Golden Harvest®

AGRONOMY IN ACTION

RESEARCH REVIEW 2023




INTRODUCTION

BRUCE BATTLES – Technical Agronomy Manager

Welcome to the 2023 Golden Harvest Agronomy In Action Research Review. This issue marks the fourth consecutive year of publishing a compilation of proprietary agronomic research trial results, along with other timely agronomic topics.

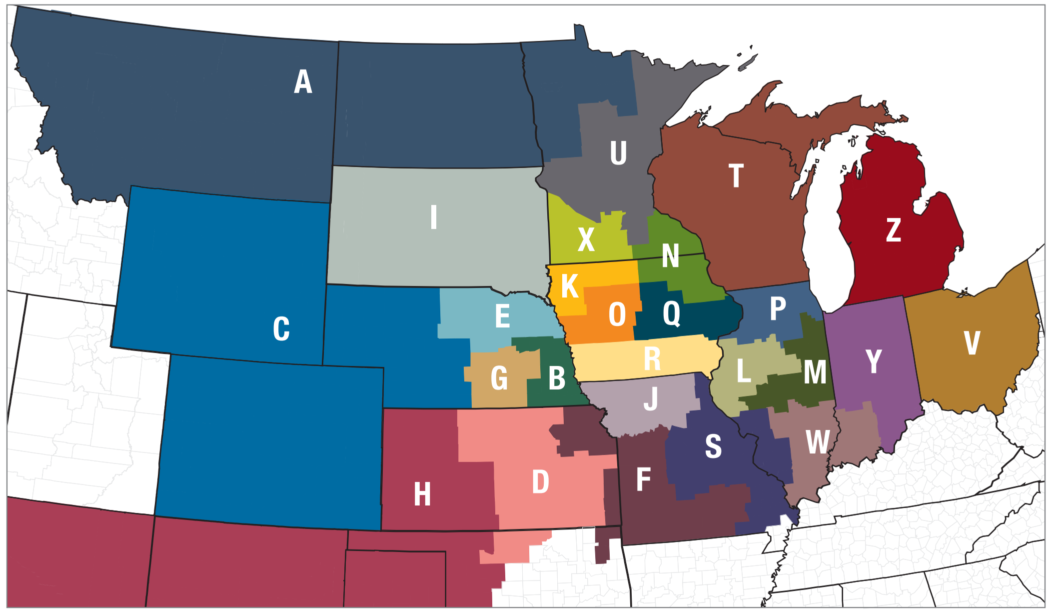
Although the Research Review has only been published in recent years, Golden Harvest has a long history of delivering timely agronomic information to its customers. With company roots dating back to the mid-1800s, the Golden Harvest brand draws on a rich heritage that has combined genetics, agronomy, and service to bring high-quality corn hybrids and soybean varieties to growers since its earliest days. What was initially known as "Agronomy Up Front" was formalized in 1984 with some of the first agronomic research trials by a seed company seeking to understand if its genetics responded differently to everyday management practices. In a time before herbicide-resistant traits existed, Golden Harvest set out with one of its first trials to characterize each hybrid for potential sensitivity to the many different postemergence herbicide programs commonly used. Over time, this proprietary agronomic research effort has transformed into what we now refer to as "Agronomy In Action."

AGRONOMY IN ACTION RESEARCH

There are limitations as to what you can afford to do on your own farm to evaluate new products or management practices. The rapid introduction of new hybrids, along with differences in how they respond to management practices, make it challenging to understand the best hybrid-specific management practices needed to maximize their true potential. Agronomic management information is readily available through university and other sources, but often lacks hybrid-specific results.

Golden Harvest Agronomy In Action Research is designed to help evaluate hybrid-specific responses to products and management practices before they get to your farm. Agronomy In Action trials compare how each hybrid uniquely responds to management factors, such as increasing seeding rates, foliar fungicides and enhancing fertility. Sound scientific approaches, such as replicating treatments within and across locations, are utilized to increase confidence in results. There are some questions that can be answered within a few trial locations and others that require more locations to account for environment. Agronomy In Action trials are conducted at nine Midwest locations, although some specific trials such as response to seeding rate may be conducted at an additional 60+ locations each year to take environment and weather into consideration.

There are lots of options when it comes to seed purchasing decisions, but at Golden Harvest we strongly believe success requires more than just good genetics. We are devoted to delivering genetics, agronomy, and service with every bag. We hope you find some helpful insights in this edition of the Research Review that you can apply to your own farm.



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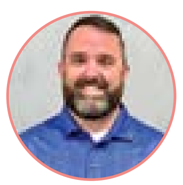
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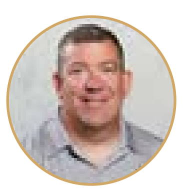
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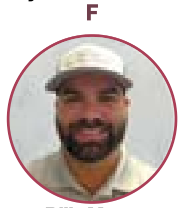
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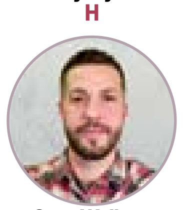
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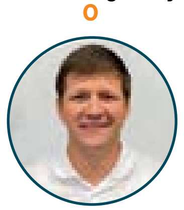
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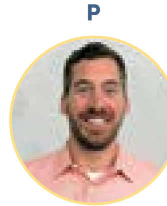
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MAIN MENU

CLICK ON A LINK BELOW TO JUMP TO THAT SECTION

Corn Management

Weather Effects

Corn Pest Management

Nutrient Management

Soybean Management

Scan the QR codes throughout to view related agronomic video content, web agronomy articles, and agronomic tools.

Agronomy In Action Research Trial Article

CORN MANAGEMENT
MAIN MENU

SOIL MOISTURE AND CORN SEEDING DEPTH

INSIGHTS

- Generally, 2-inch seeding depth for corn is optimal in most situations.
- Seeds should be planted in uniform soil moisture for even emergence.
- Increasing planting depth may be necessary to reach uniform moisture in dry soil conditions.

CORN SEEDING DEPTH

Generally, seeding corn at a depth of 2-inches is optimal in most situations for multiple reasons. Soil moisture and temperature is often most stable at 2-inches. There is adequate space for proper nodal root development to help anchor seedlings. A 2-inch depth is also typically below the concentrated chemical layer, diluting herbicides, fertilizers and other inputs before encountering the seed and newly developing roots.

However, environmental conditions, especially soil moisture, are the ultimate driving factor in determining optimal planting depth. It is important for all newly planted seeds to evenly imbibe moisture within the first 24 to 48 hours to ensure uniform emergence. Adequate soil moisture at seeding depth is needed to ensure rapid germination of the seed. Soil moisture must be spatially uniform in the seed trench for even germination and emergence.

There are multiple reasons for never planting corn shallower than 1.5-inches. Uptake of water and nutrients through the roots is reduced with shallow-planted corn. Shallow-planted corn can also develop rootless corn syndrome where young plants will fall over due to the lack of nodal root development in dry soil conditions. It is necessary to increase planting depth to reach uniform soil moisture under such conditions. It is possible in some cases, where seeding depth was sufficient, that being planted in dry loose soil means the soil will compact after hard rains. This leaves the seed at shallower depths than when planted. Planting too deep may delay germination due to low soil temperatures and increased vulnerability to soil crusting, disease and insect pests. For these reasons, planting depth recommendations are typically 2-inches or greater.

MEASURING SEEDING DEPTH POSTEMERGENCE

After emergence, planting depth can be easily determined by measuring the length of the mesocotyl (area between the seed and crown) and adding ¾ of an inch. The nodal root area, or crown, typically develops about ¾ of an inch beneath the soil surface regardless of planting depth (Figure 1).

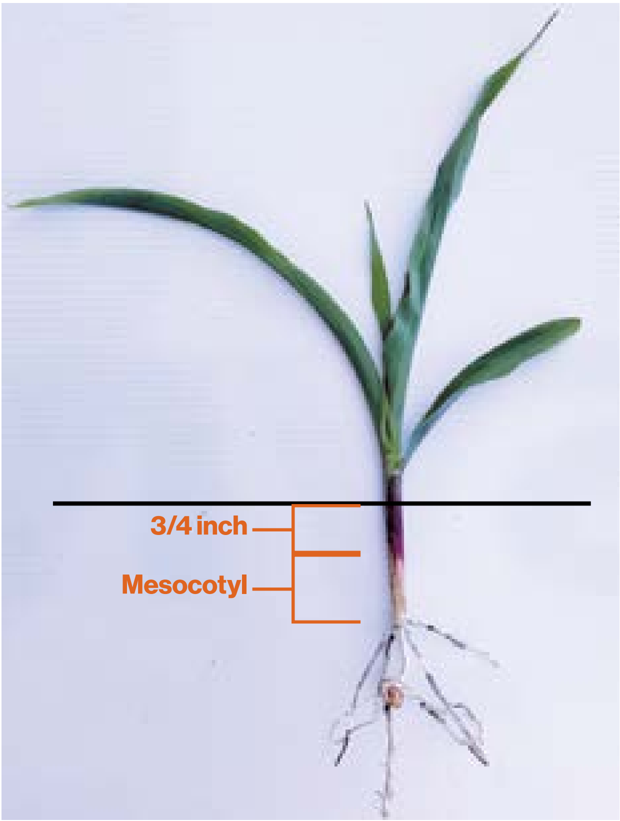
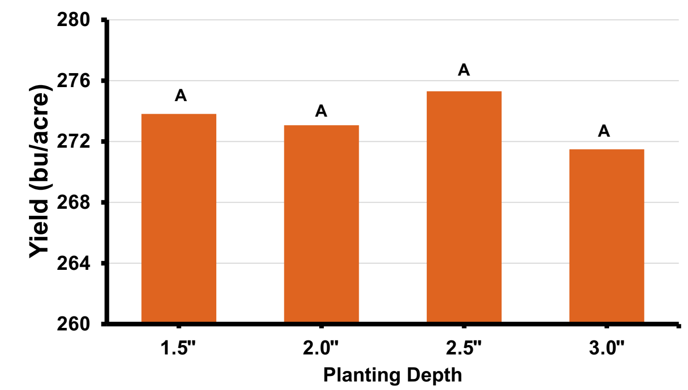
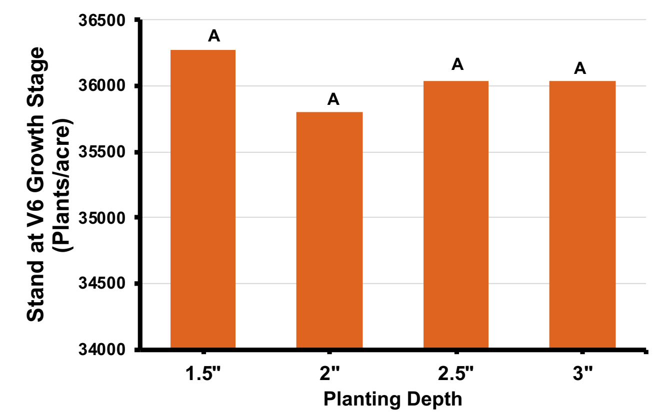


Figure 1. Adding 3/4" to the length of the mesocotyl is the seeding depth



Graph 1. Effect of planting depth on yield at Clinton, IL in 2022



Graph 2. Effect of planting depth on early-season stand at Clinton, IL in 2022

AGRONOMY IN ACTION RESEARCH TRIAL

A corn seeding depth study was conducted at Clinton, IL in 2022. Plots were planted at seed depths of 1.5 inches, 2.0 inches, 2.5 inches and 3.0 inches.

Clinton, IL experienced optimal soil moisture and temperature at planting and for much of the growing season. The only period of moisture stress was during the V8-V12 growth stages. Due to the ideal conditions at planting, emergence and early season growth, there was no yield difference between any of the four planting depths (Graph 1).

Early-season stand counts were taken and showed no significant difference in stand between seeding depths (Graph 2).

SUMMARY

Planting at depths 2-inches or greater has shown to maximize yield most consistently in university and ag industry research trials. Many producers target 1.5-inch planting depths, however slight changes in soil conditions and amount of residue on soil surface can quickly raise planting depths closer to the surface. Consistent seed depth starts with planter maintenance and soil preparation. Seed depth should be checked for each field. If soil conditions are variable for a given field, seed depth should be checked more often. Adjusting seed depth for the field characteristics is necessary for uniform emergence.

CORN MANAGEMENT
MAIN MENU

MAIN MENU

SIMPLIFYING REPLANT DECISIONS

INSIGHTS

- Remote sensing data collection with Golden Harvest and DroneDeploy software make stand assessment quicker and easier.
- The Golden Harvest® corn replant calculator helps when choosing between keeping a reduced stand and replanting at specified dates.
- There may not be a need to switch to earlier relative maturity (RM) hybrids with April and May replant dates.

Less-than-optimum final stands or variable emergence of corn can greatly influence yield potential. Replanting at a later calendar date can also have reduced yield potential and additional associated costs. Replant management decisions should be based on good information. Utilize these steps when considering replanting:

1. **Determine Existing Stand**
   To estimate the stand, count the number of healthy plants in a length of row that equals 1/1,000th of an acre (Table 1) and multiply the number of plants by 1,000. Take several counts throughout the field to get an accurate final stand. If stand loss is occurring in distinct zones, focus stand count measurements only in those areas of replant consideration. A newer alternative to manually scouting fields is to leverage remote sensing to quickly collect field data and identify areas where stand establishment was a problem. Golden Harvest and DroneDeploy have partnered to deliver real-time estimates of established stands using drone imagery collected by local Golden Harvest agronomists. DroneDeploy software can accurately estimate the number of plants and skips per acre anytime between the V2-V5 corn and soybean growth stages and generate customized reports (Figure 1) to determine approximate stand counts and variation in plant establishment across a field.

2. **Estimate Replant Yield Potential and Compare to Potential of Existing Stand**
   Previous Golden Harvest planting date trials have been used to estimate the percent yield potential of delayed planting dates compared to retaining a reduced stand from an earlier planting date (Table 2). Additional factors contribute to a replant decision, such as crop insurance, the cost of replant seed, seed availability, potential pest problems, nitrogen program, cost arising from higher grain moisture at harvest and more. The cause of the original stand loss is also important. If the poor stand is due to fertilizer injury, herbicide injury, disease or insect infestation, there is potential for the replanted crop to also be affected. To simplify decisions, Golden Harvest has created a replant calculator that compares all input costs, as well as yield loss assumptions, using state university data specific to local areas.

   GOLDEN HARVEST REPLANT CALCULATOR

3. **Decide if Relative Maturity should be Reduced for Replant**
   Once the decision to replant corn has been made, selecting the maturity of the new hybrid is important. Choose a hybrid that can reach maturity prior to the first frost. Although the growing season has been shortened in replant situations, hybrids compensate for planting date and will reach black layer within fewer growing degree units than if planted earlier. There may not be a need to switch to earlier maturing hybrids since the increased yield potential of a fuller season hybrid typically outweighs costs of drying grain. If grain drying is not an option, slight reductions in RM may be advisable. Based on drying costs, expected yield and corn prices, suggestions based on Golden Harvest Agronomy Research trials are:
   - Plant full-season hybrids adapted for a given area until the last week in May.
   - Change to a mid-season hybrid (4-7 RM earlier than full-season hybrid) the last week in May.
   - Never switch to hybrids 8-11 RM earlier than adapted full-season hybrid unless drying grain is not an option.

Row Spacing	Length of Row
Inches	Feet Inches
15	34' 10"
20	26' 1"
22	23' 10"
30	17' 5"
36	14' 6"
38	13' 10"
40	13' 1"

Table 1. Length of row equivalent to 1/1,000th of an acre at various row spacings

Percent Yield Potential of Corn by Emerged Stand and Planting Date Northern Corn Belt Trial Response / South Corn Belt Trial Response					
	Planting Date				
Established Stand	May 1 and Earlier	May 10	May 20	May 30	June 10
≥ 32,000	100 / 100	96 / 98	85 / 92	77 / 86	69 / 80
28,000	97 / 97	93 / 95	82 / 89	75 / 83	67 / 78
22,000	90 / 90	86 / 88	77 / 83	69 / 77	62 / 72
16,000	82 / 82	79 / 80	70 / 75	63 / 71	57 / 65
10,000	70 / 70	67 / 69	60 / 64	54 / 60	48 / 56

* Results best indicate performance in yield environments of 150 bu/ac or more with uniform seed spacing

Table 2. Percent yield potential

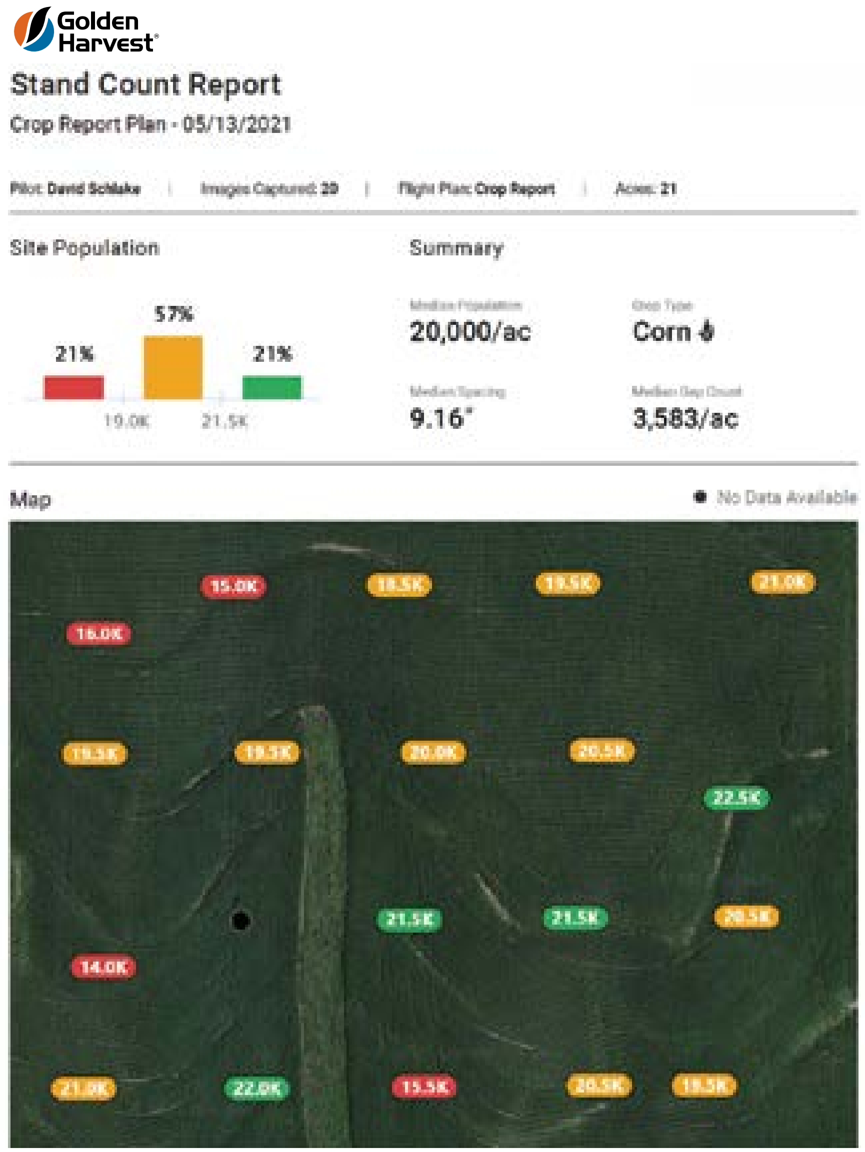


Figure 1. Example stand count report utilizing drone technology

SEEDING RATE MANAGEMENT TO OPTIMIZE CORN YIELDS

INSIGHTS

- Determining the proper seeding rate based on field potential and hybrid is an important first step to maximizing corn yield.
- Hybrid seeding rate response data can help fine-tune seeding rate recommendations.

