ingredient(s)[b] | Rate[c] | Timing |
|---|---|---|---|---|
| 1. Untreated Control | ----- | ----- | ----- | ----- |
| 2. Endigo ZCX (A) | 3A + 4A | lambda-cyhalothrin + thiamethoxam | 3.5 fl oz | 26 Jun |
| 3. Endigo ZCX (B) | 3A + 4A | lambda-cyhalothrin + thiamethoxam | 3.5 fl oz | 11 Jul |
| 4. Belay (A) | 4A | clothianidin | 6.0 fl oz | 26 Jun |
| 5. Belay (B) | 4A | clothianidin | 6.0 fl oz | 11 Jul |
| 6. Asana XL (A) | 3A | esfenvalerate | 6.0 fl oz | 26 Jun |
| 7. Asana XL (B) | 3A | esfenvalerate | 6.0 fl oz | 11 Jul |
| 8. Fungicide ST[d] | ----- | ----- | ----- | ----- |
| 9. Sivanto (A) and fungicide ST[d] | 4D | flupyradifurone (ST) | 0.045 mg ai/seed | ----- |
| 10. Sivanto (B) and fungicide ST[d] | 4D | flupyradifurone (ST) | 0.068 mg ai/seed | ----- |
| 11. Gaucho FS and fungicide ST[d] | 4A | imidacloprid (ST) | 0.2336 mg ai/seed | ----- |
| 12. Gaucho FS and<br>Sivanto and fungicide ST[d] | 4A<br>4D | imidacloprid (ST)<br>flupyradifurone (ST) | 0.2336 mg ai/seed<br>0.045 mg ai/seed | ----- |
| 13. Aeris and<br>Gaucho FS and fungicide ST[d] | 4A + 1A<br>4A | imidacloprid + thiodicarb (ST)<br>imidacloprid (ST) | 209 ml ai/seed<br>0.1324 mg ai/seed | ----- |
| 14. Fastac CS | 4C | sulfoxaflor | 280 ml/ha | 26 Jun |

[a] Insecticide group according to the Insecticide Resistance Action Committee (*http://www.irac-online.org/*); [b] Does not contain a fungicidal/insecticidal seed treatment (ST) unless noted; [c] per acre unless noted; and [d] Fungicide ST includes: prothioconazole 0.012 mg ai/seed + fluoxastrobin 0.012 mg ai/seed + metalaxyl 0.024 mg ai/seed.

## Table 8. Injury ratings and yield for treatments for soybean gall midge at the Northwest Research Farm in 2019

| Treatment and Formulation | Injury Rating[a] | Injury Rating - LSD[b] | Yield ± SEM[c] | Yield - LSD[d] |
|---|---|---|---|---|
| 1. Untreated Control | 1 | A | 49.93 ± 2.50 | FG |
| 2. Endigo ZCX (A) | 1 | A | 54.90 ± 1.64 | DEF |
| 3. Endigo ZCX (B) | 1 | A | 55.25 ± 1.59 | DEF |
| 4. Belay (A) | 1 | A | 55.92 ± 1.89 | DE |
| 5. Belay (B) | 1 | A | 53.79 ± 3.18 | EF |
| 6. Asana XL (A) | 1 | A | 57.19 ± 1.51 | CDE |
| 7. Asana XL (B) | 1 | A | 56.16 ± 1.91 | DE |
| 8. Fungicide ST[d] | 1 | A | 55.73 ± 2.17 | DEF |
| 9. Sivanto (A) and fungicide ST[d] | 1 | A | 56.62 ± 0.80 | DE |
| 10. Sivanto (B) and fungicide ST[d] | 1 | A | 59.90 ± 1.47 | BCD |
| 11. Gaucho FS and fungicide ST[d] | 1 | A | 64.79 ± 1.16 | AB |
| 12. Gaucho FS and Sivanto and fungicide ST[d] | 1 | A | 66.39 ± 0.84 | A |
| 13. Aeris and Gaucho FS and fungicide ST[d] | 1 | A | 65.67 ± 1.72 | ABC |
| 14. Fastac CS | 1 | A | 46.87 ± 1.96 | G |

[a] Final mean injury rating for soybean gall midge ± the standard error of the mean (SEM); [b] LSD (least significant difference) of injury rating at alpha = 0.05 (df =13, 3); [c] yield is reported in bushels per acre ± SEM; and [d] LSD of yield at alpha = 0.05 (P<0.0001; F=6.41; df =13, 3).