Yield potential of corn hybrids continue to increase yearly with introduction of new genetics. It is easy to credit these gains entirely to breeding efforts, however the change of management practices such as seeding rates have also played a critical role in yield gains. Average seeding rates have increased by over 24% in the last 30 years, although this would not have been possible without advances in stress tolerance through breeding. Due to this continued trend and the inherent differences in how hybrids respond to seeding rate (Figure 1), the Golden Harvest® Agronomy In Action research team has conducted trials (Figure 2) since 1992 to provide hybrid specific guidance on seeding rates. Determining the best seeding rate for a field or zones within a field is not a simple process and requires understanding of multiple factors that drive final outcome.

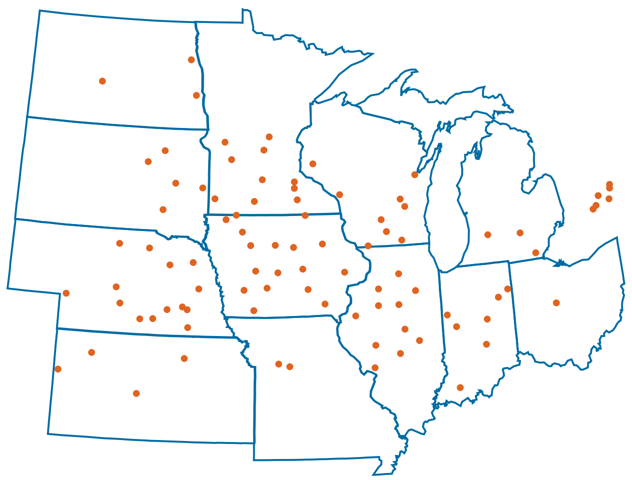
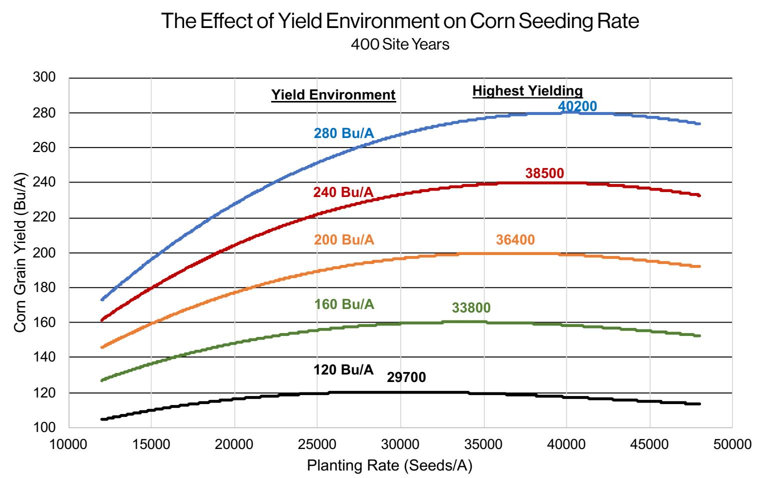


Figure 2. 2022 replicated corn Seeding rate trial sites



Graph 1. Yield environment influence on seeding rate

POPULATION RESPONSE FACTORS

1. **Yield Environment**
   Optimum seeding rate increases as overall field yield potential increases. Penalty associated with incorrect seeding rate selection increases with yield environments (Graph 1).

2. **Hybrid Response**
   Yield response to increasing or decreasing seeding rates differs considerably among hybrids (Figure 1). Golden Harvest evaluates every hybrid's seeding response starting one year prior to commercialization to help fine-tune field recommendations by yield environments.

3. **Economic Factors**
   The optimum seeding rate for maximizing return will always be slightly lower than the highest yielding seeding rate due to seed cost. The optimum economic seeding rate will also go up or down with commodity prices. Table 1 compares several seeding rates and commodity prices in various yield environments.

DETERMINING OPTIMUM SEEDING RATES

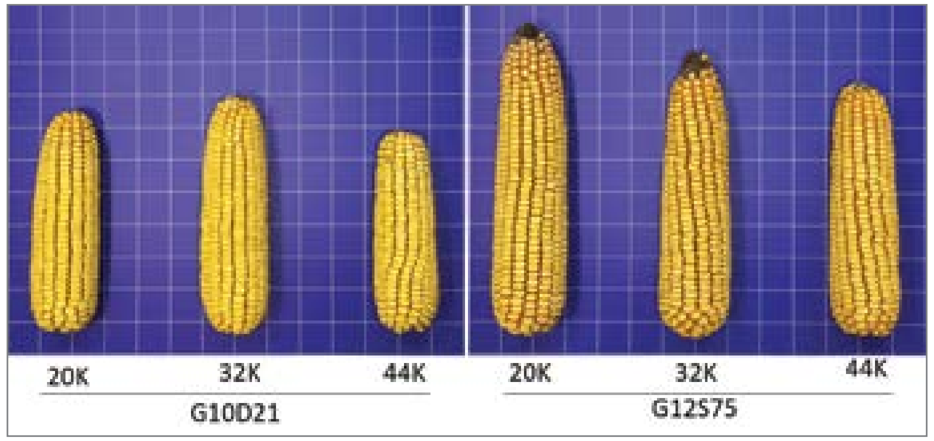


Figure 1. Hybrid differences in response to changing seeding rates

1. Table 1 estimates the optimum seeding rate for anticipated yield potential and grain pricing. When estimating yield environment, consider the proven historical yield of the field across multiple years.
   Example: A 200 bu/A yield environment and $4.00/bu grain price = 32,300 seeds/A optimum seeding rate.
2. Work with a local Golden Harvest® Seed Advisor to adjust seeding rate up or down from optimum found in Table 1 for specific hybrids based on Golden Harvest multi-site and multi-year seeding rate trial results.
3. Consider individual hybrid root and stalk strength scores to determine if the hybrid will have suitable agronomic characteristics to support increased seeding rates (lower scores indicate more suitable).
4. For more insight, use the Golden Harvest Corn Seeding Rate Selector tool to help estimate the most economical seeding rate for individual hybrids and yield environments.

GOLDEN HARVEST CORN SEEDING RATE SELECTOR

CREATING VARIABLE RATE PRESCRIPTIONS

Most planters now offer a way to vary seeding rates to specific zones within a field. Many sources of data are available to help interpret zone productivity such as: fertility, drainage, topography, NDVI imagery, soil type and yield maps. Multiple years of individual field yield data will best predict high and low yield zones. Using more than one year of data helps to better account for outlier years caused by drought or flood prone areas. When yield data isn't available, soil productivity data can be useful in predicting areas of the field with different potential. Small increases and decreases in seeding rates with higher and lower yield zones will typically help maximize returns on investment potential, but always take individual hybrid characteristics into consideration.

TIPS FOR DEVELOPING A FIELD PRESCRIPTION

- ✔ More years of data for creating productivity zones is better.
- ✔ Highly variable fields will show greater responses to variable seeding rates.
- ✔ Creating validation areas with 3 or more seeding rates within the field can confirm prescription accuracy.

Talk to your Golden Harvest Seed Advisor about utilizing E-Luminate® (a digital tool running a proprietary product placement algorithm) to assist you in developing customized prescriptions for your fields.

Yield Environment (bu/A)	Highest Yielding Seeding Rate (seeds/A)	Optimal Seeding Rate (seeds/A) by Commodity Price ($/Bu) (Seed cost = $200/80K unit)		
		$3.00	$3.50	$4.00
280	**40200**	36600	37100	37500
240	**38500**	34100	34700	35100
200	**36400**	31000	31700	32300
160	**33800**	26900	27700	28400
120	**29700**	20900	21900	22700

Table 1. Influence of commodity price and yield environment on selecting seeding rates

MANAGING HIGHER CORN SEEDING RATES WITH NARROWER ROW SPACINGS

INSIGHTS

- Like seeding rate, row spacing responses are dependent on the environment.
- Positive yield responses to narrower row spacings are most consistent when seeding rates are above typical 30-inch row seeding rates for a given environment.
- Hybrids respond differently to changes in row spacing so selecting a hybrid that performs well in narrower rows is key.

Corn grain yield is the product of the number of plants per acre, kernels per plant and weight per kernel. Because kernels per plant and weight per kernel are primarily affected by environmental conditions after initial agronomic management factors are implemented in modern commercial field corn, the yield component factor most under manual control is seeding rate.

Currently, the average corn seeding rate in the U.S. is just under 32,000 seeds/A and has increased by an average of 400 seeds/A/year since the 1960s. As this trend continues, the average U.S. corn seeding rate will reach 38,000 seeds/A in 15 years and 44,000 seeds/A in 30 years. These higher seeding rates reduce the plant-to-plant spacing within the row and the intensifying crowding stress may become yield-limiting. Narrower row spacings can be used to increase plant-toplant spacing within a row to reduce crowding and subsequently reduce competition among individual plants, allowing the crop to better utilize available light, water and nutrients.

Currently, the vast majority of corn is planted in 30-inch row spacings, with narrow rows generally defined as any row spacing or configuration less than 30-inches. Planting corn in a 15-inch row creates twice as much distance between plants within a row compared to 30-inch row spacings at a given seeding rate. For example, at a seeding rate of 38,000 seeds/A, there is 11 inches between plants when planting in 15-inch row spacings compared to only 5.5 inches between plants in 30-inch row spacings.

PREVIOUS FINDINGS

In 2019, The Golden Harvest® Agronomy In Action research team evaluated more than 46 hybrids in 30-inch and 20-inch row spacings at various seeding rates across 5 locations. Three of the five locations had a positive yield response to 20-inch rows, one location had no response, and one location had a negative response. On average, across all locations, seeding rates and hybrids there was a 2 bu/A yield advantage to planting 20-inch rows compared to 30-inch rows.

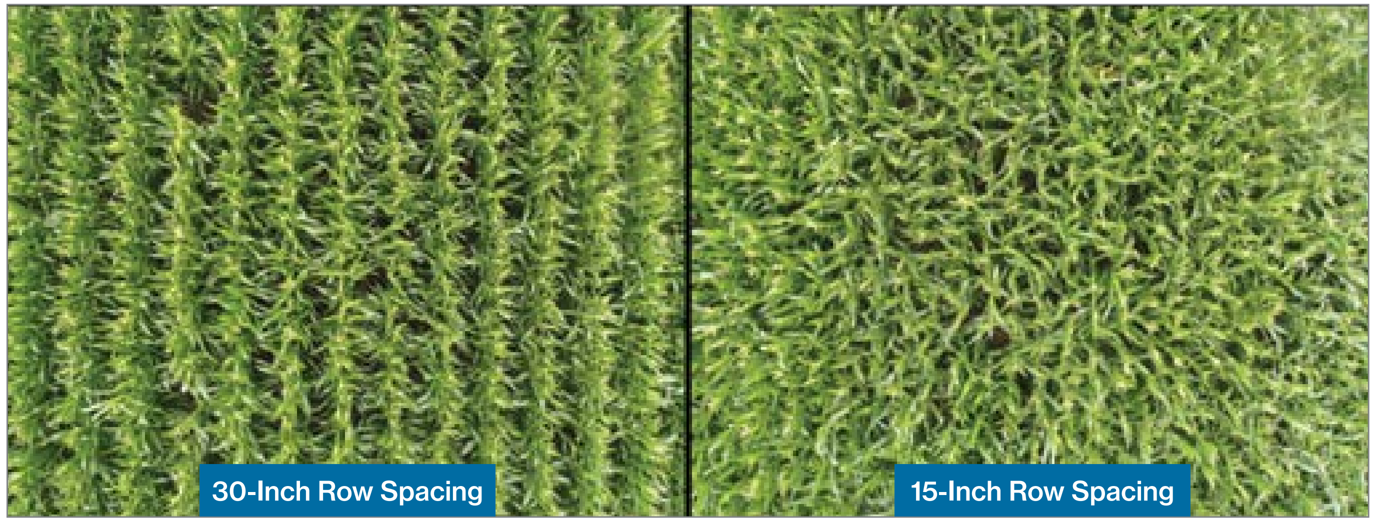


Figure 1. Aerial photo of corn planted in 30-inch and 15-inch row spacings within 2020 rows spacing trials

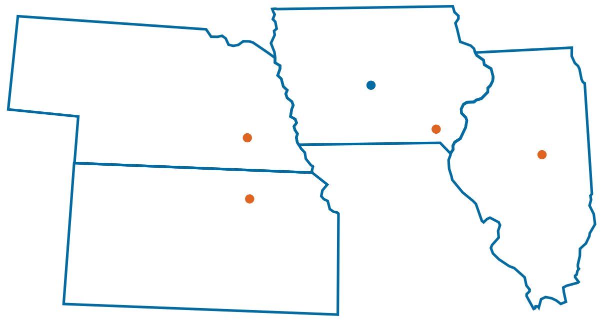


Figure 2. Row spacing evaluation trial locations in 2020, locations lost to the derecho are in blue

In general, 20-inch rows tended to perform better at seeding rates greater than 35,000 seeds/A and less than 50,000 seeds/A. When populations were below 35,000 seeds/A, the 30-inch row spacing tended to yield greater. At 50,000 seeds/A or greater there was little yield difference between the row spacings.

Hybrid responses to 20-inch row spacings were variable across locations. Some hybrids tended to have a positive yield response to 20-inch rows while other hybrids had a negative yield response.

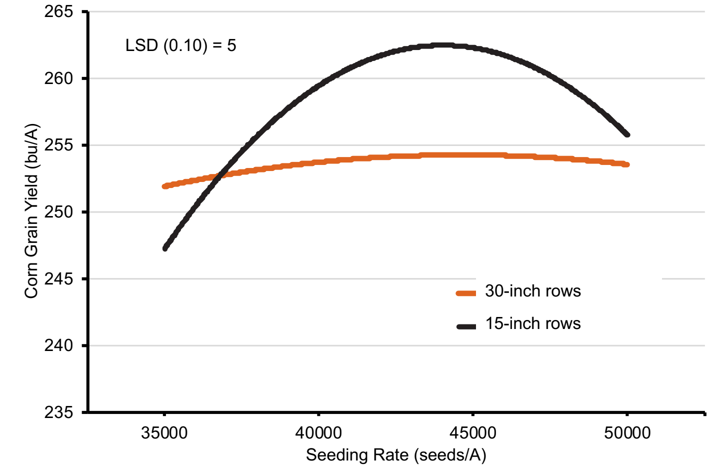
2020 NARROW ROW CORN TRIALS

In 2020, four seeding rates ranging from 35,000 to 50,000 seeds/A were evaluated in 30-inch and 15-inch rows across seven hybrids (Figure 1). These trials were established at Clay Center, Kansas, Clinton, Illinois, Fairfield, Iowa, Seward, Nebraska, and Slater, Iowa (Figure 2). Due to the late season derecho wind events, the Slater location was removed from any data analysis.

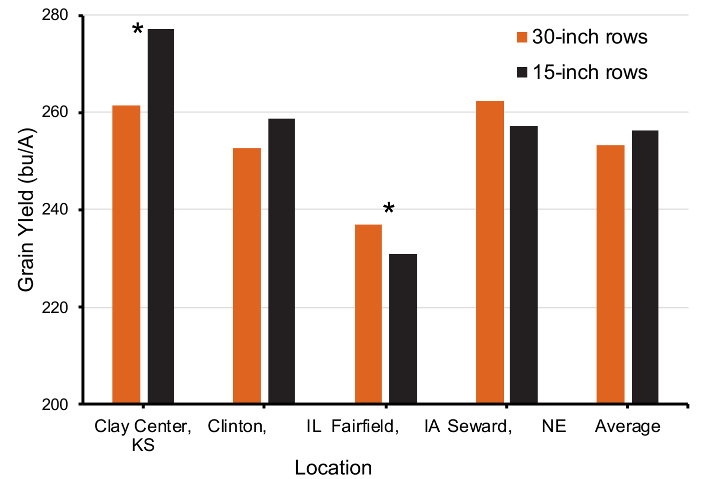
EFFECT OF SEEDING RATE AND ROW SPACING ON GRAIN YIELD

When averaged across all locations and hybrids, there was a significant interaction between row spacing and seeding rate. At the lowest seeding rate of 35,000 seeds/A, planting 30-inch rows yielded 5 bu/A greater than planting 15-inch rows (Graph 1). Lower seeding rates in narrower rows increased in-row plant spacing, likely resulting in a loss of narrow row efficiency for capturing solar radiation. However, 15-inch rows produced an 8 bu/A yield advantage at 40,000 seeds/A and a 5 bu/A yield advantage at 44,000 seeds/A compared to 30-inch row spacings (Graph 1). Interestingly, the yield potential of plants grown in a 15-inch row decreased dramatically at 50,000 seeds/A, whereas plants in a 30-inch row were not as negatively impacted, resulting in similar yields between row spacings at this seeding rate. Likely, plants experienced enough in-row competition that changes in the between-row environment were not meaningful.

A recent study found similar results where the greatest yield advantage of narrower row was in the seeding rate range between 44,000 and 50,000 seeds/A.[1] They

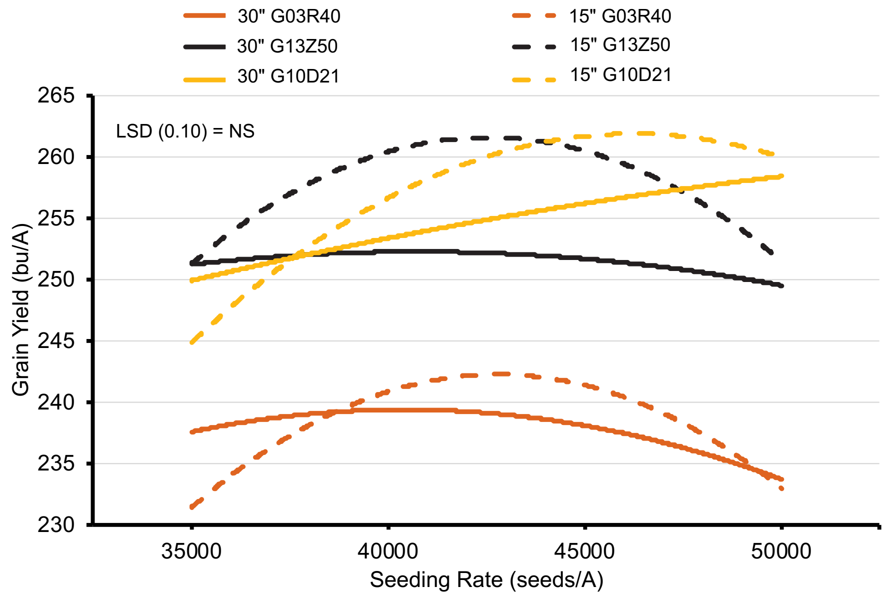


Graph 1. Effect of row spacing and seeding rate on grain yield averaged across seven hybrids and four locations in 2020



*significant difference between row spacings at α=0.10

Graph 2. Effect of row spacing on grain yield at four locations averaged across four seeding rates and seven hybrids in 2020 observed that as seed rate increased, plants focused their energy and resources to producing above-ground biomass at the expense of below-ground biomass. For every additional 6,000 plants/A, the size of the root system decreased 15-18%. However, when switching from a 30-inch row to a 20-inch row, the better plant-to-plant spacing resulted in a 22% increase in root mass. They concluded that narrower row spacings helped mitigate crowding stress at greater seeding rates by promoting phenotypic changes that consequently led to greater yields.



Graph 3. Yield response of hybrids G03R40, G13Z50 and G10D21 to seeding rate and row spacing

There were differences in response to row spacing for each location. Yield response to 15-inch rows ranged from -5 bu/A to 16 bu/A at 4 locations (Graph 2). Two out of the four locations had a positive yield response to the narrower row spacing while the other two locations showed a negative yield response.

The significant interaction between location and row spacing is not surprising, given the typical interaction between location and seeding rate. Both row spacing and seeding rate change the spatial arrangement of plants in a field, which has a major impact on the ability of plants to capture sunlight and acquire nutrients and water. In addition, it effects the movement of air through the canopy which can influence disease development and canopy temperature. The degree of impact on grain yield from these plant spatial arrangement effects depends on the environment.

HYBRID RESPONSE TO NARROWER ROWS AND SEEDING RATE

Hybrids responded differently to row spacing and seeding rate. In a 30-inch row, hybrid G03R40-DV had no yield response to seeding rate until rates exceeded 45,000 seeds/A when yield began to decrease. Alternatively, G03R40-DV responded positively to increased seeding rates in a 15-inch row maximizing grain yield at rates between 40,000 – 45,000 seeds/A. There was little to no yield difference between planting G03R40-DV in 15-inch rows compared to 30-inch rows across the different seeding rates. Hybrid G13Z50-DV showed a similar response to seeding rate. However, the yield response to narrower rows was much greater (Figure 3 and Graph 3). When planted in a 15-inch row compared to a 30-inch row, G13Z50-DV yielded 8 and 9 bu/A more at seeding rates of 40,000 and 45,000 seeds/A, respectively. Hybrid G10D21-3330 was much more responsive to higher seeding rates than the other hybrids in both a 30-inch and 15-inch row spacing (Figure 4 and Graph 3). G10D21-3330 was also responsive to narrower rows at seeding rates of 40,000 and 45,000 seeds/A yielding 5 bu/A greater on average.

Figure 3. Ear size of hybrid G13Z50-5222 in response to seeding rate and row spacing

Figure 4. Ear size of hybrid G10D21-3330 in response to seeding rate and row spacing

The difference in response between these hybrids demonstrates the importance of selecting the right hybrids to match the management system. Researchers also found that hybrids respond differently to seeding rate and narrower row spacings, attributing the differences to the inherently distinct phenotypic traits of the hybrids.[2]

CONSIDERATIONS WHEN PLANTING IN NARROWER ROWS

When planting in narrower rows, it is important to select a hybrid that is responsive to higher seeding rates and narrower rows. A hybrid with excellent agronomic characteristics, such as good stalk strength, standability and a solid root system is beneficial in these more intensive cropping systems.

There tends to be a more consistent response to narrower rows at increased seeding rates for the given environment. For example, in these environments the average seeding rate is around 35,000 seeds/A in a 30-inch row. Switching to 15-inch rows while keeping the same seeding rate resulted in a yield decrease. However, by increasing the seeding rate to 40,000 seeds/A in a 15-inch row there was a yield increase of 8 bu/A compared to the standard practice of planting 35,000 seeds/A in a 30-inch row. Increased seeding rates when planting in narrower rows can be adjusted accordingly based on the typical seeding rates in 30-inch rows for the given environment and hybrid.

At greater seeding rates, crop management becomes even more important. Adequate fertility is critical to setting a higher potential and foliar protection is needed to maintain that yield potential throughout the growing season in these more intensive cropping systems.

EXPLORING HYBRID CORN SEED SIZE ON GENETIC YIELD POTENTIAL

INSIGHTS

- Hybrid corn seed shape and size vary with location on the cob.
- Trial results found that seed size did not influence genetic yield potential of two hybrids.
- Planter adjustment and proper planting conditions are critical for maximizing seed genetic potential.

INTRODUCTION

Because of the architecture of an ear of corn, individual kernel shape (round vs. flat) and size (Figure 1) can vary based on physical location on the cob (Figure 2). Hybrid seed corn is separated and bagged according to general shape and size classifications to provide the most consistent seed size and allow producers to better match planter capabilities to specific seed size. Both the seed production field environment and the genetic differences can greatly influence the portion of seed falling into a specific seed size. Due to these uncontrollable factors, a farmer's first choice in seed size may not always be available. As a result, farmers often want to understand if seed size can affect germination, emergence, seedling vigor and, most importantly, yield potential. While various screen sizes can separate seed into designated sizes, there are still small variations of seed size and shape within each category. As a result of customers wanting to know if the within-lot seed size variance impacts yield, Agronomy in Action Research trials were established to better understand any potential differences.

Figure 1. Seed size examples of large flats (left) small flats (middle) and large rounds (right)

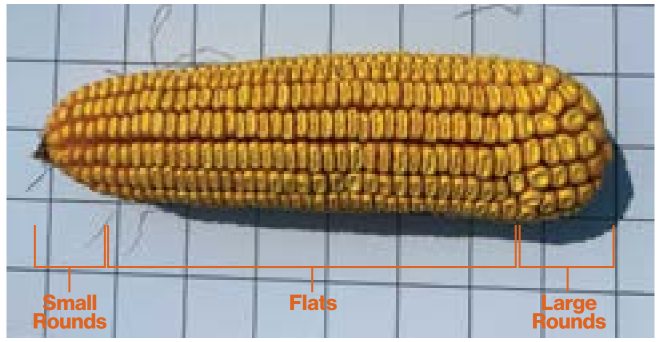


Figure 2. Seed shape and size on a corn ear

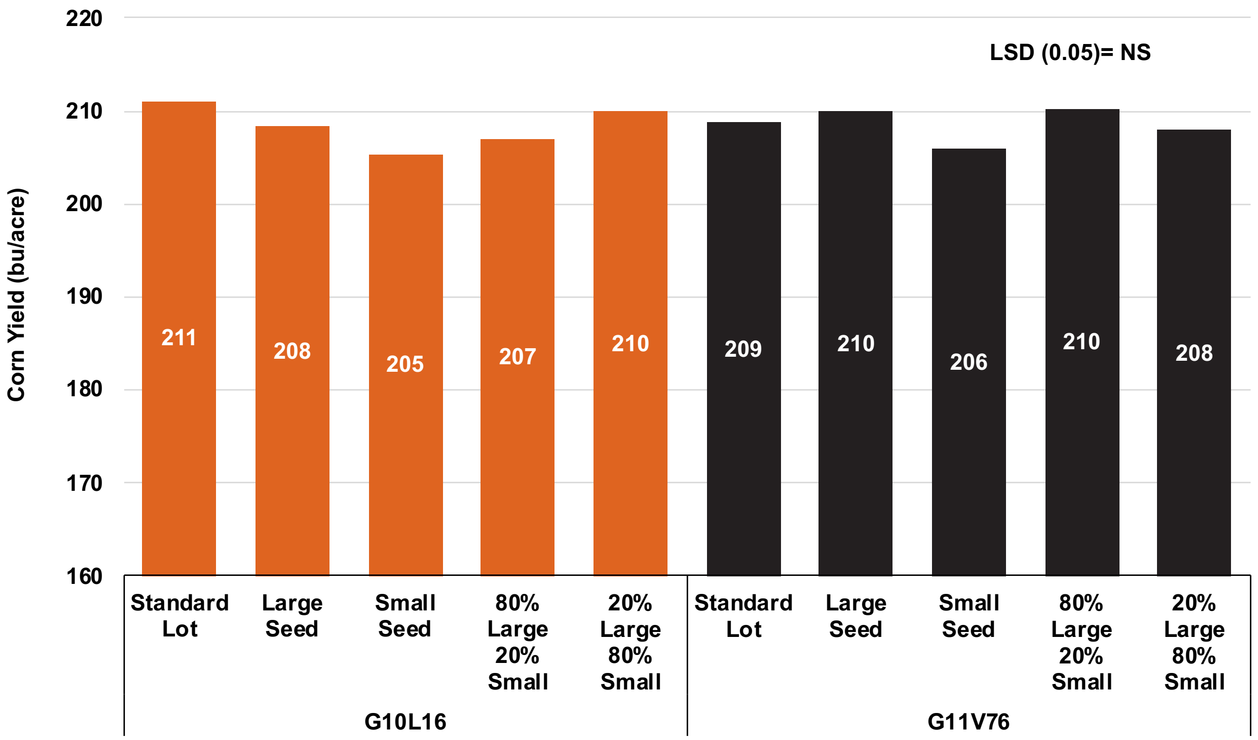
TRIAL DETAILS

To test for genetic yield potential differences of seed size within a seed lot, two hybrids, G10L16 and G11V76, were tested in several seed size combinations at the Waterloo, NE, location. A single lot number of each hybrid was selected, and hand sorted into overall large versus small seed. Refuge seed was discarded. The two sorted seed sizes were blended at specific ratios to create the following treatments:

1. Original seed lot prior to sorting
2. 100% large kernels from lot
3. 100% small kernels from lot
4. 80% large and 20% small
5. 20% large and 80% small

TRIAL RESULTS

No notable differences in emergence rate, vigor or final stands were observed in this trial (data not shown). Seed size had no significant effect on genetic yield potential for either hybrid (Graph 1). Specifically, for G10L16, grouping smaller or larger seeds from within the lot did not yield any more than the original lot mixture as it came from the production facility. For G11V76, most individual seed size groupings yielded within + or – one bushel of the original lot. The slightly lower yielding small seed size of G11V76 was not statistically different and was most likely the result of natural field variability. These yield results align with previous university trials that found as long as optimal populations are established, seed size does not influence yield.[1,4,5,6] Previous research did not show differences in germination across seed sizes[1,2,3] although other studies did show that smaller seed can germinate faster in dry soil due to less water needed to initiate germination.[5]



Graph 1. Effect of corn seed size on grain yield in two hybrids at Waterloo, NE

HYBRID CONSIDERATIONS

When corn seed is planted at optimal soil temperatures, seed size has very minimal to no impact on germination. Under very cold soil conditions, germination may slightly vary among seed sizes due to their physiological composition, because smaller seeds have less energy reserves than larger ones. However, these visual differences, if they do exist, are short-term and do not affect genetic yield potential.

To maximize genetic yield potential of corn seed:

- Purchase high-quality seed. Refer to the seed tag for the germination score. This indicates the minimum germination percentage under ideal planting conditions.
- Planting date should be dictated by soil temperature, not calendar date.
- Adjust planter settings to match seed size. When unadjusted, risk of poor singulation increases.
- Starter fertilizer, especially in early-planted or no-till fields, can counterbalance temperature-induced fertility deficiencies.

SUMMARY

Hybrid corn seed size does not impact genetic yield potential. Matching planter settings to seed size and shape should not be overlooked, as unadjusted settings can result in uneven planting depth and/or poor singulation. Purchasing high-quality seed, indicated by the germination score, and proper planting dates dictated by soil temperature are the first foundational steps in maximizing genetic yield potential.

CORN MANAGEMENT
MAIN MENU

RYE COVER CROP TERMINATION TIMING AND NITROGEN APPLICATION EFFECT ON CORN YIELD

INSIGHTS

- Delaying cover crop termination timing close to planting can significantly reduce corn yield potential.
- Well-placed nitrogen (N) applied with a planter may minimize yield loss caused by cereal rye.
- Terminating cereal rye early reduces total biomass and the C:N ratio, lessening the amount of N immobilization and associated yield effect.

INTRODUCTION

Cover crops have grown in popularity in recent years. One of the most common cover crop choices is cereal rye as it can be easily established in the fall, overwinters well, and grows vigorously in early spring. Benefits of planting cover crops can vary with geography and farming practices. The fibrous roots of rye can reduce soil erosion, improve soil structure and increase soil permeability. These combined benefits can help reduce field runoff of pesticides and nutrients, such as phosphorous that are tightly bound to soil particles, as well as increase in-season soil moisture availability. Another benefit to using cover crops is their ability to scavenge nitrogen and other nutrients at a time when a crop is normally not present. Nutrients taken up by the cover crop are protected from loss while later decomposing into organic matter for uptake by the following crop.

CHALLENGES TO COVER CROP ESTABLISHMENT

Despite the many benefits of cover crops, there are challenges that come with adapting cover crops into a crop rotation.

- **Narrow establishment window:** Cover crop seeding date can present a challenge, especially when trying to establish after crops such as corn and soybeans that may not be harvested until November. Seeding with an airplane or modified high-clearance sprayer may allow for earlier cover crop establishment before cash crops are harvested, giving them a better chance to have significant growth before a fall frost.

Figure 1. Corn planted into cereal rye residue terminated two weeks prior to planting (right) and the day of planting (left)

- **Reduced soil moisture:** Drought-prone soils could be dried out further by rye moisture uptake.
- **Increased pest pressure:** Delaying termination of rye until after planting can result in a "green bridge" for disease and insects to relocate from cover crop to newly seeded crop after die-back begins. *Pythium*, wheat stem maggot, black cutworm and armyworm have been observed to cause worse crop damage after cover crop termination.
- **Reduced nitrogen availability:** Corn planted directly into green rye can often have a yellow, stunted appearance when emerging. It is believed that previously applied nitrogen may be tied up in the rye cover crop and not available until the rye dies and begins to be mineralized back into the soil.
- **Allelopathy:** Allelopathic chemicals are released by rye and are known to inhibit germination and early growth of many smaller-seeded plants. Terminated rye begins to degrade and release allelopathic chemicals into the upper soil surface. Field effects of allelopathic chemicals on large-seeded crops like corn and the impact on germination and early growth are not well understood. Lab studies have indicated a possibility of reduced early growth or germination; therefore, it is often recommended to terminate rye at least two weeks before planting.
- **Hybrid sensitivity:** There is not a great understanding as to why corn planted into rye will sometimes have a negative yield impact. The effect of rye mulch on soil warming and drying, in combination with other factors such as nitrogen tie-up and soil pathogens, likely all interact to potentially create a negative response. Due to this, understanding the reason for hybrid differences is even more challenging.

2022 COVER CROP MANAGEMENT TRIAL

Cereal rye cover crop trials were initiated at Clinton, IL, to further investigate the effects of timing rye termination on the following corn crop. Rye was broadcast seeded following soybean harvest in the fall of 2021. Areas with no cover crop were maintained to compare the effect of various cover crop termination timings to no cover crop. The following spring, cereal rye blocks were either terminated two weeks prior to planting or on the day of planting (green planting) (Figure 1). Each of the trial treatments (no cover, early termination, termination at planting) was planted with six corn hybrids to better understand individual hybrid response to rye cover crop. At planting, 30 lbs of nitrogen was applied as UAN in a 2x2x2 placement to half of the three trial treatments to better understand how cereal rye residue affected nitrogen availability. Early growth differences and stand counts were taken for hybrids across all treatments. The trial was harvested with a research combine and grain weight and moisture recorded for all plots.

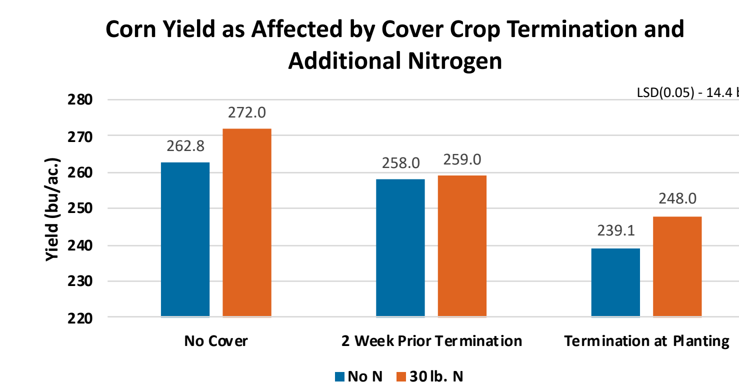
TRIAL RESULTS

Stand establishment was more challenging when delaying termination until the day of planting (4.8% fewer plants). Corn establishment when rye was terminated two weeks

Figure 2. No cover (left), two-week prior termination (center), and termination at planting (right) growth and vigor differences

prior to planting was similar to when no cover crop was present. Corn growth at the V5 stage appeared identical between the no cover crop and early termination timing but was significantly reduced when the termination timing was delayed until the day of planting (Figure 2).

Cereal rye cover crops generally reduced yield potential, although they were more penalizing when termination was delayed until time of corn planting. Terminating cereal rye two weeks prior or on the day of planting reduced yields by 13 and 24 bu/ac respectively within treatments receiving an extra 30 lbs N/acre (Graph 1). Yield loss was most likely the result of a combination of slightly reduced plant stands, reduced nitrogen availability and corn plant competition with rye biomass. Nitrogen was likely a limiting factor independent of cover crop presence as indicated by the small response to nitrogen when no cover crop was present (Graph 1). The additional 30 lbs N/ac applied with the planter also increased early plant growth when termination was delayed until time of planting but resulted in a smaller overall yield increase and did not recover the full yield potential (Graph 1). Delaying termination allowed



Graph 1. Corn yield as affected by cover crop termination timing and additional nitrogen

for more cereal rye biomass to develop and resulted in higher cereal rye carbon to nitrogen (C:N) ratios. Increased C:N ratios are known to also increase N immobilization and is likely one of the primary reasons for yield loss in this trial with delayed termination timings.

COVER CROP TIMING AND NITROGEN INFLUENCE ON CORN YIELD POTENTIAL

Hybrid brands G10D21 and G12S75 incurred larger yield penalties with the earlier termination timing than other hybrids. All hybrids were negatively affected by the delayed termination timing (Table 1). The 2021 rye cover crop trials evaluating the same hybrids showed G12S75 brand was one of the most sensitive to cereal rye cover crops and G10D21 brand was slightly less susceptible (data not shown). The 2022 trial again implies that both hybrids may be more sensitive to rye cover crop systems with both early and late termination timings. The other four hybrids tested had smaller yield penalties when cereal rye was terminated early but all hybrids experienced large statistical yield losses when termination was delayed (Table 1). Hybrid management decisions based on this single trial should be limited, but also indicate that hybrid differences may exist. This trial reinforces the overall importance of terminating cereal rye as far in advance of corn planting as possible. It also suggests that well-timed and placed nitrogen applications can help minimize some potential yield loss.

Hybrid Brand	No Cover Crop Yield	Termination Timing Yield Difference from No Cover Crop	
		2-week Pre-plant	At Planting
G10D21	259.8	-22.5 *	-26.4 *
G11V76	265.1	-0.7	-18.6 *
G12S75	280.4	-14.2	-27.0 *
G13Z50	258.2	-5.6	-20.5 *
G14N11	261.9	-1.1	-23.9 *
G15L32	278.4	-8.3	-26.1 *

* Indicates within hybrid LSD (0.05) =17.6

Table 1. Hybrid yield at cover crop termination timing

TIPS FOR PLANTING INTO GREEN COVER CROPS

Terminating cereal rye at least 14 days before the anticipated planting date greatly reduces many of the risks associated with rye cover crops. When this is not an option, consider the following for green planting:

- Allow corn or soybeans to germinate prior to terminating cover crop.
- Total nitrogen should not need to change, but timing 30-60 pounds per acre of highly available nitrogen at or around planting close to the seed, may reduce tie-up by rye.
- Apply in-furrow nitrogen containing starter or higher rates of nitrogen in 2x2, 2x2x2 or dribbled to the side of row at planting and consider additional early sidedress, if needed.
- Scout for insects and be prepared to manage pests that could become an issue in the emerging crop, such as armyworm and black cutworm.
- Pay extra attention at time of planting to:
  – Adjust down pressure and depth. Seed depth changes due to cover crop residue.
  – Use opening wheels, coulters, trash whippers or other planter attachments to clear cover crop debris.
- Consider planting rye cover crop into wider, 30-inch rows to allow for clean corn/soybean planting strips the following spring.
- Always make sure soil conditions are optimum for good seed germination and growth.
- Larger, maturing cover crops can be hard to control with herbicides. Ensure adequate application rates are used while plants are actively growing.
- Consider the planting restrictions of herbicides that could be used to terminate a cover crop.
- Maximize spray volume and ensure application weather conditions are good to get the best control of cover crops.
- Tillage can be an option for certain species, but multiple passes may be needed which negate the benefits the cover crop is providing.

ON-FARM GENETIC x ENVIRONMENT x MANAGEMENT TRIALS

INSIGHTS

- Better crop management increases hybrid yield potential.
- Hybrids respond differently to enhanced management.
- Local hybrid x management system trials help place the right product on the right acre to maximize yield potential.