## Table 9. List of treatments and rates for soybean gall midge at the Griswold Farm in 2019

| Treatment and Formulation | Group[a] | Active Ingredient(s)[b] | Rate[c] | Timing |
|---|---|---|---|---|
| 1. Untreated Control | ----- | ----- | ----- | ----- |
| 2. Endigo ZCX (A) | 3A + 4A | lambda-cyhalothrin + thiamethoxam | 3.5 fl oz | 3 Jul |
| 3. Endigo ZCX (B) | 3A + 4A | lambda-cyhalothrin + thiamethoxam | 3.5 fl oz | 16 Jul |
| 4. Belay (A) | 4A | clothianidin | 6.0 fl oz | 3 Jul |
| 5. Belay (B) | 4A | clothianidin | 6.0 fl oz | 16 Jul |
| 6. Asana XL (A) | 3A | esfenvalerate | 6.0 fl oz | 3 Jul |
| 7. Asana XL (B) | 3A | esfenvalerate | 6.0 fl oz | 16 Jul |
| 8. Fungicide ST[d] | ----- | ----- | ----- | ----- |
| 9. Sivanto (A) and fungicide ST[d] | 4D | flupyradifurone (ST) | 0.045 mg ai/seed | ----- |
| 10. Sivanto (B) and fungicide ST[d] | 4D | flupyradifurone (ST) | 0.068 mg ai/seed | ----- |
| 11. Gaucho FS and fungicide ST[d] | 4A | imidacloprid (ST) | 0.2336 mg ai/seed | ----- |
| 12. Gaucho FS and<br>Sivanto and fungicide ST[d] | 4A<br>4D | imidacloprid (ST)<br>flupyradifurone (ST) | 0.2336 mg ai/seed<br>0.045 mg ai/seed | ----- |
| 13. Aeris and<br>Gaucho FS and fungicide ST[d] | 4A + 1A<br>4A | imidacloprid + thiodicarb (ST)<br>imidacloprid (ST) | 209 ml ai/seed<br>0.1324 mg ai/seed | ----- |
| 14. Fastac CS | 4C | sulfoxaflor | 280 ml/ha | 3 Jul |

[a] Insecticide group according to the Insecticide Resistance Action Committee (*http://www.irac-online.org/*); [b] Does not contain a fungicidal/insecticidal seed treatment (ST) unless noted; [c] per acre unless noted; and [d] Fungicide ST includes: prothioconazole 0.012 mg ai/seed + fluoxastrobin 0.012 mg ai/seed + metalaxyl 0.024 mg ai/seed.

## Table 10. Injury ratings and yield for for treatments for soybean gall midge at the Griswold Farm in 2019

| Treatment and Formulation | Injury Rating ± SEM[a] | Injury Rating - LSD[b] | Yield ± SEM[c] | Yield - LSD[d] |
|---|---|---|---|---|
| 1. Untreated Control | 4.75 ± 0.22 | DE | 5.39 ± 1.14 | C |
| 2. Endigo ZCX (A) | 4.00 ± 0.35 | ABCD | 16.94 ± 4.86 | C |
| 3. Endigo ZCX (B) | 4.75 ± 0.22 | DE | 6.93 ± 1.23 | C |
| 4. Belay (A) | 4.25 ± 0.22 | BCDE | 12.20 ± 3.39 | C |
| 5. Belay (B) | 4.50 ± 0.25 | CDE | 11.08 ± 4.98 | C |
| 6. Asana XL (A) | 4.50 ± 0.43 | CDE | 11.80 ± 5.43 | C |
| 7. Asana XL (B) | 4.00 ± 0.35 | ABCD | 17.70 ± 5.57 | C |
| 8. Fungicide ST[d] | 3.75 ± 0.22 | ABC | 22.40 ± 3.75 | BC |
| 9. Sivanto (A) and fungicide ST[d] | 4.00 ± 0.35 | ABCD | 21.80 ± 8.65 | BC |
| 10. Sivanto (B) and fungicide ST[d] | 4.25 ± 0.41 | BCDE | 10.30 ± 4.14 | C |
| 11. Gaucho FS and fungicide ST[d] | 3.50 ± 0.25 | AB | 42.00 ± 10.01 | AB |
| 12. Gaucho FS and Sivanto and fungicide ST[d] | 3.50 ± 0.43 | AB | 43.80 ± 12.23 | A |
| 13. Aeris and Gaucho FS and fungicide ST[d] | 3.25 ± 0.22 | A | 42.50 ± 8.48 | AB |
| 14. Fastac CS | 5.00 ± 0.00 | E | 4.30 ± 1.02 | C |