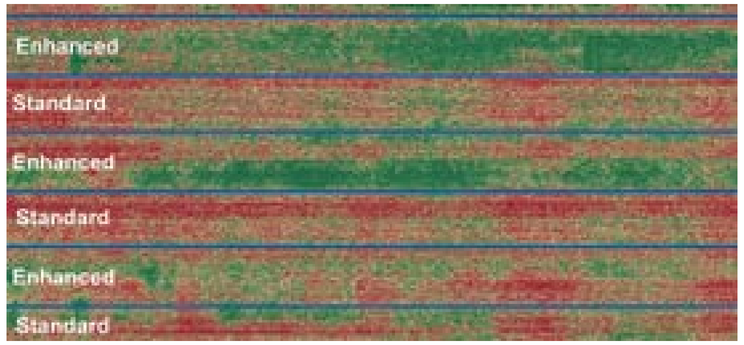


Figure 2. NDVI image from Stacyville, IA with strips of standard management and enhanced management

Previous research conducted by the Golden Harvest® Agronomy in Action research team demonstrated that hybrids respond differently to management practices across a variety of environments. In 2022, Golden Harvest agronomists collaborated with farmers and implemented genetic x environment x management (G x E x M) on-farm replicated strip -trials to better understand how hybrids respond to enhanced management at a local level (Figure 1).

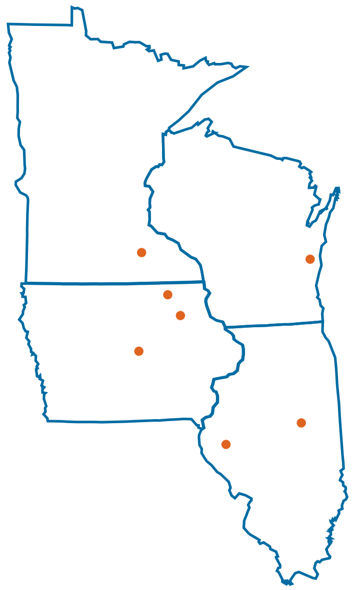


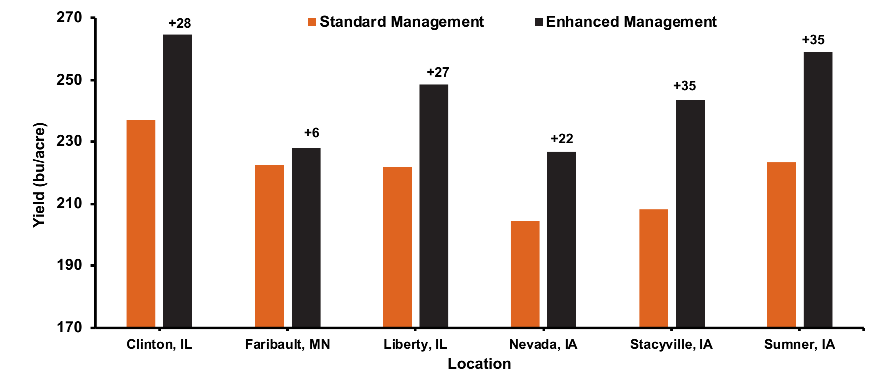
Figure 1. Locations for on-farm G x E x M trials in 2022

Trials consisted of four hybrids planted in both standard management and enhanced management systems. Management practices varied depending on location. Applied treatments for each location are listed in Table 1.

ON-FARM G X E X M TRIAL RESULTS

Yield response to the enhanced management system ranged from 6-35 bu/acre, depending on location (Graph 1). Stacyville, IA and Sumner, IA were the most responsive locations both yielding 35 bu/acre greater with enhanced management compared to standard management (Graph 1 and Figure 2). Stacyville had a more intensive, enhanced management program than Sumner but the response was the same illustrating how the environment, hybrid, and base management program all play roles in the magnitude of yield benefit from management. Fairbault, MN had minimal response to enhanced management potentially related to the enhanced system only receiving an additional in-furrow application of 7-21-7 at 3 gal/acre + zinc at 1 pt/acre along with 50 additional lbs of N/acre sidedress compared to the standard system.

On average across all locations, there was a 26 bu/acre yield improvement with enhanced management suggesting there is yield potential to be gained on these



Graph 1. Average hybrid yield response to enhanced management at six locations in 2022

Location	Standard	Enhanced (Standard +)
Clinton, IL	• Preplant broadcast 32% UAN @ 200 lbs N/acre	• In-furrow 6-24-6-.25Zn @ 5 gal/acre • Surface dribble 32% UAN @ 17 gal/acre + ATS @ 5 gal/acre • 2x2x2 NACHURS Triple Option® @ 15 gal/acre • Sidedress 32% UAN @ 17 gal/acre • R1 foliar Miravis® Neo fungicide @ 13.7 oz/acre
Faribault, MN	• 2x2x2 UAN @ 60 lbs N/acre + ATS @ 2 gal/acre + Boron @ 0.5 pt/acre + Humic Acid • Sidedress UAN @ 100 lbs N/acre	• In-furrow 7-21-7 @ 3.5 gal/acre + Zinc 9% EDTA @ 1 pt/acre • Sidedress UAN @ 50 lbs N/acre
Liberty, IL	• Preplant anhydrous ammonia @ 175 lbs N/acre • Broadcast Potash @ 78 lbs K$_2$O/acre + MicroEssentials® SZ® @ 12 N, 40 P2O5, 10 S, 1 Zn lbs/acre	• In-furrow 6-24-6 @ 5 gal/acre • 2x2 28% UAN @ 15 gal/acre + ATS @ 5 gal/acre • Sidedress ATS @ 5 gal/acre • R2 foliar Trivapro® fungicide @ 13.7 oz/acre + Silencer @ 3 oz/acre + Logan Agri-Yield® Premium Foliar @ 1 qt/acre + Logan Agri-Yield® All-E-Viate @ 4 oz/acre + Logan Agri-Yield® SUGAR CompleX @ 2 pt/acre
Nevada, IA	• Preplant anhydrous ammonia @ 150 lbs N/acre • Preplant broadcast UAN @ 30 lbs N/acre • Preplant broadcast DAP @ 30 N, 77 P2O5 lbs/acre • Envita® seed treatment	• In-furrow 6-24-6 @ 4 gal/acre + NACHURS CropMax® @ 1 gal/acre • R1 foliar Trivapro fungicide @ 13.7 oz/acre
Stacyville, IA	• Strip-banded MAP @ 8 N, 39 P2O5 lbs/acre + Potash @ 90 lbs K$_2$O/acre + Gypsum @ 9 lbs S/acre • Dribble UAN @ 38 lbs N/acre + ATS @ 2 N, 5 S lbs/acre • Sidedress UAN @ 65 lbs N/acre + ATS @ 2 N, 5 S lbs/acre + Boron @ 0.5 pt/acre	• In-furrow 6-24-6 @ 4 gal/acre + 0-0-25-17S @ 1 gal/acre + Syntose FA® @ 1 pt/acre + 1 pt/acre Zinc 9% EDTA • Sidedress UAN @ 20 lbs N/acre + ATS @ 1 N, 1.5 S lbs/acre + Boron @ 0.15 • R1 foliar Miravis Neo fungicide @ 13.7 oz/acre + Silencer® @ 1.6 oz/acre + Boron @ 0.5 pt/acre + Elara MS @ 8 oz/acre
Sumner, IA	• Preplant anhydrous ammonia @ 150 lbs N/acre • Broadcast MAP @ 8 N, 40 P$_2$O5 lbs/acre + Potash @ 60 lbs K$_2$O/acre	• 2x2x2 ATS @ 10 gal/acre • R1 foliar Miravis Neo fungicide @ 13.7 oz/acre + Silencer @ 1.6 oz/acre

Table 1. Standard and enhanced treatments for on-farm G x E x M trial locations

farms through better crop management. In these trials, there were varying levels of standard and enhanced management systems with an array of different products. To obtain the most consistent return on investment, it is imperative to understand the most limiting yield factors on each farm and focus management strategies on those factors.

HYBRID RESPONSE TO MANAGEMENT

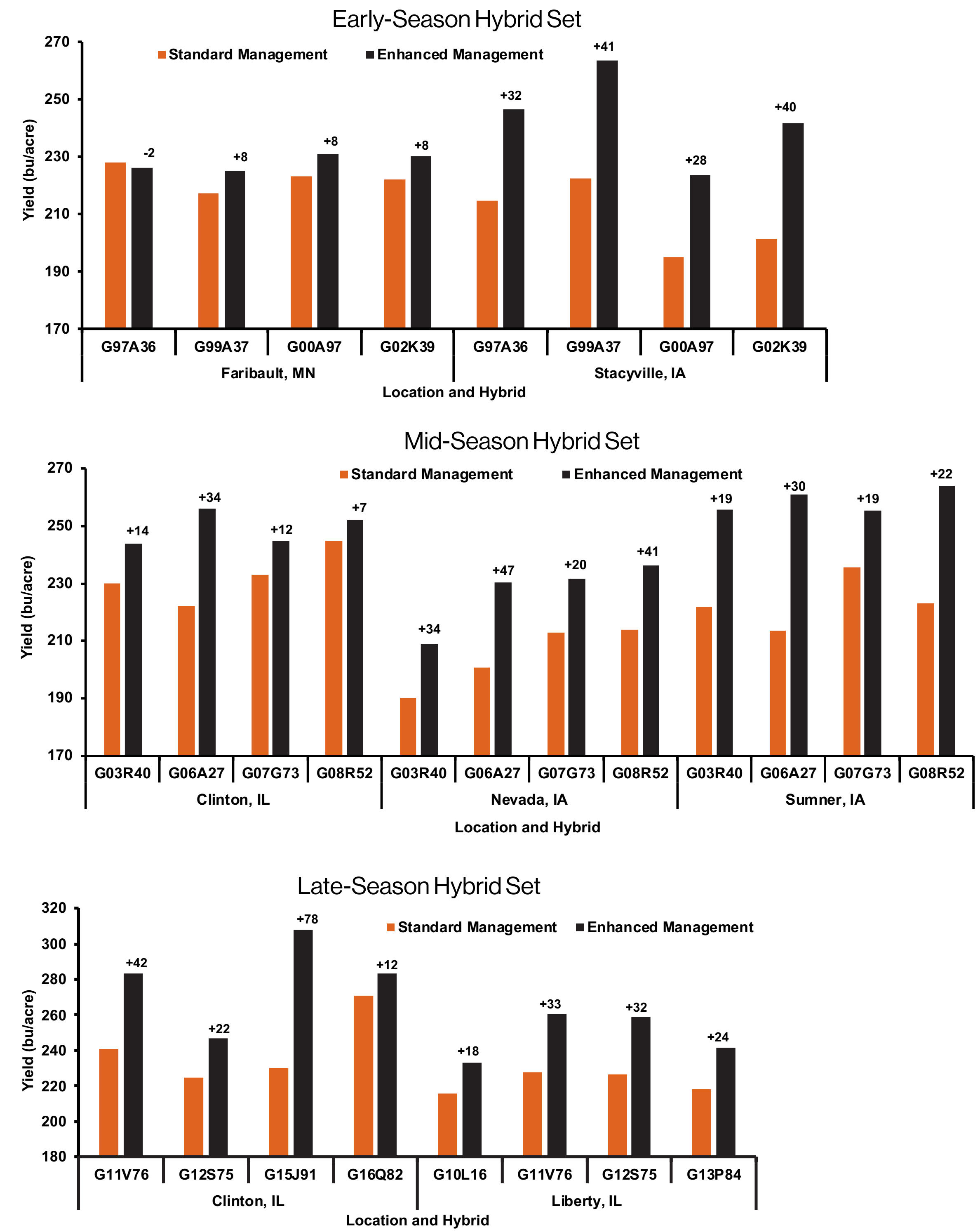
Hybrids responded differently to enhanced management (Graph 2). Although similar small responses were seen across all hybrids at Faribault, G99A37 and G02K39 responded noticeably more than others at Stacyville (Figure 3 and Graph 2). In the mid-season hybrid set, G06A27 was the most responsive hybrid at all three locations (30-47 bu/acre range). G08R52 also experienced a large yield increase with enhanced management at Nevada, IA (+41 bu/acre) and Sumner (+22 bu/acre). In comparison to the other hybrids, G07G73 was less responsive to enhanced management at the three sites (12-20 bu/acre) but still had a consistent yield bump to additional management. Although different hybrids were used at the two late-season locations, G11V76 and G15J91 showed the greatest yield increase when planted in the enhanced management system compared to standard management system within the late-season hybrid set.

SYSTEM APPROACH TO HIGH-YIELD CORN

It is evident that enhanced management can improve yield potential. However, are some agronomic factors or management timings more important than others?

At Sheboygan, WI, four management factors (in-furrow, sidedress, R1 foliar and population) were assessed across two hybrids (G00A97 and G02K39) for their individual and cumulative impact on yield. The entire trial received a base rate of fertility outlined in Table 2. The standard system did not receive any additional inputs and was planted at 32,000 plants/acre. Each factor was individually added to the standard system to determine the effect each individual factor has on yield. The enhanced system received all four factors and was planted at 38,000 plants/acre. Each factor was individually removed from the enhanced system to determine the effect each individual factor has on yield.

With all enhanced factors combined as an agronomic package and compared to the standard system, yield



Graph 2. Hybrid yield response to enhanced management in 2022

CORN MANAGEMENT
MAIN MENU

increased by 55 bu/acre (Table 3). These yield improvements can be attributed to maximizing early-season light interception with increased plant growth and higher plant density, providing season-long nutrition, and lengthening photosynthetic duration with foliar protection.

The management factor that had the greatest impact on yield in both the standard and enhanced system was the foliar package applied at R1 (Figure 4 and Table 3.) The addition of the R1 foliar application to the standard system increased yield by 20 bu/acre while its omission from the enhanced system decreased yield by 19 bu/acre.

The sidedress package added 19 bu/acre to the standard system and reduced yield by 16 bu/acre when removed from the enhanced system. When added to the standard system, the in-furrow package increased yields by 6 bu/acre while its omission to the enhanced system decreased yield by 13 bu/acre. The in-furrow application provided more benefit in the enhanced system than if it was just added alone to the standard system. The enhanced system had more plants to support and the in-furrow application provided that early-season fertility. With a solid base program and good growing condition at Sheboygan, the higher plant population yielded 13 bu/acre greater even in the standard system. If there were not enough plants (32,000 plants/acre) with all the additional fertility and foliar protection in the enhanced system, yields were reduced by 15 bu/acre compared the higher plant population (Table 3).

In this study, each individual factor added to the standard system totaled 264 bu/acre while the enhanced system which included all factors combined yielded 261 bu/acre. Although not observed in this trial, previous research has shown that combining multiple management factors together creates synergy and tends to boost yields greater than the summation of each individual factor.[1] High-yield corn management requires a systems approach to set a high potential early in the season (racehorse hybrids, fertility, higher plant populations) and maintain that yield potential throughout grain fill (fertility and foliar protection).

<table>
<tr><th colspan="3">Entire Trial Received
• 2x2 band of MicroEssentials® S10® @ 18 N, 60 P2O5 and 15 S lbs/acre + Aspire® @ 87 K2O & 0.75 B lbs/acre
• Surface dribble of 29-0-0-4S @ 128 N & 18 S lbs/acre + NACHURS CropMax® @ 1 gal/acre + Manganese @ 1 qt/acre</th></tr>
<tr><th>Management Factor</th><th>Standard</th><th>Enhanced</th></tr>
<tr><td>In-furrow</td><td>None</td><td>• NACHURS imPulse® @ 5 gal/acre
• NACHURS K-fuel® @ 2 gal/acre
• Zinc 9% EDTA @ 2 qt/acre
• Bio-Forge® Advanced @ 8 oz/acre</td></tr>
<tr><td>Sidedress</td><td>None</td><td>• 29-0-0-4S @ 20 gal/acre
• NACHURS Sideswipe® @ 2 qt/acre
• Zinc 9% EDTA @ 1 qt/acre
• Sugar Mover® Premier @ 1 qt/acre</td></tr>
<tr><td>R1 Foliar</td><td>None</td><td>• Miravis® Neo fungicide @ 13.7 fl oz/acre
• NACHURS Finish Line® @ 1 qt/acre
• Bio-Forge Advanced @ 1 pt/acre
• X-Cyte™ @ 1 pt/acre</td></tr>
<tr><td>Population</td><td>32,000 plants/acre</td><td>38,000 plants/acre</td></tr>
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Table 2. Corn management factors and treatment levels for standard and enhanced agronomic systems evaluated at Sheboygan, WI in 2022

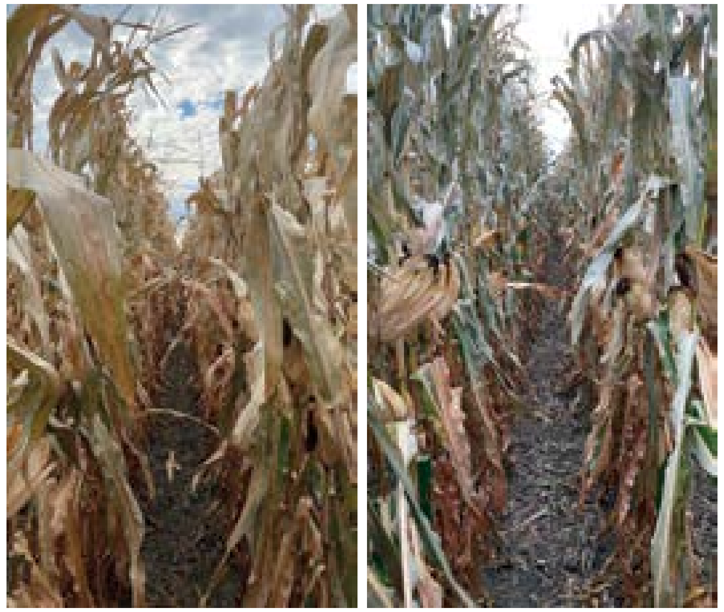


Figure 3. Hybrid G99A37 in standard system on left and enhanced system on right at Stacyville, IA in 2022

Management Factor	Standard		Enhanced	
	Yield	Δ	Yield	Δ
	bu/acre			
None or All	206		261	
In-furrow	212	+6	248	-13
Sidedress	225	+19	245	-16
R1 Foliar	226	+20	242	-19
Population	219	+13	245	-15

Table 3. Yield of standard and enhanced management systems and the yields resulting by adding individual factors to the standard system or subtracting individual factors from the enhanced system. Yields are averaged across two hybrids, G00A97 and G02K39 brands, at Sheboygan, WI in 2022

Figure 4. No R1 foliar package applied on left leaf with severe tar spot. R1 foliar package applied on right leaf with significantly less tar spot at Sheboygan, WI in 2022

SUMMARY

The on-farm genetic x environment x management trials were designed to better understand how hybrids respond to intensive management at a local level. The environment plays a major role on yield potential and understanding the interaction with hybrid and crop management allows for better product placement to maximize yield potential.

The key takeaways from these trials include:

1. There is yield to be gained with more intensive crop management during preplant, at-planting, during vegetative growth, and early reproductive growth stages.
2. Hybrids differ in their response to enhanced management. Some hybrids yield well under minimal management while other hybrids require more intensive management to maximize yield potential.
3. High-yield corn requires a systems approach to set a high yield potential and maintain that yield potential through grain fill.

It is important to understand that in these trials there were multiple inputs used to achieve the yield responses that were seen. The yield levels reinforce that many farms still have untapped yield potential. However, a consistent return on investment may not always be achieved without first better understanding the most limiting yield factors on each farm. Identifying the limiting factors can help focus management strategies so a consistent return on investment can be attained.

Local hybrid x management system trials help place the right product on the right acre to maximize yield potential.

If you are interested in participating in local genetic x environment x management trials, please reach out to your local Golden Harvest Agronomist or Sales Representative.

GREEN SNAP INJURY IN CORN

INSIGHTS

- Green snap is the breakage of corn stalk nodes.
- The growth stage when damaging wind events occur plays a significant role in potential green snap damage.
- Green snap injury in corn has the potential to significantly reduce yield potential.

INTRODUCTION

Green snap, otherwise known as brittle snap, is the breakage (snap) of corn stalk nodes resulting from excessive winds (Figure 1). Most susceptible during these weather fronts, are corn plants that are in rapid canopy growth stages prior to pollination. Green snap occurs yearly, but only a few acres are affected in most years. It is predominantly seen in the Western and Northern Corn Belts when rapid corn growth is mixed with high wind speeds.

Green snap can be seen at the lower nodes (close to the soil surface) and nodes at or above the ear. During accelerated growth, stalk internodes elongate rapidly, and the node and internode tissue are packed with water. Cell walls have not matured, and very little structural lignin has formed, resulting in water-packed cell walls that are quite fragile. It is at this stage that the corn plant is susceptible to high winds and breakage at the nodal "plates".

Figure 1. Severe green snap in a research trial plot

TIMING AND GROWTH STAGES

The two most common times when green snap risk increases are when the growing point is at or just above the soil line (V5 to V8) and the two weeks period prior to pollination (V12 to R1). The two specific time periods are when plants are normally going through a rapid growth phase in which internode plant cells are rapidly elongating, making them extremely vulnerable to breaking when under pressure. Due to the sensitivity at these specific timings, damage is often associated with wind events from storms.

GREEN SNAP AT V5-V8

- More susceptible after a period of favorable precipitation and temperatures that encourage good growth followed by a wind event.
- Snapped plants will not recover as breakage occurs below the active growing point.
- Tillers may develop following green snap but will not yield a productive plant.
- Yield impact will vary depending on the number of plants that were not snapped.
- Unaffected plants will partially compensate for lost plants when snapping occurs early due to the reduced plant competition.

GREEN SNAP AT V12 THROUGH TASSELING

- Plant undergoes most rapid growth at 2-4 inches per day with rapidly expanding leaves and height, making the plant more susceptible to wind events.
- Plants are prone to snapping at ear node and nodes just below or above it.
- Ear shoots may develop after snapping, although grain production is not likely or will be greatly reduced due to the lack of leaf surface area for photosynthesis.
- Snapping at this time can cause more severe yield loss due to being too late to compensate for reduced plant stand. Yield loss is dependent on the severity of plants broken.
- When maximum plant height is achieved upon tassel emergence, internode cell elongation stops, reducing susceptibility to future snapping.

YIELD LOSS ASSOCIATED WITH GREEN SNAP

Yield loss associated with green snap is based on where the breakage took place on the plant along with the number of plants affected. The loss of harvestable ears per acre is the primary cause of yield loss associated with green snap. Research has differed in yield loss potential from green snap over time. The University of Nebraska-Lincoln concluded that yield loss decreases approximately 1% for every 1% in stalk breakage (1:1 ratio).[1] However, several subsequent research studies, by university and internal Golden Harvest agronomy research, have suggested that the yield loss from stalk breakage is generally much less severe with modern corn hybrids[2] (Table 1).

Stalk Breakage Percentage	Yield (bu/Ac)	Yield % of Check
70% Breakage	121	53%
50% Breakage	161	37%
30% Breakage	210	18%
0% Breakage	256	

Table 1. Simulated stalk breakage data from York, NE, study in 2021 using corn hybrid G11V76

GOLDEN HARVEST HYBRID RESEARCH

Golden Harvest® corn hybrids are routinely screened for sensitivity to green snap. Trials are conducted every year using helicopters to apply high winds to hybrids at two specific growth stages (Figure 2). Snapped plants are counted to calculate percent green snap and aid in discarding susceptible genetics prior to commercialization. Using this type of measurable characteristic also helps to identify stronger genetics and predict how hybrids will perform in areas highly prone to green snap.

Even the most tolerant hybrids are still somewhat susceptible to green snap when well-timed wind events occur at the most susceptible growth stages.

MULTIPLE FACTORS INFLUENCE SEVERITY OF SNAPPING

Multiple factors are involved in influencing the potential severity of green snap damage. It may be difficult to understand why some fields or hybrids were affected and others where not. Environmental or management conditions that optimize for high yield potential are also favorable for causing green snap. Subtle changes in management practices, such as a planting date that slightly delayed growth, can result in differences within the same hybrid that otherwise grew under the same conditions. The following list includes some of the most common factors that contribute to green snap severity differences:

- Time of day the wind event occurred – plants are most turgid in the morning hours from overnight moisture uptake
- Severity of wind speed, gusts and direction
- Stage and rate of growth – most susceptible during rapid internode elongation
- Hybrids can vary in length of time they are sensitive to green snap in a growing season
- Herbicide – growth regulators increase susceptibility
- Higher nitrogen (N) rates may speed up plant growth
- Planting date
- Favorable growing conditions (temperature and soil moisture)
- Plant size affecting wind resistance
  – Leaf area
  – Leaf orientation
  – Row direction

Figure 2. Helicopter creating high winds over hybrid research trials

WEATHER EFFECTS
MAIN MENU

REASONS FOR VARIABLE CORN YIELDS

INSIGHTS

- Field-to-field yield differences can often be explained by better understanding what yield-limiting factors were dissimilar across fields.
- Grouping hybrid yield data by specific yield-limiting factors can help with future hybrid selection and placement.

Yield data can be a fantastic tool for understanding how well a hybrid did or did not perform and ultimately in helping make decisions on what to plant next year. However, in some years, corn yield can be highly variable, making data-driven decisions difficult unless you are able to gather performance results into groups that best represent why performance varied. Temperature and precipitation are two of the main drivers associated with fluctuations in year-to-year yield potential. Temperature changes tend to span across bigger geographies and explain large yield trends. However, they may not explain field-to-field yield variability within smaller geographies. Conversely, rainfall patterns may cover big swaths or vary greatly within a few miles, which could sometimes explain field-to-field performance variability. In addition to rainfall and temperature, many different soil parameters can influence plant available water capacity (PAWC) and lessen or worsen the effect of drought conditions. The following paragraphs will help better understand how precipitation, temperature and soil parameters interact and result in high yield variability.

TEMPERATURE VARIABILITY

Corn is well adapted to warmer days to maximize growth and cooler nights, which help plants recover. Analysis of state-county yield data across years has shown a trend for yield penalties ranging from 2.8-4.7 bu/A for every 1°F increase in July and August average night temperatures. A lack of cooler nights leads to a decline in physiological efficiency that can either reduce kernel set or kernel size depending upon when the warm nights occur. Heat stress as pollination begins is known to reduce

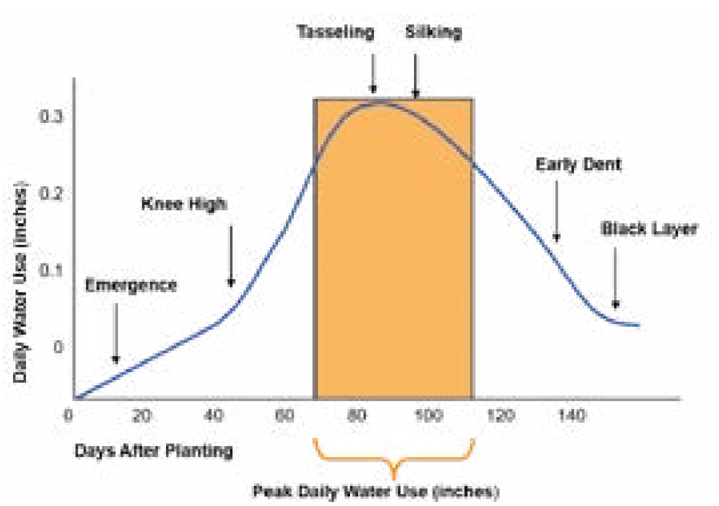
Temperature		Grain Ear Weight	Kernel Size	Grain Fill Duration
Day (°F)	Night (°F)	(g)	(mg)	(days - silk to blacklayer)
77	59	124 a	213 a	57 a
77	77	103 b	175 b	49 b
95	59	72 c	130 c	42 c
95	77	69 c	119 c	39 d

Table 1. High day and night temperatures can negatively impact ear weight, kernel size and grain fill duration.[1]

kernel set, whereas heat occurring later in grain fill stages can reduce kernel size, weight and grain fill duration as shown in Table 1. Drought and heat often occur simultaneously. However areas experiencing excessive heat in combination with timely rainfall may still encounter significant ear tip back.

PRECIPITATION VARIABILITY

Drought conditions can reduce nutrient uptake and grain fill period as well as cause premature plant death. The crop stage and duration of the drought stress play a critical role in how the crop may be impacted due to changes in daily plant water use (Graph 1). Research shows that drought stress during pollination (peak daily water use) can cause



Graph 1. Peak water use occurs just prior to pollination, making it the most sensitive time for drought to occur. Source: Syngenta

up to 50% yield loss, whereas stress prior to or after pollination only resulted in 20-25% yield loss.[2]

In extended dry periods, corn plants have reduced nutrient and water uptake from the soil, resulting in reduced grain fill (shallow kernels) and subsequent yield loss. Dry conditions slow root growth, limiting the ability to access nutrients within the soil. Insufficient soil moisture also reduces the ability for nutrients such as nitrogen and potassium to flow freely in soil solution to roots, further reducing uptake. The combination of reduced root growth and nutrient movement in soil often results in plant deficiencies which may require the plant to reallocate nutrients from other areas of the plant to complete grain fill. Nutrients are generally stolen from the lower stalk, making plants more susceptible to late-season lodging.

SOIL FACTORS CAUSING SPATIAL YIELD VARIABILITY

Soil texture, structure, depth and organic matter all interact to determine plant-available water content. Often these soil parameters can help explain field-to-field yield variability where precipitation and temperature were similar.

Soil Texture is characterized by its proportion of sand, silt and clay, each of which have varying particle sizes. Spatial changes in texture alter both soil nutrient and water-holding capacity, greatly influencing variability of corn yields.

Soil Structure is a description of how individual sand, silt and clay particles are assembled into what is more commonly referred to as aggregates. Soil structure is important because it influences water infiltration and retention rates as well as oxygen availability in the soil. Soils with poor structure will tend to be poorly drained, anaerobic soils that limit oxygen needed for metabolic processes in addition to restricting root elongation and penetration into the soil. Soil structure is commonly degraded from excessive tillage or compaction from heavy machinery.

Soil Depth is the depth in which the root system can physically penetrate, greatly influencing the amount of nutrients and water plants can absorb. Root depth could be limited by how shallow bedrock or impenetrable subsoils are or by the formation of a plow pan from tillage and compaction.

Organic Matter is anything that contains carbon compounds formed by living organisms. Increased soil organic matter provides many benefits such as managing storage and release of nutrients, providing aggregation for improved soil structure, moisture retention, improved water infiltration, reduced compaction and reduced surface crusting.

Factors beyond plant water availability such as soil pH and nutrient levels, should not be overlooked as potential explanations for yield variability. Any differences between management practices such as planting dates, nitrogen application or loss and presence of disease can contribute to field-to-field yield variation.

SELECT THE BEST PRODUCTS FOR YOUR FIELDS

Continue scouting and monitoring fields throughout the growing season to set yield expectations and not be caught off-guard by variable yield. The most important way farmers can manage increasingly variable conditions is to plant the right hybrid for the right acre. Work with your Golden Harvest Sales Representative or Seed Advisor for hybrid-specific field placement recommendations that are designed around the unique conditions you anticipate seeing in future growing seasons.

WEATHER EFFECTS
MAIN MENU

SOLAR RADIATION: EFFECT ON CORN YIELD AND STANDABILITY

INSIGHTS

- Solar radiation, or plant-available light, is a key factor in corn yield potential. The Midwest has seen an increased trend since 1980 (Graph 1).
- Pollination and grain fill are critical corn growth stages for sufficient solar radiation, however, there is a trade-off between precipitation and solar radiation in the data trends.

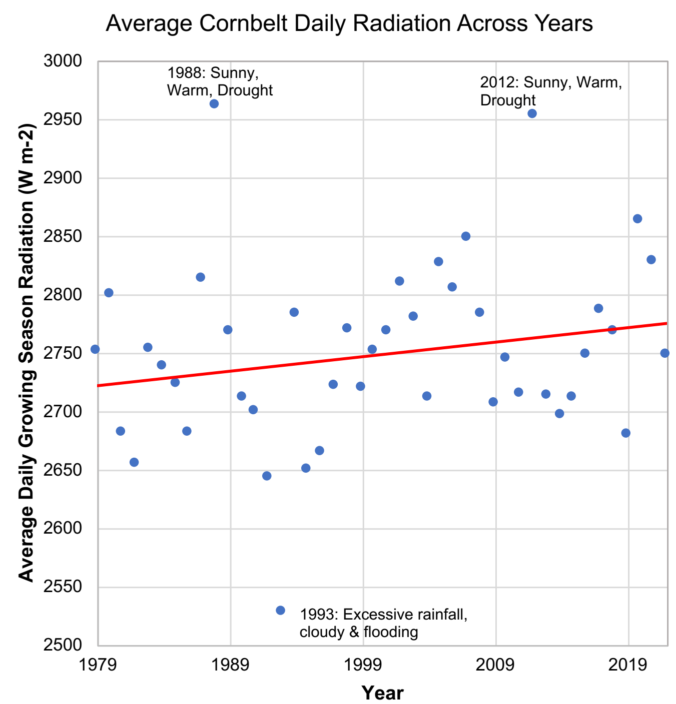
INTRODUCTION

Solar radiation is an important component of corn yields. It is speculated by many researchers that an overall increase in solar radiation throughout the Midwestern United States over the last several decades has been a major driver for increased corn yields.[1] However, the relationship between solar radiation and corn is nuanced and there are many factors to consider, depending upon the season.

CROP STAGES WHEN SOLAR RADIATION DEFICIT IS MOST IMPACTFUL

Reductions of plant-available light at key growth stages can have negative impacts on yield and possibly put plants at higher risk for stalk lodging. Low solar radiation has the biggest effect on yield potential during silking and grain fill periods. Experiments that intentionally shaded corn to approximately 50% solar radiation reduced yield by 12-20% when shaded during silking and by 19-21% when shaded during grain fill.[2,3] Shading during silking results in ear tip-back or fewer kernels per row, whereas shading during grain fill results in decreased kernel weight from shallower kernels.

Flowering commonly occurs mid- to late-July, followed by grain fill throughout August in most geographies with normal planting dates. July and August are therefore the most critical months when evaluating seasonal sunlight deficiencies impact on yield and stalk strength. If planting



Graph 1. Average daily radiation across Corn Belt; publicly available data

was delayed into late May/early June, it may be more applicable to consider August and September solar radiation impact on corn since flowering and grain fill dates would occur later than normal.

Corn can become even more susceptible to lodging if sunlight is limited during the grain fill period. Limited photosynthesis during grain fill signals the plant to remobilize carbohydrates from the stalk to the developing ear, weakening the stalk. This problem can be further exacerbated when near-perfect growing conditions during ear size determination (V6-V12 for rows/ear and V18 for kernels/row) and pollination are followed with below-normal solar radiation during grain fill.

Favorable growing conditions throughout flowering will set plants up for higher yield potential, creating a greater demand for carbohydrates during grain fill than the plant may be able to supply with limited light availability.

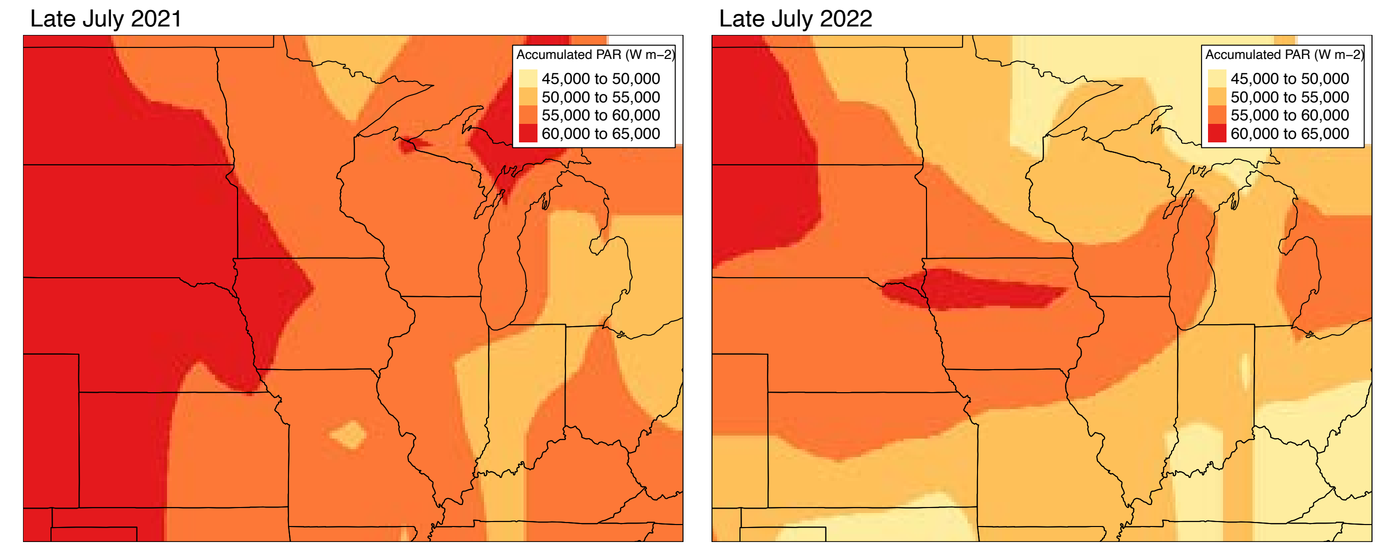


Figure 1. Variability in solar radiation between July 2021 (left) and July 2022 (right); publicly available data

SOLAR RADIATION LONG-TERM TRENDS

Much of the Midwestern United States has experienced an increase in solar radiation since the 1980s (Graph 1). Greater-than-normal solar radiation stands out in monumental years like 1988 and 2012, which both experienced widespread drought conditions resulting in fewer clouds. Extremely cloudy years, such as 1993 which experienced record-breaking rainfall amounts, also clearly show below-average solar radiation. It is speculated by some researchers that the long-term trends of increased solar radiation may be responsible for as much as 27% of the ongoing corn yield gains observed over the last three decades.[3] Progressively more radiation occurring during grain fill over this time would create ideal conditions for kernel development. Similarly, a recent publication from the University of Nebraska attributed 48% of gains in corn yield to climate trends, with a large part of gains due to ample radiation during a prolonged grain fill period.[4] In more recent years, annual variability such as a below-normal 2019 followed by above-trend 2020, have likely influenced yields in some areas of the Midwest.

SPATIAL VARIATION AND SOIL MOISTURE INTERACTIONS

Increased solar radiation is most beneficial in irrigated regions and rain-fed areas with ample soil moisture to support long periods of sunshine. Since there is a trade-off between precipitation and solar radiation, some of the trends associated with increases in solar radiation are also associated with increases in drought conditions and thus, lower yields as seen in in 1988 and 2012. Looking at long-term trends can also mask spatial and yearly variability in solar radiation. Many regions over the last several years have experienced a deficit of solar radiation during key growth stages due to increased precipitation, overcast conditions or periods of smoke from wildfires.

The last two weeks in July during the last two years provide a recent example of variability in solar radiation (Figure 1). Across the entire Midwest, there was more solar radiation in 2021. While some areas were similar between years, other areas like Nebraska, Missouri, and southern Illinois, received 20% less solar radiation during grain fill in 2022 compared to 2021. This may have been reflected in decreased yield or decreased stalk strength in some cases.

It is important to be aware of available solar radiation during key growth stages. If there are concerns about solar radiation deficits during grain fill, it is necessary to scout for stalk strength and consider if an earlier harvest could reduce lodging risk.

HYBRID TOLERANCE AND RESCUE NITROGEN APPLICATIONS IN SATURATED SOILS

INSIGHTS

- Rescue nitrogen (N) applications can be economical in saturated soils.
- Nitrogen management is more important than the level of soil saturation.
- Hybrids tend to vary in their tolerance to waterlogged soils.