[a] Final mean injury rating for soybean gall midge ± the standard error of the mean (SEM); [b] LSD (least significant difference) of injury rating at alpha = 0.05 (P=0.0230; F=2.26; df =13, 3); [c] yield is reported in bushels per acre ± SEM; and [d] LSD of yield at alpha = 0.05 (P=0.0007; F=3.67; df =13, 3).

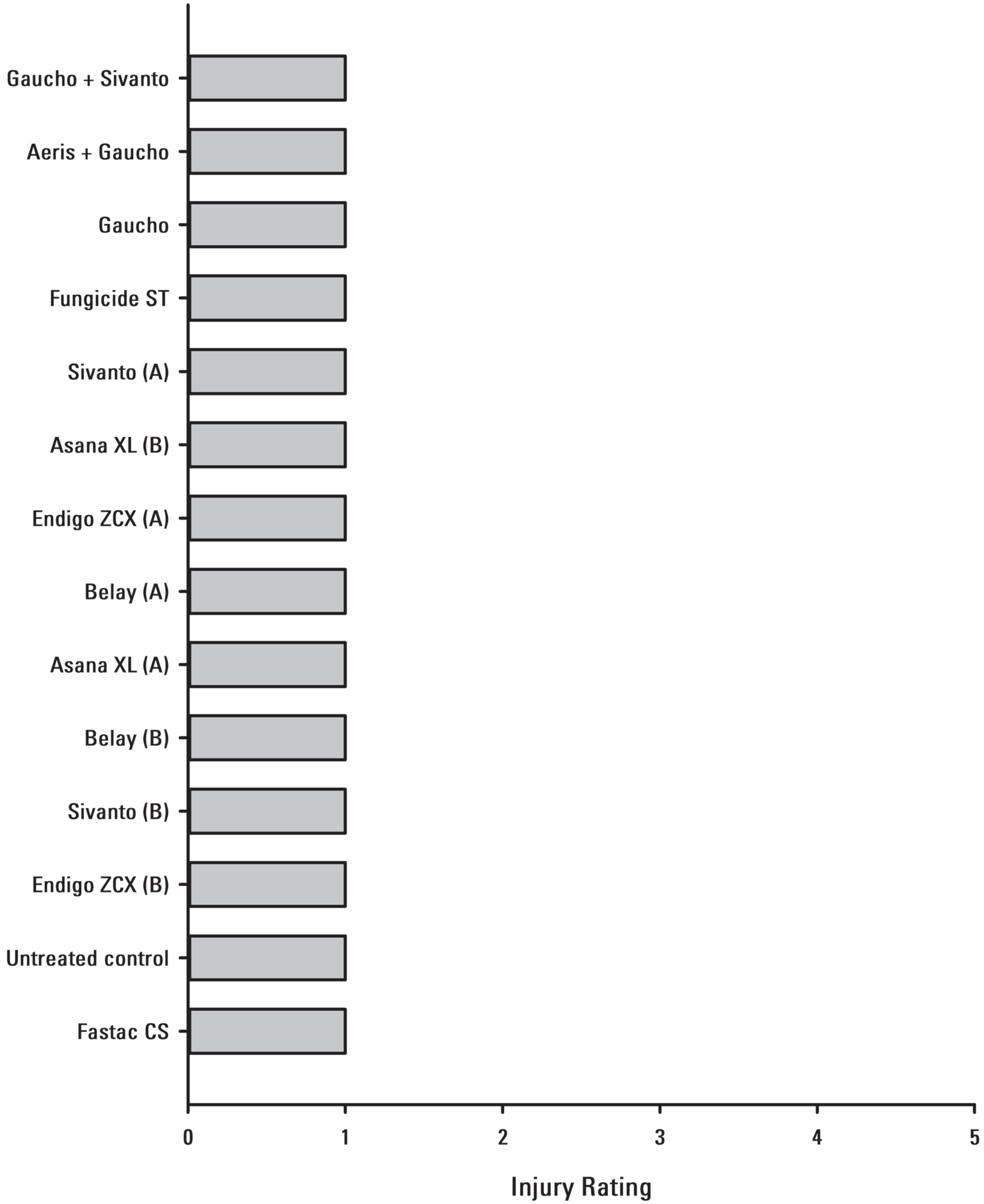


**Figure 6. Final injury rating for soybean gall midge treatments at the Northwest Research Farm in 2019. See Table 7 for a full list of treatments and rates.**