SATURATED SOILS

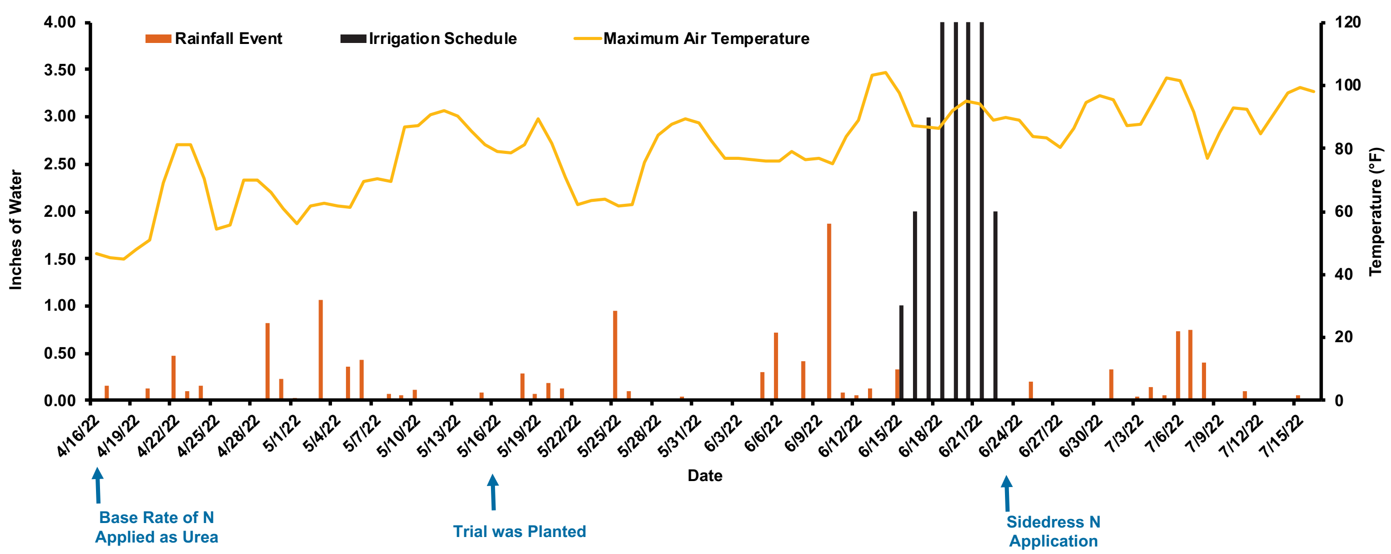
Excessive rainfall and soil types that are poorly drained can cause saturated or "waterlogged" soil within fields. At times of heavy precipitation, there can be ponding water in certain areas of a field. Prolonged wet soils will negatively affect crop growth and yield. Saturated soils reduce oxygen availability to the roots and increase risk of nitrogen loss through leaching and denitrification. The level of standing water, crop growth stage, air temperature and days of soil saturation all play a role in the degree of impact on yield.

ARTIFICIAL SOIL SATURATION TRIAL

Golden Harvest Agronomy in Action Research conducted a trial at Slater, IA in 2022 using surface drip irrigation to create artificial saturated soil conditions. There were three questions addressed in this study:

1. What impact does saturated soils have on crop growth and yield?
2. If early-season ponding water creates N deficiency, can plants be "rescued" with a sidedress application of N?
3. Do hybrids differ in how they tolerate low soil oxygen levels and N loss from saturated soils?

Treatments included two water regimes, two nitrogen programs and 10 Golden Harvest® corn hybrids. The water regimes were either blocks watered repeatedly with surface drip irrigation to create artificial saturated soil or blocks that were rainfed. Irrigation began at the V5 growth stage with a total of 24 inches of water being applied over eight consecutive days to keep the soil saturated within



Graph 1. Inches of water from rain and irrigation and the maximum air temperature from 16-April – 16-July.

Figure 1. Excessive water applied with surface drip irrigation to simulate saturated or waterlogged soils at Slater, IA in 2022

designated blocks (Figure 1). When the ground was dry enough to walk on after irrigation, half of both water regime blocks received 50 lbs of N/acre sidedressed as 32% UAN dribbled on the soil surface along both sides of the crop row using a hand applicator. Irrigation treatment schedule and quantities are outlined in Graph 1.

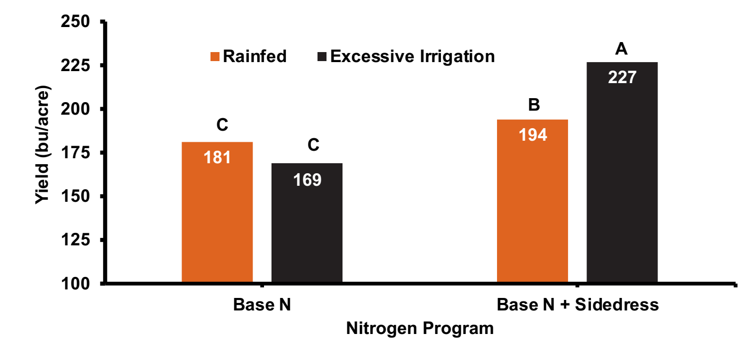
SLATER, IOWA, WEATHER PATTERNS

The base rate 160 lbs of N/acre was applied as broadcast urea on April 16. After the base rate of N was applied Slater received a total of 4.3 inches of precipitation over several weeks delaying planting until May 16. After planting, there was an additional 5.4 inches of rainfall before any blocks of corn were irrigated. The spring rainfall events likely created wet anaerobic conditions conducive to N loss through leaching across the entire trial. Excessive irrigation began on June 15 and 24 inches of water was applied over the next seven days, creating saturated soils and N deficiency symptoms (Figure 2).

Following the last day of irrigation, a sidedress of 50 lbs of N/acre was applied along the crop row dribbled on the soil surface on June 23. During this application, the soil profile in the excessively irrigated blocks was full of water compared to the rainfed blocks that were dry. The rainfed blocks had only received 0.4 inches of rain over the previous 10 days with an average daily high temperature of 93°F. After the sidedress application, there was no significant rainfall event of 0.5 inches or more until 0.7 inches of precipitation on July 6.

YIELD RESULTS

Nitrogen was a limiting factor across the entire trial indicated by the 13 and 58 bu/acre yield response to the sidedress N application in rainfed and excessive irrigation regimes, respectively (Graph 2). On average across all hybrids, excessively irrigating to create saturated soils reduced yields by 12 bu/acre in plots that only received the base rate of N (Graph 2). Nitrogen leaching and reduced oxygen availability in the soil stunted crop growth and ultimately yield. Surprisingly, in plots that received the base rate of N and the sidedress application, there was a 33 bu/acre yield advantage in the excess irrigation blocks



Graph 2. Effect of water regime and nitrogen program on yield averaged across 10 Golden Harvest hybrids at Slater, IA, in 2022

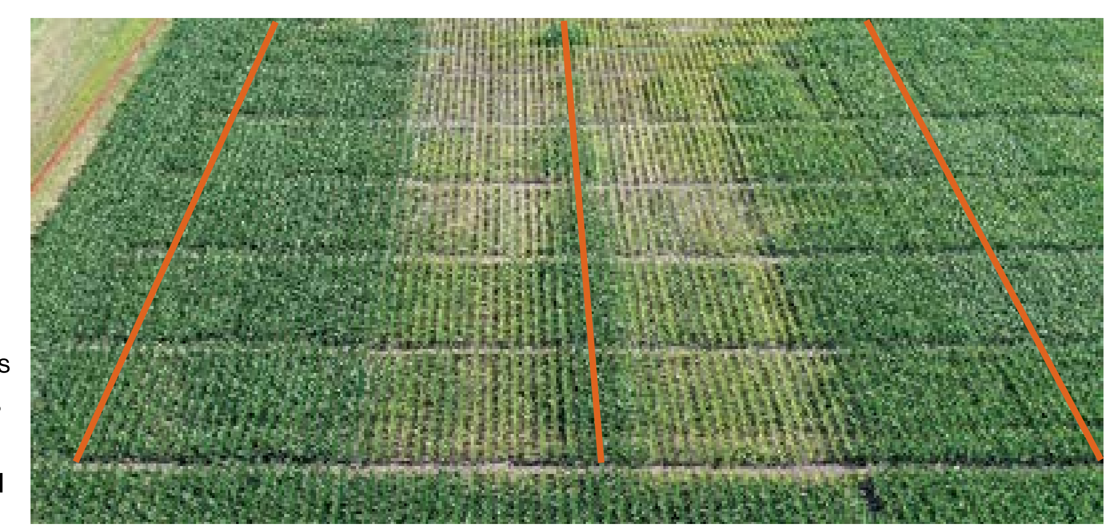


Figure 2. Two out of four reps illustrating rainfed blocks and excessive irrigation blocks at Slater in 2022. Saturated soils for seven days in the excessive irrigation blocks caused nitrogen deficiency symptoms

Hybrid	Rainfed	Excessive Irrigation	Δ
	bu/acre		
G06A27	151	168	+17
G09T26	180	152	-28
G10D21	183	184	+1
G10K03	178	112	-66
G10L16	227	196	-31
G12A22	194	176	-18
G12S75	167	187	+20
G13N18	146	152	+7
G13P84	166	200	+34
G15J91	220	162	-59

LSD (0.10) Hybrid x Water Regime = 29

Table 1. Effect of excessive irrigation on yield for 10 Golden Harvest hybrids within the base N blocks

Hybrid	Base N (160 lbs N/acre)	Base N + Sidedress (160 + 50 lbs N/acre)	Δ
	bu/acre		
G06A27	168	227	+60
G09T26	152	219	+67
G10D21	184	240	+55
G10K03	112	217	+105
G10L16	196	229	+33
G12A22	176	229	+53
G12S75	187	241	+54
G13N18	152	217	+65
G13P84	200	237	+37
G15J91	162	215	+53

LSD (0.10) Hybrid x N Program = 21

Table 2. Effect of sidedress N on yield for 10 Golden Harvest hybrids within the excessive moisture blocks

compared to rainfed. Nitrogen was limiting in both the rainfed and excessive irrigation blocks because of the heavy spring rain events. It is speculated that the sidedress application was more effective on the excessive irrigation blocks because the soil was saturated and N was able to move through the soil profile to the rootzone. The rainfed blocks were dry during sidedress with little precipitation after the application, therefore the plants were not able to utilize as much of the sidedressed N. In addition, the lack of rainfall and high temperatures following the dribbled sidedress created conditions conducive to N loss through volatilization. These initial findings indicate that under waterlogged or ponding conditions, a rescue application of N can enhance yields.

Like many other management and environmental factors, hybrids varied in their tolerance to an extended period of saturated soils. Five of the 10 hybrids tended to be negatively affected by the lack of oxygen and nitrogen in the soil while the other five hybrids were more tolerant to saturated soils (Table 1). However, many of these responses were not statistically significant due to the large amount of variability across water regimes. Natural variation in drainage across the excessive irrigation blocks created variability in hybrid responses.

There can be many genotypic and phenotypic hybrid characteristics influencing why some hybrids tolerate waterlogged soils better than others.

Plants at Slater were deficient in N regardless of water regime. On average, across both water regimes and all hybrids, there was a 36 bu/acre yield increase to the 50 lbs of N/acre sidedress application. Hybrids also varied in the level of response to N sidedress applications (Table 2).

On average, the five hybrids that tended to be more negatively impacted by excessive water had a 62 bu/acre response to the rescue N application. In comparison, the five hybrids that tended to be more tolerant to the excessive water had a 54 bu/acre response to the sidedress N. Hybrids that showed less tolerance to stress, especially N stress, resulted in a larger yield increase to the additional N.

SUMMARY

Initial findings from this study suggest yield decreases from waterlogged soils can be mitigated with rescue N applications. The nitrogen program had a larger effect on yield than soil saturation level, illustrating the importance of N management. In situations where areas of a field experience ponding, it is economical to sidedress/topdress additional N in those areas when the soil is fit. In this study, the sidedress application was made while the soil was still saturated which may not be applicable with heavy machinery. In addition, the sidedress application placed N directly near the rootzone compared to topdressing urea which is commonly used for rescue applications due to less corn being run over. Crop response to rescue N applications will vary based on application timing and method.

Hybrids tended to respond differently to being in waterlogged soils. Similar results were found in another study illustrating genetic differences in tolerance to saturated soils.[1] That study also concluded that waterlogged soils have a greater negative impact during early vegetative stages (V2-V7) compared to later vegetative and reproductive stages.[1]

These results are from only one location which had several environmental interactions such as nitrogen loss prior to planting followed by excessively hot and dry conditions during June-August. Environmental conditions caused unique nitrogen loss and plant utilization scenarios for both base N and sidedress N applications. Natural variation in drainage across the excessive irrigation blocks caused high variability in hybrid responses. A previous study evaluating the effect of tile drainage on corn yield showed yields to be much more variable between drain tiles compared to over drain tiles, demonstrating the importance of tiling and adequate drainage.

Additional research is needed to confirm the consistency in response for water regimes, nitrogen management and repeatable differences amongst hybrids.

Figure 3. Slowed growth and development from excess moisture (right)

WEATHER EFFECTS

MAIN MENU

ABNORMAL EAR DEVELOPMENT IN CORN

INSIGHTS

- Abnormal corn ears are often the result of stress caused by environment or management practices.
- Minimizing water or nutrient deficiencies and managing diseases may reduce occurrence of some ear abnormalities.

Modern corn hybrids have 750-1,000 individual embryos develop on the uppermost ear shoot, all of which form individual silks and possess the potential to pollinate and develop into kernels. Realistically, less than 800 embryos successfully pollinate and mature into harvestable kernels. The number of kernel rows is determined largely by plant genetics and will not change much with growing conditions, although the number of kernels per row (ear length) is often influenced by growing conditions. Although normal ears often have 16-20 individual rows and 30-60 kernels per row, in some cases environmental conditions or management practices can result in "abnormal" ear size and shape. Symptoms and causes of some of the more common abnormalities are described in the following paragraphs in greater detail.

BLUNT EAR SYNDROME (ARRESTED EAR OR HOLLOW EAR DEVELOPMENT OR "BEER CAN EAR")

Symptoms:

- Reduced ear size and fewer kernels per row. Normal ear formation abruptly ends, ceasing cob and kernel row development.
- Husk length and number of kernel rows are normally unaffected.
- May be associated with multiple ears per node.

Blunt Ear Syndrome

Causes:

- Development of initial ear likely disrupted by a single triggering stress occurring at a very specific time during ear development several weeks prior to pollination.
- Rapid drop in temperatures as low as 40-50° F occurring during row number determination stages (V5-V12) followed by warming conditions are speculated to injure meristematic tissue within the ear shoot, ceasing cob and embryo development.
- Researchers have also reproduced symptoms by applying a single application of nonionic surfactant (NIS) at V12-V14 growth stages. Symptoms were not observed when only applying fungicide at similar growth stages.
- Similar ear symptoms can be observed when Multiple Ear Syndrome is present.

UNFILLED EAR TIPS (TIP-BACK OR TIP-DIEBACK)

Unfilled Ear Tips

Symptoms:

- Missing or shrunken kernels toward the tip of the ear that are progressing downward.

Causes:

- Later developing silks unable to receive pollen due to delayed emergence, drying out or insect clipping.
- Environmental stress conditions such as high temperatures, severe drought, reduced solar radiation, foliar diseases and nitrogen deficiencies often cause fertilized kernels to abort due to insufficient sugar and starches needed for proper grain fill.
- Younger kernels at tip of ears are more vulnerable to aborting from stress occurring early in grain fill process.

INCOMPLETE BASAL FILL

Symptoms:

- Unpollinated kernels are found at the base of the ear.

Causes:

- Silk emergence began prior to the start of pollen shed.
- First emerging silks were desiccated from drought or heat stress and unable to receive pollen.
- Selective silk clipping by insects such as corn rootworm beetles.

Incomplete Basal Fill

ZIPPER EARS (BANANA EAR)

Symptoms:

- Partial or entire rows of kernels are absent or stunted.
- Ear may be curved or misshapen from the lack of developing kernels on that side of the ear.

Zipper Ears

Causes:

- Poor pollination or kernel abortion following pollination, often from environmental stressors.
- Interplant competition for water and nutrients causing kernel abortion (observed in higher seeding rates).
- Defoliation injury after pollination.

INCOMPLETE KERNEL SET (SCATTERED / POOR KERNEL SET)

Symptoms:

- Reduced or scattered kernel set with a limited number of kernels on the ear.

Incomplete Kernel Set

Causes:

- Failed pollination likely from asynchronous pollen shed, inadequate pollen supply or clipped silks (insect or mechanical damage).
- Severe drought, high temperatures.
- Kernel abortion from stressors that significantly reduce plant photosynthesis.

UNPOLLINATED EAR (MISSED NICK)

Symptoms:

- Normal cob development without any kernels present.

Causes:

- Pollen shed and silk emergence timings were not synchronized due to environmental stress such as drought delaying silk emergence while pollen shed continues at normal timing.
- Severe silk clipping from insects prohibited silks receiving pollen.

Left ear was not successfully pollinated due to delayed silk emergence, whereas neighboring hybrid was less affected.

MULTIPLE EAR SYNDROME (BOUQUET EARS)

Symptoms:

- Multiple ears develop at the same ear shank and the ears usually have fewer kernels developing.

Hypothesized Causes:

- Corn hybrid genetics may play a role.
- Environmental stressors (extreme temperatures) or chemical stressors during early ear formation.
- Loss of primary ear shoot dominance from damage.

Multiple Ear Syndrome

BARBELL-EARS (PINCHED EARS)

Symptoms:

- Usually kernels on one or both ends of the cob with a pinched appearance middle of the cob.

Causes:

- Ovule abortion in early ovule development from a stressor.
- Combination of susceptible genetics and an environmental stressor.
- Stressors include temperature (chilling), specific ALS herbicides and plant hormone abnormalities occurring in the V7-V10 growth stages.

Barbell-ears

TRANSLUCENT KERNEL

Symptoms:

- Random fertilized kernels with clear or translucent kernels spread randomly amongst a normal sized ear.
- Clear kernels collapse as they begin to mature, leaving a shrunken shell.

Translucent Kernels

Causes:

- Often associated with late or off label glyphosate herbicide applications.

INSECT INJURY

There are many insects that may cause damage to developing corn ears leading to various symptoms. Insect feeding on developing ears, silks and kernels have the potential to cause malformed ears and reduce kernel quality. Insects include corn rootworm beetles, Japanese beetles, stink bugs, Western bean cutworm, corn earworm and European corn borer.

There are more corn ear abnormalities not described here. Overall, environmental factors such as drought, high temperatures, lack of nutrients or chemical applications may cause significant stress to corn plant development leading to unusual ear abnormalities.

Viptera™ trait stack corn hybrid ears on the top; Insect feeding damage caused by Western bean cutworm to the 4 ears on the bottom from a corn hybrid that does not have Viptera trait stack.

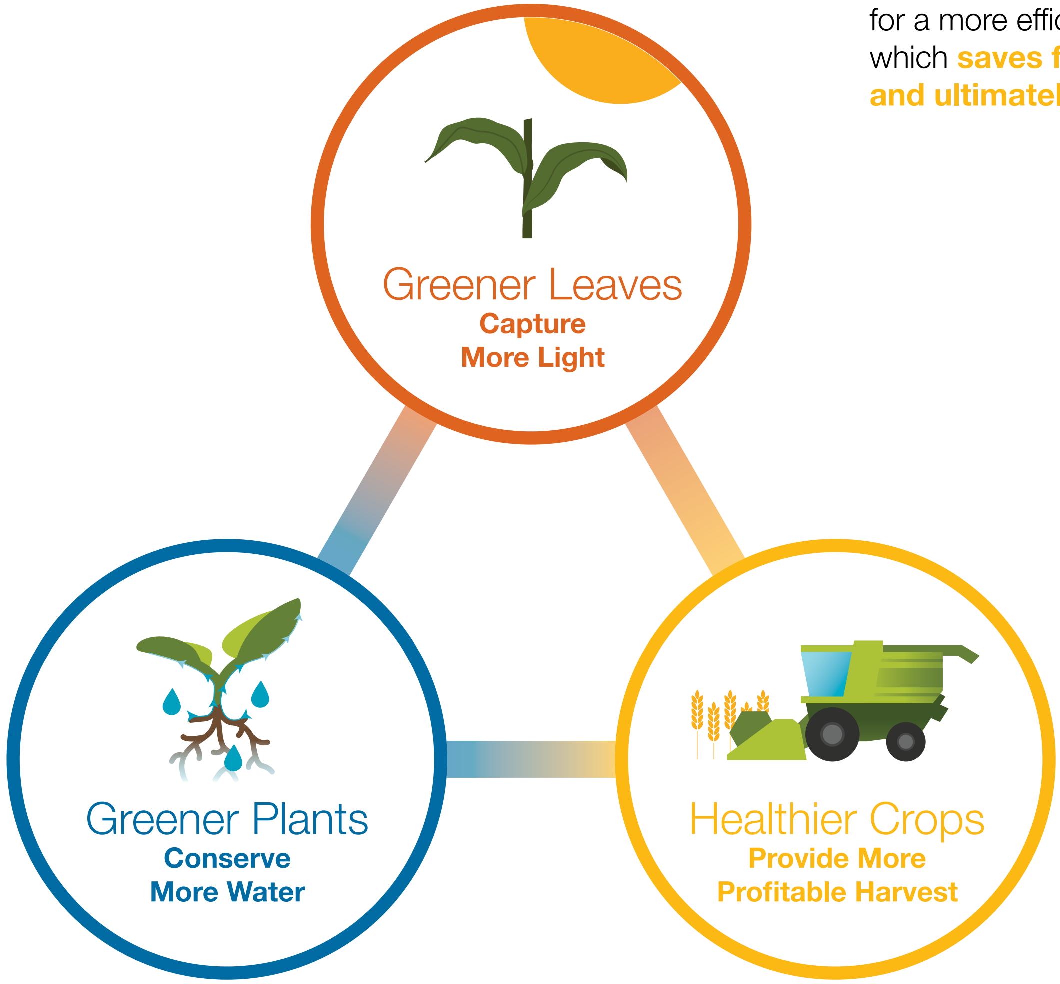
cleaner AND greener

Healthier Plants. Higher Potential Yield with Miravis® Neo and Trivapro®.

The cleaner & greener difference delivers more than unmatched disease control.
Cleaner and greener fungicides contain exclusive SOLATENOL® or ADEPIDYN® technology. These two powerhouse technologies help drive yield and ROI potential by:

1. Keeping leaves greener, allowing more energy capture for maximum grain fill.
2. Using less water, optimizing nutrient absorption and grain development.
3. Preserving standability, grain quality and harvestability, resulting in more bushels in the bin.

Better standability allows for a more efficient harvest, which **saves fuel, time and ultimately money.**



CORN HYBRID RESPONSE TO FOLIAR FUNGICIDES

INSIGHTS

- Making farm and field fungicide decisions can be complex.
- Results from this study help understand individual hybrid potential response to fungicide which can aid in the decision process.

There are many factors that go into making fungicide application decisions. Scouting and timely applications should always be the biggest drivers in the final decision. There are many levels of complexity beyond scouting that go into making farm-by-farm fungicide decisions. Golden Harvest® Agronomy in Action research conducts a yearly study that provides results to better understand the potential of individual hybrid response to fungicide treatment. Understanding hybrid susceptibility to a disease is extremely important in fields where disease pressure is highly predictable. There is an opportunity to further improve fungicide return on investment by understanding hybrids that respond more frequently and at high magnitudes when disease pressure is low.

ESTIMATING RESPONSE WITH LOW DISEASE PRESENCE

Fungicide trials are established each year using Golden Harvest hybrids to evaluate individual responses to R1

Figure 1. Fungicide being applied to hybrids at R1 in research trials

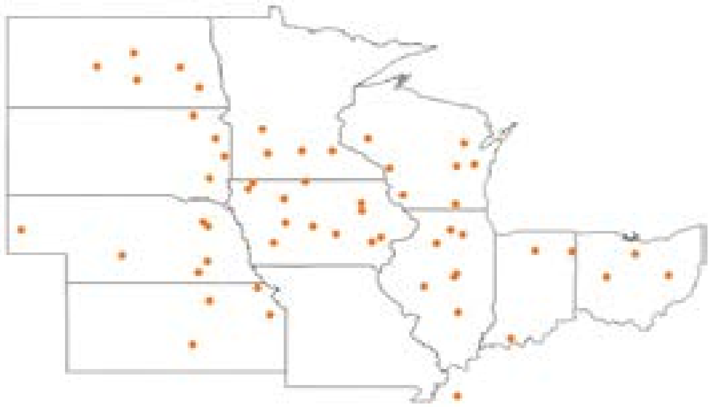


Figure 2. 2022 Fungicide by Hybrid Response Trial Locations

fungicide application timings (Figures 1 and 2). Fungicides such as Miravis® Neo and Trivapro® have been found to provide more than just traditional disease control. Active ingredients in these fungicides have shown to provide three unique advantages beyond disease control:

1. Keep leaves greener, allowing more energy capture
2. Use less water, optimizing nutrient absorption and grain development
3. Preserve standability for efficient harvest

Trial locations are categorized as either low or highly responsive to fungicide. Information from these trials is used to categorize hybrids into response categories of Best, Good, Fair and Poor, to indicate the probability to respond in lower disease environments

HYBRID SELECTION IN FIELDS WITH HIGH DISEASE RISK

ASSESSING CORN FUNGICIDE APPLICATION AND TIMING

Timely fungicide applications prior to disease establishment almost always pay off when disease is present, especially when hybrids are highly susceptible to a specific disease. Selecting hybrids with good disease tolerance and utilizing foliar fungicides are important in areas with high disease risk.

CONDITIONS INCREASING DISEASE RISK

- Continuous corn rotations
- Reduced tillage fields with high residue levels where pathogens can overwinter
- Extended periods of high humidity and leaf wetness that can favor disease development
- Fields with history of standability issues
- Observations of disease presence across multiple years
- Early signs of disease infection on lower leaves

BENEFITS BEYOND YIELD – STRONGER STALKS

In addition to disease control and potential yield response benefits, fungicide applications can also help improve standability at time of harvest. Previous trial data has shown that utilizing a foliar fungicide can:

- Improve stalk integrity
- Reduce stalk lodging
- Decrease harvest losses
- Reduce harvest time

USING THE CORN HYBRID FOLIAR FUNGICIDE RESPONSE RATINGS

DECISION PROCESS FOR FUNGICIDE APPLICATION

1. Select best suited hybrid for field based on adaptability, agronomics and relative maturity.
2. Determine disease risk potential of field and use appropriate decision tool.

LOW DISEASE FUNGICIDE RESPONSE

- Utilize "Low Disease Fungicide Response ratings" to understand which hybrids have the best chance of responding in these conditions.
- Best or Good indicates the hybrid responded more often and at a greater magnitude.
- Fair or Poor indicates responses may be smaller and less consistent.

HIGH DISEASE FUNGICIDE RESPONSE

- Utilize hybrid diseases susceptibility ratings specific to disease of concern from chart below to understand which hybrids are more vulnerable to yield loss.
- Scout fields and apply timely fungicide at sight of symptoms, focusing on most susceptible hybrids at first.

Hybrid	RM	Low Disease Fungicide Response	Rating			
			GLS	NCLB	SR	TS
G80Q01	80	Fair	-	4	-	2
G84J92	84	Good	-	3	-	4
G85Z56	85	Good	-	3	-	3
G87A53	87	Good	-	3	-	2
G90B11	90	Good	5	5	-	5
G91V51	91	Good	-	3	-	3
G92A51	92	Fair	3	4	-	4
G93A49	93	Fair	3	4	-	4
G95D32	95	Good	4	5	-	4
G97B68	97	Good	3	3	-	4
G98B99	98	Good	4	3		3
G98M44	98	Fair	5	4	-	5
G99E68	99	Fair	2	2	-	4
G00A97	100	Good	3	3	-	4
G01B63	101	Good	4	3	-	3
G02K39	102	Fair	3	4	-	4
G03R40	103	Best	4	5	3	3
G03B19	103	Good	3	4	-	3
G04S19	104	Good	4	4	-	4
G05K08	105	Good	4	3	5	5
G06A27	106	Best	3	3	2	5
G06B57	106	Fair	4	3	-	4
G07G73	107	Good	3	3	3	5
G08R52	108	Best	5	3	3	4
G08B38	108	Good	3	3	-	4
G08D29	108	Good	4	2	5	4
G09Y24	109	Good	5	2	5	4
G09B15	109	Good	2	5	-	5
G09T26	109	Fair	4	3	4	3
G10B61	110	Good	3	4	3	3
G10L16	110	Good	4	6	4	4
G10D21	110	Fair	2	2	4	3
G11V76	111	Best	4	3	4	3
G12A22	112	Fair	3	3	3	4
G12S75	112	Fair	3	3	4	2
G13N18	113	Best	6	4	6	-
G13B17	113	Good	4	3	3	3
G13D55	113	Fair	3	3	3	3
G13P84	113	Fair	4	2	2	3
G13Z50	113	Fair	4	3	5	-
G13H15	113	Poor	3	4	-	-
G14B65	114	Good	3	3	-	3
G15J91	115	Best	4	2	4	2
G15L32	115	Good	3	4	5	-
G16Q82	116	Good	3	3	3	5
G16K01	116	Fair	5	4	5	-
G17A81	117	Good	3	3	3	3
G17B31	117	Good	3	2	-	3
G17E95	117	Fair	3	4	3	-
G17A74	117	Fair	3	4	4	3

Hybrid Response Ratings: Best Good Fair Poor

Disease Resistance Rating Scale: 1-2 = Highly Resistant; 3-4 = Resistant; 5-6 = Moderately Resistant; 7-8 = Moderately Susceptible; 9 = Susceptible: - = Insufficient data; GLS = Gray Leaf Spot; NCLB = Northern Corn Leaf Blight; SR = Southern Rust; TS = Tar Spot

MAIN MENU

MANAGING TAR SPOT WITH A COMBINATION OF GENETICS AND FUNGICIDE

INSIGHTS

- Tar spot is a relatively new disease in the U.S., but it has already spread throughout the Corn Belt and become an established pathogen.
- Hybrid susceptibility or tolerance to tar spot is the key factor in yield loss potential after tar spot infects a corn field.
- Dialing in the timing of fungicide application(s) is critical to tar spot management.

Tar spot of corn is a relatively new disease to the U.S. It was first reported in northwest Indiana and north-central Illinois in 2015. Prior to 2015, tar spot only occurred in Mexico, Central America and northern parts of South America in cooler, high elevation environments. In 2018, this disease caused significant yield loss in a multi-state outbreak and has spread as far west as Nebraska and as far south as Georgia and Florida (Figure 1).

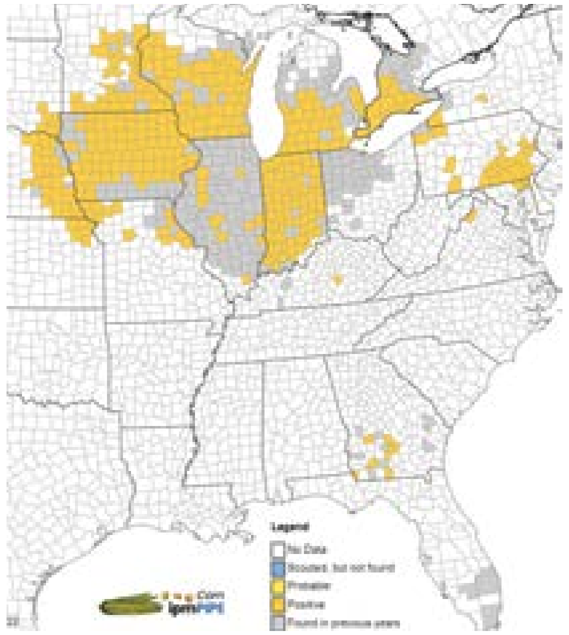


Figure 1. Counties confirmed with tar spot incidence (Corn ipmPIPE 11/17/22)


Figure 2. *Phyllachora maydis*, the fungus causing tar spot, with and without lesions forming around stromata.

FUNGAL PATHOGEN RESPONSIBLE

Tar spot observed in the United States is caused by a fungus referred to as *Phyllachora maydis*.[1] In Latin America where *P. maydis* was first observed, it has been known to form a complex with a secondary fungal pathogen, *Monographella maydis*. The combination of the two fungi are referred to as tar spot complex and known to cause more severe yield loss when both pathogens are present.[2] *Monographella maydis* and its association with P. maydis has not yet been observed in North America, although significant yield loss is frequently observed.

IDENTIFICATION

- Tar spot can be identified by raised black, irregular-shaped fungal structures (Figure 2) called stromata, which appear as specks of tar splattered onto the leaf surface.
- Lesions have a bumpy feel that is not easily rubbed off.
- Spots can be surrounded by a small, tan halo giving a "fish-eye" appearance.
- The disease begins on the lower corn leaves and moves to the upper plant and ear husks.
- Tar spot is found on both healthy and dead plant tissue on upper and lower surfaces of leaves.
- Often confused with:
  1) common and southern rust late in season as they switch from producing orange-red spores (urediniospores) to black spores (teliospores). However, rust pustules may easily be scraped from the leaf.
  2) saprophytic organisms that break down dead plant tissue late in season, however those will not exhibit a bumpy texture.
- Laboratory diagnosis may be required to correctly diagnose the disease.

DEVELOPMENT

The repeated occurrence of tar spot in the Midwest indicates it is well adapted to overwintering on soil and residue. Tar spot development and infection is highly dependent on extended periods of cool nighttime temperatures, often observed when average night-day temperatures reduce to 60-70°F. Infection is also highly dependent on having extended periods of leaf wetness resulting from high overnight humidity levels. Infection can occur at any stage of crop development if inoculum is present and favorable environmental conditions exist. After infection it can take 14-21 days before tar spot lesions begin to appear. Symptoms generally start on lower leaves and rapidly move up the plant if favorable environmental conditions persist. Typical hot and dry July weather patterns delay tar spot infections until later in the growing season. However, tar spot can develop earlier in the season, resulting in severe loss of leaf area, reducing yield potential and standability. Late season disease development, occurring just prior to or at crop maturity, is more frequently observed and depends on the infection timing, so it may have minimal impact on yield.

Part of what makes potential tar spot a challenging disease is that it is polycyclic, meaning that within a 21-day period it can complete a growth cycle and form new spores that can spread and cause secondary infections (Figure 3). Spores move by wind and plant residue that can be carried by field equipment to other fields. .

FIVE KEY FACTORS DRIVE YIELD LOSS POTENTIAL

1. Hybrid tolerance to tar spot
2. Presence and quantity of inoculum in a field
3. Environmental conditions for infection and spread
4. Growth stage of corn when it is infected and when lesions form
5. Effectiveness of management practices

The timing of tar spot infection is a driver in yield loss potential from this disease. Temperature and moisture influence when the infection from present inoculum begins. The later in the season that infection occurs, the less yield loss potential. Since tar spot is polycyclic and can produce new spores in overlapping cycles, the disease pressure can grow and spread rapidly.

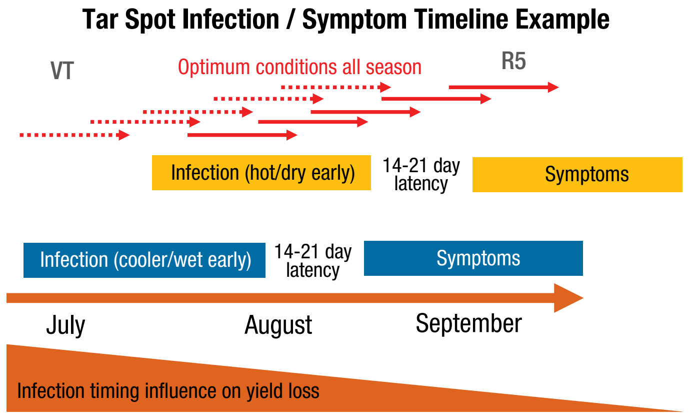


Figure 3. Tar spot infection timeline example diagram

MANAGEMENT PRACTICES

Due to the newness of this disease in the United States, best management practices are still being developed. Employing multiple management practices are critical for dealing with tar spot.

GOLDEN HARVEST TALKS TAR SPOT

1. **Hybrid Selection:** Hybrids differ in susceptibility to tar spot infection, making hybrid selection one of the first tools for managing this disease. Hybrid differences observed in Table 1 can be used in hybrid placement decisions for fields with known history of tar spot.

CORN PEST MANAGEMENT

MAIN MENU

2. **Crop Rotation and Tillage:** Burying residue with tillage and rotating crops to avoid exposure of overwintering pathogens is a common cultural practice used to manage many diseases. Recent research on tar spot has shown small reductions in disease severity from using these cultural practices. The ability of tar spot spores to spread within the growing season is likely minimizing most benefits of using rotation or tillage. Rotation and tillage may help in some situations but are likely not effective enough to use as a standalone management practice.
3. **Fungicide Application:** Early fungicide applications at or before first signs of development have been effective at reducing tar spot in previous trials.[3] However, infection often occurs weeks before symptoms, making timing of preventative fungicide applications challenging. Late-season curative applications of fungicides are typically not effective. Scouting, along with using the Tarspotter app to understand when conditions are most conducive for disease development, can help better time spray applications.
   - If conditions are favorable for tar spot development early in the season, an application at V4-V8 corn growth stage and/or the V10-VT growth stage with a registered product could reduce infection within fields confirmed with tar spot in prior years.
   - A second application may be warranted if conditions persist for infection around the VT-R3 growth stage.
   - If any of these exist, a second application could be needed: 1) susceptible hybrid was planted, 2) a conducive environment for infection continues, or 3) the field has a history of significant tar spot.
   - Fully registered Syngenta fungicide options include Trivapro® and Miravis® Neo to manage tar spot.
   - It is important to also consider other disease risks. Potential for other diseases like gray leaf spot, Northern corn leaf blight, Northern corn leaf spot and rust can help simplify decisions to treat fields with a broad-spectrum fungicide that can manage multiple diseases simultaneously.
4. **Other Considerations:** Observations of reduced tar spot severity in dryland corners of irrigated fields have highlighted the potential influence of irrigation on tar spot development. Current research is further investigating limiting irrigation to daytime hours to determine if that can help minimize disease development.

RM	Golden Harvest Hybrid Series	Tar Spot (1-9)
80	G80Q01	2
85	G85Z56	3
86	G84J92	4
87	G87A53	2
90	G90S99	4
91	G91V51	3
92	G90Y04	4
92	G92A51	4
93	G93A49	4
94	G94P48	7
95	G95D32	4
95	G95M41	6
96	G96R61	3
97	G97A36	2
97	G97N86	3
98	G98M44	5
99	G99A37	3
99	G99E68	4
100	E100A3	4
100	G00A97	4
100	G00H12	2
102	G02K39	4
102	G02W74	4
103	G03B96	4
103	G03C84	3
103	G03R40	3
104	G04G36	3
104	G04S19	4
105	G05K08	5
106	G06A27	5
106	G06Q68	4
107	E107C1	3
107	G07F23	3
107	G07G73	5
108	G08D29	4
108	G08M20	6
108	G08R52	4
109	G09A86	4
109	G09T26	3
109	G09Y24	4
110	G10D21	3
110	G10L16	4
110	E110F4	2
111	G11V76	3
112	G12A22	4
112	G12S75	2
113	G13D55	3
113	G13P84	3
115	G15J91	2
116	G16Q82	5
117	G17A81	3

Table 1. Golden Harvest Hybrid Tar Spot 1-9 Rating 1= best 9= worst

IDENTIFYING AND MANAGING CORN EAR ROTS

INSIGHTS

- Corn ear diseases can impact the quality of grain for storage and feeding.
- Mycotoxins can be harmful to humans and animals and may potentially be present without the visible presence of a mold.