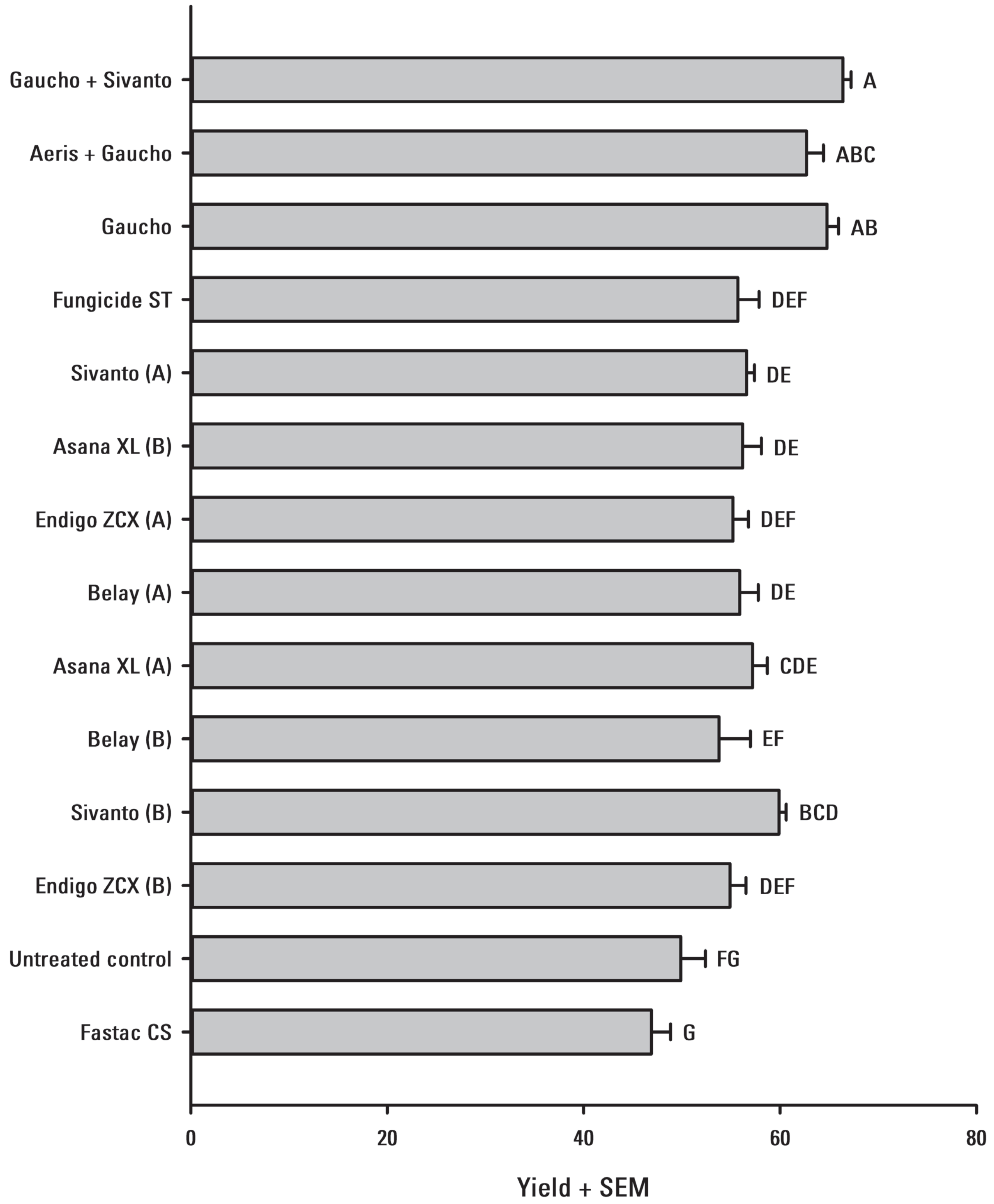


**Figure 7. Mean separation of yield + standard error the mean for soybean gall midge treatments at the Northwest Research Farm in 2019. See Table 7 for a full list of treatments and rates. Means with a unique letter are significantly different at alpha = 0.05 (P=0.0001; F = 6.41; df = 13, 3).**

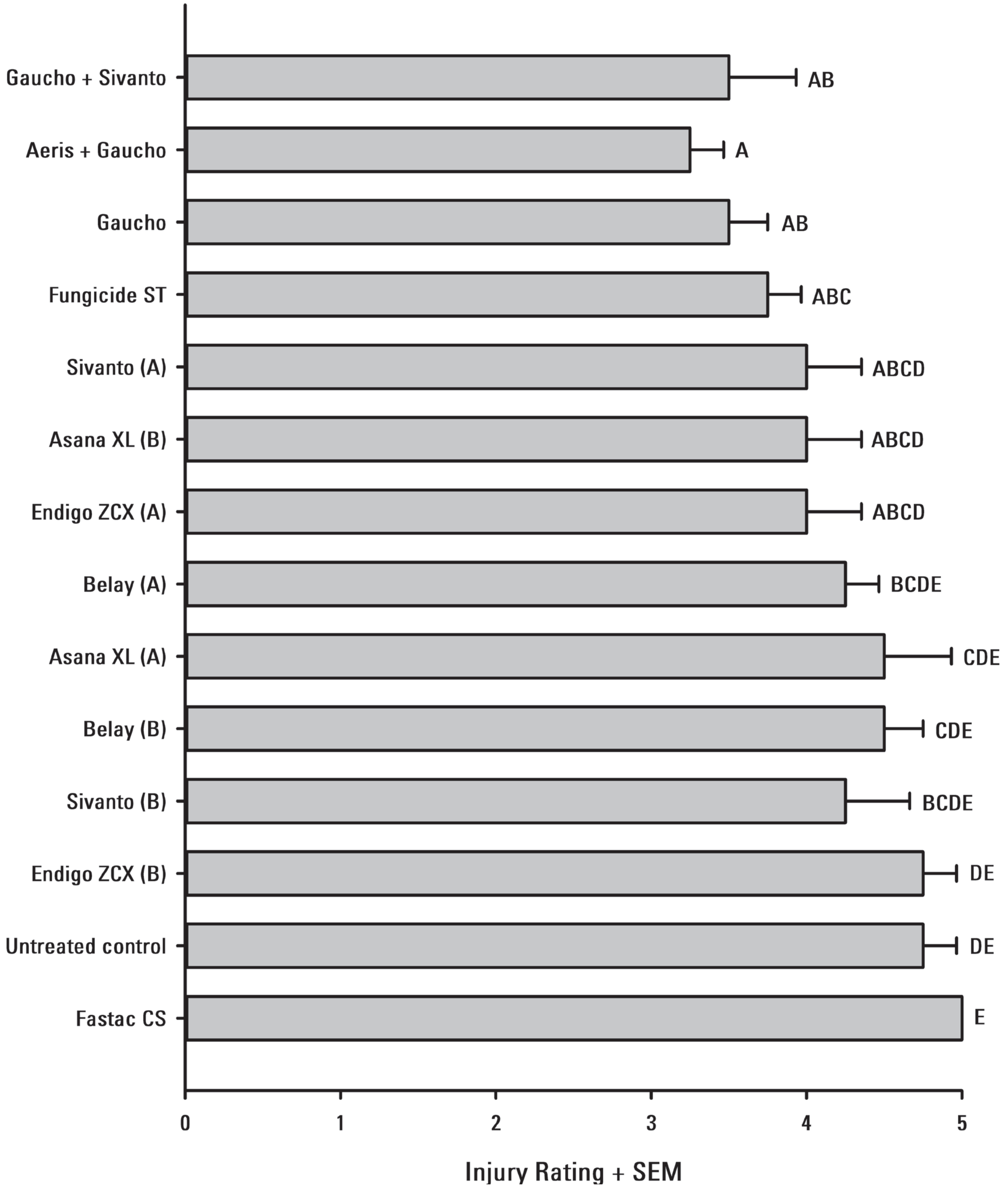


**Figure 8. Final injury rating for + standard error the mean for soybean gall midge treatments at the Griswold Farm in 2019. See Table 9 for a full list of treatments and rates. Means with a unique letter are significantly different at alpha = 0.05 (P=0.0230; F = 2.26; df = 13, 3).**

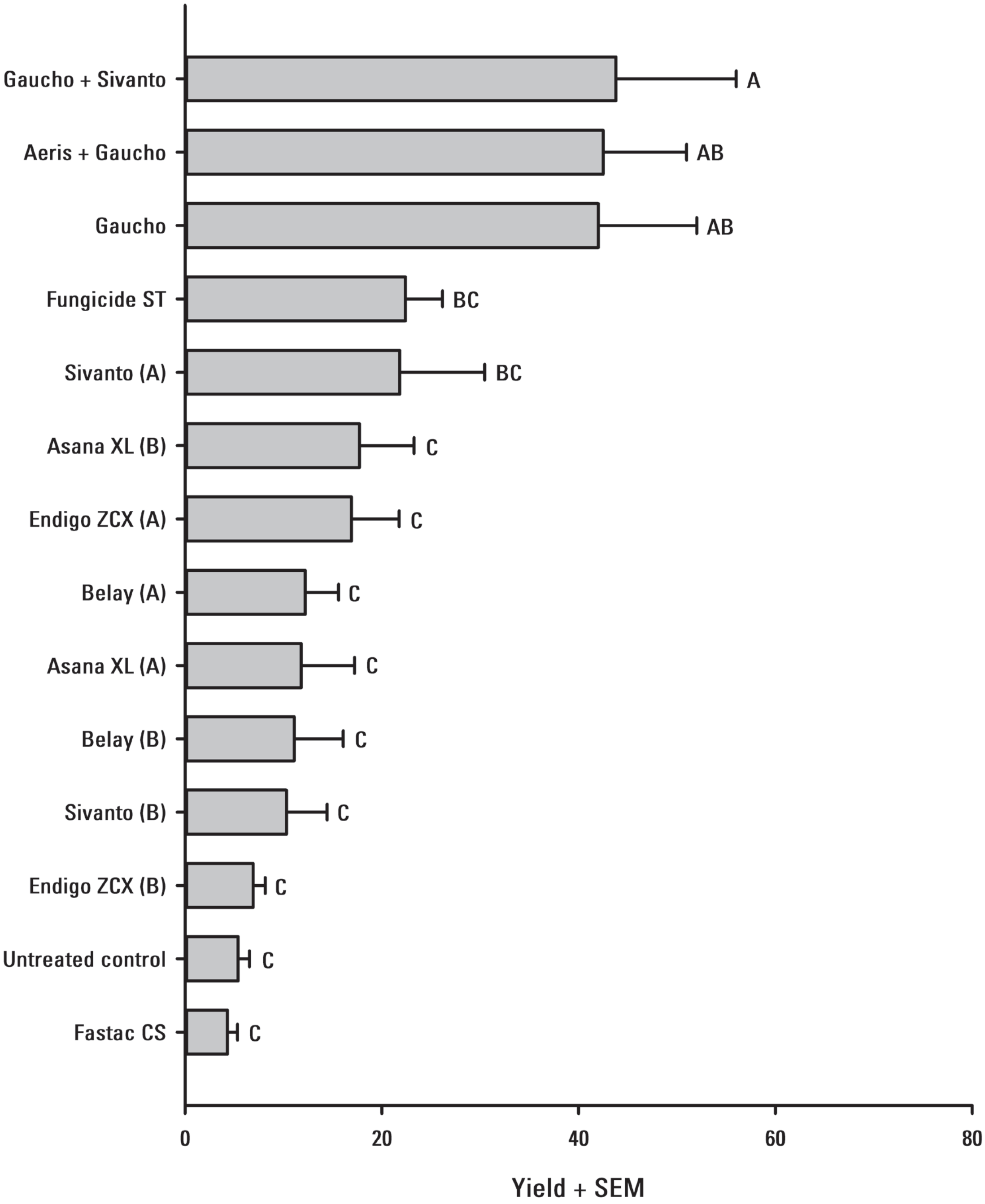


**Figure 9. Mean separation of yield + standard error the mean for soybean gall midge treatments at the Griswold Research Farm in 2019. See Table 9 for a full list of treatments and rates. Means with a unique letter are significantly different at alpha = 0.10 (P=0.0007; F = 3.67; df = 13, 3).**

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