There are several fungi that can cause ear rot disease in corn, resulting in lighter, poor-quality kernels, and mycotoxins that can affect grain feed value and marketability. Below are some common ear diseases seen in the field along with some information to help identify and best manage them.

DIPLODIA EAR ROT

- White mold appearance first developing at the base of the ear, and sometimes covering the entire ear.
- Black bumps, or pycnidia, can also be seen on individual kernels.
- Development is favored by cool, wet weather during grain fill.
- May cause kernels to have poor quality and appearance as well as low test weight.
- Not known to cause any harmful mycotoxins.
- Minimize further storage loss by adjusting combine settings to help discard lighter, diseased kernels, and drying harvested grain to 15-16% moisture as soon as possible.

FUSARIUM EAR AND KERNEL ROT

- One of the most common ear rot diseases in corn.
- White to pinkish fungal growth on the kernels typically starting at the ear tip.
- Also known to cause a "starburst" symptom on kernels.
- Often associated with hail or insect damage.
- Can occur under most weather conditions, but more prevalent when warm and dry.
- Can sometimes cause mycotoxins (fumonosin, deoxynivalenol or DON and zearalenone or ZEN) in grain, mainly impacting swine and equine if used for feed.
- Minimize storage loss by drying quickly and storing at 18% or less.

GIBBERELLA EAR ROT

- Caused by the fungus *Gibberella zeae*.
- Common throughout the Corn Belt, but more problematic in Northern and Eastern Corn Belt.
- Identifiable by pink to red (pale appearance in some cases) fungal growth almost always starting on the ear tip and only covering entire ear in severe cases.
- Silks and husks will sometimes stick to the ear when the disease is severe.
- Development is favored by cool, wet weather (65-70°F) after flowering.
- Can sometimes be a precursor to one of two mycotoxins.
  1. DON, also known as vomitoxin, which affects livestock feeding, especially swine.
  2. Zearalenone - less frequently observed.
- Minimize further development in storage by drying quickly and storing at 18% or less.

ASPERGILLUS EAR ROT

- Gray-green, yellow-green, yellow-brown or olive color in appearance with powdery mold on and between kernels.
- Commonly infects and appears on the ear tip or areas damaged by insect feeding, hail, early frost or other injury.
- Infection can also occur through growth down the silk channels while silks are yellow-brown and still moist.
- Most common under drought, high temperatures (80-100°F) and high relative humidity (85%) conditions occurring during pollination and grain fill.
- Caused by *Aspergillus flavus*, but also associated with other Aspergillus species.

Figure 1. Diplodia ear rot

Figure 2. Fusarium ear mold after insect feeding.
Source: G. Munkvold, Iowa State University

Figure 3. Giberella ear rot. Source: G. Munkvold, Iowa State University

Figure 4. Aspergillus ear rot after earworm feeding

- *Aspergillus flavus* and *Aspergillus parasiticus* are responsible for the mycotoxin known as Aflotoxin.
- Aflotoxins are the only mycotoxin the U.S. FDA has established action levels on and is considered a carcinogen and toxic to livestock at high concentrations.
  – Corn grain with aflatoxin greater than 20 parts per billion (ppb) may not be sold for transport across state lines.
  – Severity of ear rot present does not always correlate to actual mycotoxin levels, so grain testing should be considered when the disease is observed.

UNDERSTANDING MYCOTOXINS

Mycotoxins are a group of toxins produced by specific molds or fungi. Not all fungi produce toxins and most fungi only produce toxins under certain environmental conditions. Mycotoxins can be present without the visible presence of a mold, and they can also remain in the plant after the mold is removed. There is potential for mycotoxins in grain whenever a fungus infects the grain, usually from early season plant infection, fungal spores entering through silks or damaged areas.

The most frequent toxins present in corn are aflatoxin, fumonisin, DON, ZEN and T-2 toxin. Some are more common than others and vary significantly in acceptable thresholds as well as their impact on animals consuming contaminated grain.

IMPACT OF MYCOTOXINS

Mycotoxins may be extremely harmful to humans and animals. They are known to disrupt the synthesis of DNA, RNA and proteins. Mycotoxins can impair animal health, cause death and result in metabolites being passed through animal products such as milk.

The economic impact of mycotoxins is significant. They reduce the crop value from the restricted use of contaminated grain and are a cause of rejection of unacceptable DDGs (dried distillers grains). Harvest moisture and handling can influence grain infection also. Higher grain moisture, improper storage and damaged kernels can increase the likelihood of mycotoxins in the grain.

MANAGEMENT TIPS

- Consider adjusting the combine fan speed to blow out lightweight, infected kernels and retain healthy, heavier kernels.
- Manage stored grain as most fungi from ear molds will continue to grow in sub-optimal storage conditions.
  1. Dry grain quickly to 18% moisture or lower depending on temperature.
  2. Periodically check storage tanks for mold growth.
  3. Test grain for mycotoxins prior to feeding if Gibberella and Fusarium were observed in field.
  4. Contact your State Department of Agriculture prior to blending mycotoxin contaminated grain to know what is allowable.
- Minimize incidence in future years by managing residue that pathogens overwinter on using tillage or rotating crops.
- Select hybrids based on how susceptible they are to specific pathogens historically observed in a field.
- Consider using a Viptera™ or DuracadeViptera™ traited hybrid to minimize insect damage which can serve as a pathway for infection by pathogens.

IDENTIFYING STALK ROTS IN CORN

INSIGHTS

- Stalk and root rot diseases of corn are a common problem and appear at varying degrees of severity each year.
- Most stalk rots are caused by opportunistic pathogens that infect the plant after being weakened by preexisting plant stress.

STALK ROT INFECTION

1. Plant stress often reduces photosynthesis causing the plant to pull carbohydrates from the root and lower stalk area to support grain fill.
2. The weakened stalk area becomes more vulnerable to colonization by stalk rot pathogens.
3. Weakened vascular tissue in the stalk can no longer transport water or carbohydrates effectively, resulting in premature death and shortening of the grain fill period.
4. Yield may be impacted by both a reduction in grain density and potential harvest losses due to weakened stalks.

Upon premature plant death, secondary pathogens begin to colonize dead plant material, making diagnosis of causal pathogens even more difficult. It is important to understand causal pathogens to manage in the future.

STRESS THAT PREDISPOSES PLANTS TO STALK ROT INFECTION

- Nutrient Deficiency
- Saturated Soils
- Droughty Soils
- Foliar leaf disease
- Leaf area loss due to hail or insect damage
- Cloudy during grain fill

CROWN ROT

The predecessor to stalk rots is often known as root and crown rot. Root rots are commonly associated with multiple *Fusarium* species and may be difficult to visually identify specific species. Symptoms include:

- Wilting of plants
- Brown discoloration of pith in lower nodes (Figure 1)
- May be associated with insect injury
- Can be observed as mid- to late-season stalk lodging

Figure 1. Crown Rot

ANTHRACNOSE STALK ROT

Figure 2. Anthracnose

- Black, shiny lesions on the rind of stalk (Figure 2)
- Discolored and shredded appearance on inside of stalks
- Stalks easily crush when pinched

GIBBERELLA STALK ROT

- Pink to reddish discoloration of the stalk pith (Figure 3)
- No distinct lesions on outside of stalk
- Small, round bluish-black bodies may occur around nodes of stalk
- Infection usually occurs shortly after pollination
- More prevalent under warm and wet conditions

Figure 3. Gibberella; Source: G. Munkvold, Iowa State Univ.

DIPLODIA STALK

Figure 4. Diplodia stalk rot; Source: A. Robertson, Iowa State Univ.

- Caused by the fungus *Stenocarpella maydis*
- Numerous black pinhead or smaller-sized black dots (pycnidia) on outside lower internodes not easily scraped off
- Shredded pith of stalk, lacking any red coloration (Figure 4)
- Infection favored by dry, early season conditions, followed by warm, wet conditions after silking
- More severe in minimum-, no-till or continuous corn fields

CHARCOAL ROT

- Caused by the fungus *Macrophomina phaseolina*
- Pith inside of stalk has gray appearance from many tiny black microsclerotia (Figure 5)
- String-like appearance within stalk after pith disintegrates leaving only the vascular strands, covered in granular gray speckles
- More common under hot, dry, drought-like conditions
- Sclerotia survive in crop residue and soil for more than one year
- Soybeans and alfalfa are also good host crops, making crop rotation non-effective

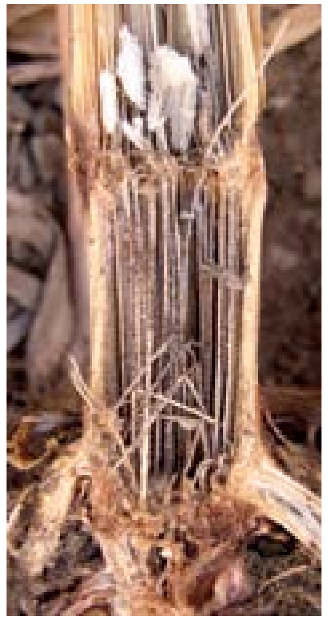


Figure 5. Charcoal rot; Source: G. Munkvold, Iowa State Univ.

FUSARIUM STALK ROT

- The most common stalk rot in the Midwest, caused by multiple fungal pathogens in the Fusarium genus
- Causes shredded pith with whitish-pink to salmon color
- Stalks easily collapse when pinched
- Brown streaks may be observed on the outside of lower internodes
- Lacks dark-colored or black "specks" associated with other stalk rots
- Favored by warm and dry conditions prior to pollination, and warm and wet conditions after pollination

Figure 6. Fusarium stalk rot

CORN AND SOYBEAN SEEDLING DISEASE

INSIGHTS

- Seedling diseases can be caused by several common soilborne pathogens.
- Multiple factors contribute to pathogen infection in seedlings, such as soil moisture and temperature.

Diseases and their causal pathogens can sometimes be difficult to identify. Proper identification is often the first step in determining the best future management practice. University and third party labs can often isolate and identify specific diseases, which may help in evolving future management. The following information can help identify specific diseases based on common symptoms.

FUSARIUM

- Multiple species are responsible. Most common are *graminearum, oxysporum, culmorum* and *moniliforme*.
- *Fusarium virguliforme* is the causal fungi for sudden death syndrome in soybeans.
- Mostly soilborne but can sometimes be seedborne.
- Most common in dry soils but can survive under moist conditions.
- Causes decay of the growing point stem tissues.
- Identified by tan to reddish brown lesion on the root or mesocotyl, the first internode of the stem (Figure 1).
- Corn mesocotyl will often have shriveled appearance under more severe infection.
- Attacks root surface area by reducing root hairs and small fibrous roots.
- Reduces ability of roots to take up nutrients and moisture.
- Fusarium species infection can often develop into late season crown and root rots.

Figure 1. *Fusarium* infected corn seedling

PHYTOPHTHORA - *PHYTOPHTHORA SOJAE* (SOYBEANS ONLY)


Figure 2. Phytophthora infection in soybeans

- Water-mold fungus, *Phytophthora sojae*, survives as (fertilized) oospores.
- Moves in soil water as (asexual) zoospores.
- Spores germinate and infect roots in warm, wet soils. Infection can occur at any stage of plant development but is most common in seedlings and young plants.
- Infected plants appear soft and bruised, have rotted secondary roots. Leaves yellow and later turn brown, followed by wilting and death (Figure 2).
- Plants that die or appear stunted later in the season show dark stem discoloration. Dying leaves stay attached to the plant.
- There are more than 40 races of *Phytophthora* identified in soils.
- There are 15 RPS (resistance to *Phytophthora sojae*) genes identified of which eight are commonly used to develop resistant soybean cultivars.
- Due to RPS genes specificity to designated races, infection can still be observed depending on the race present and RPS genes used, although the same RPS genes can protect against other races.

PYTHIUM


Figure 3. Soybean damping off caused by *Pythium*

- Water-mold fungus/brown algae that survives as oospores.
- Moves in soil water as zoospores, requiring wet soils to produce infection.
- Most common in cool, wet soil conditions.
- Some species have adapted to develop under warmer, wet conditions.
- More than 14 species of Pythium have been identified to affect corn and soybeans.
- No known genetic resistance.
- Can infect young seedlings prior to and after emergence, often observing rotted seed or emerged plants damping-off, dying (Figure 3).
- Symptoms occur scattered across entire fields and may make identification difficult.

RHIZOCTONIA

- Can cause both preemergence and postemergence damping-off.
- Prefers warmer, drier soil.
- Distinctive reddish-brown sunken cankers form on roots, crown and brace roots (Figure 4).
- Causes brown lesions on corn mesocotyl and roots that can eventually girdle and rot off roots.
- Above-ground symptoms are not often noticed other than stunting.
- Typically infects seedlings when they are under stress conditions, such as drought, higher temperatures, herbicide damage, compaction and insect feeding.
- Has many hosts, including weeds.
- May also cause crown rot in older plants.


Figure 4. *Rhizoctonia* infected soybean seedlings

GENERAL SEEDLING DISEASE MANAGEMENT

- Utilize a robust fungicide-containing seed treatment that has multiple modes of action against diseases most problematic to the field (Figure 5).
- Create a field environment that reduces the likelihood of disease:
  – Bury residue with tillage
  – Rotate to non-host crops if possible
  – Improve soil drainage
  – Minimize field compaction
- Delay planting until soil temperatures are nearing 50°F and 48-hour forecast is favorable.
- Avoid planting into wet soil conditions.

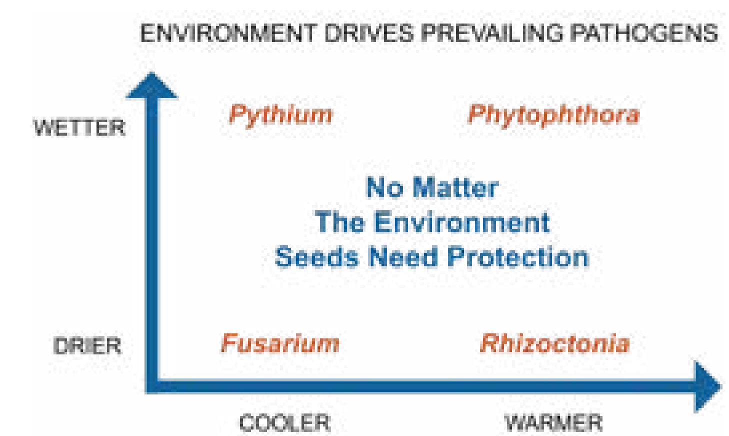


Figure 5. Early-season pathogens contributing to stand loss and reduced root development

CORN PEST MANAGEMENT
MAIN MENU

MANAGE PROBLEMATIC *PYTHIUM* SPECIES WITH A NOVEL MODE OF ACTION – VAYANTIS

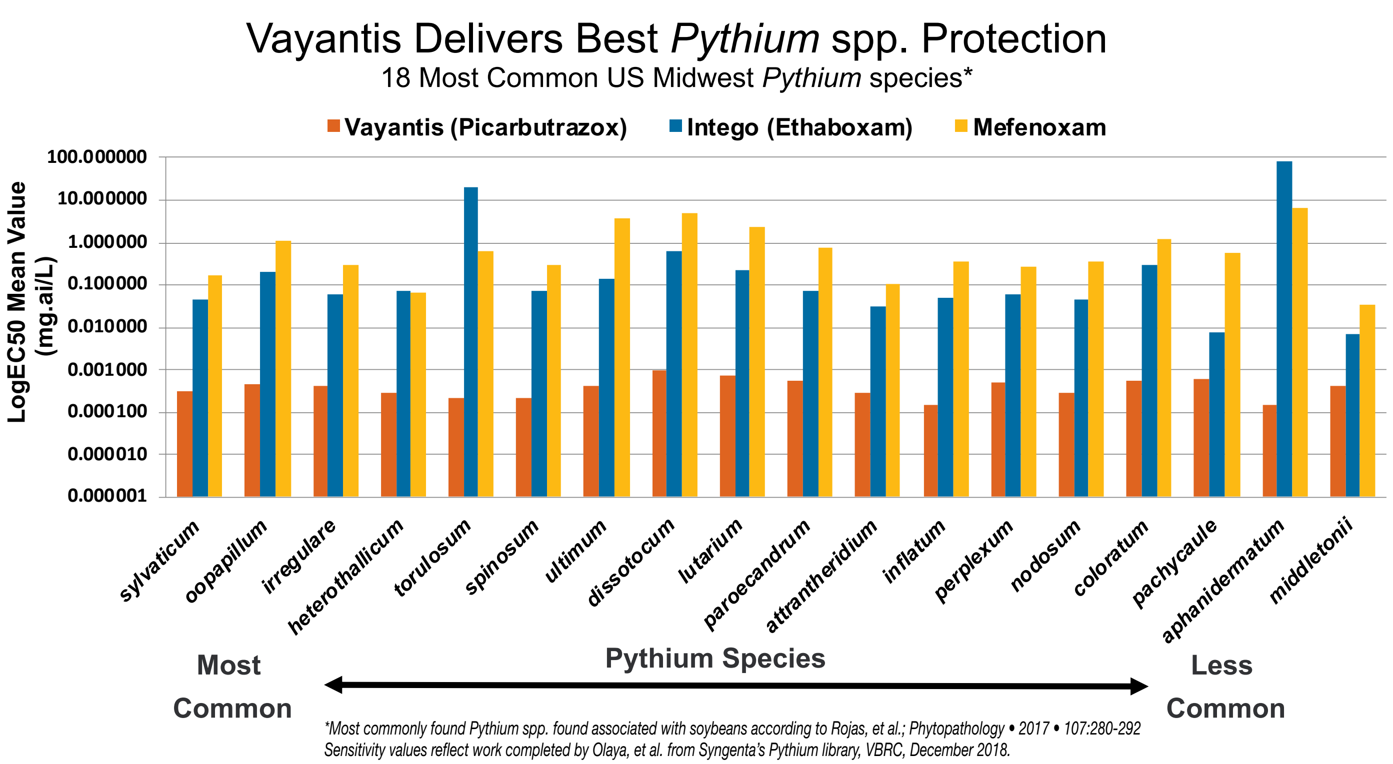
INSIGHTS

- Many species of *Pythium* have been identified in grower fields with differing levels of sensitivity to traditional *Pythium* fungicides.
- Vayantis®, a fungicide seed treatment for *Pythium*, has shown to broaden protection across hard-to-control *Pythium* species at lower use rates than other fungicides.

Every year, thousands of acres of corn experience uneven growth and reduced final plant stands. Symptoms often occur in areas planted early, followed by a rapid drop in soil temperature and surplus rainfall for an extended time. These environmental conditions are conducive for seedling diseases such as *Pythium* to infect young seedlings, slowing growth, and even causing death in extreme situations.

MANAGING *PYTHIUM* WITH SEED TREATMENTS

Pythium is most commonly the first disease encountered by germinating corn and soybean seed. Fungicide seed treatments are generally used to protect germinating seeds from infection by soilborne pathogens. Most seed treatments are a combination of individual fungicides that offer protection against specific pathogens. Proper combinations of individual fungicides can offer broad spectrum protection against most common soilborne pathogens. Metalaxyl or mefenoxam (ApronXL®) are broadly utilized by seed companies for their excellent activity against *Pythium* species. Additional fungicides such as azoxystrobin, trifloxystrobin, fluoxastrobin and pyraclostrobin, are routinely added for protection against other pathogens, but when used in combination with metalyaxyl or mefenoxam, also provide supplemental *Pythium* protection.



Graph 1. Sensitivity of 18 Pythium species collected from ND, SD, MN, NE, KS, IA, IL, WI, IN and MI to 3 separate fungicides

NEED FOR MULTIPLE MODES OF ACTION

Recent surveys of Midwestern corn and soybean fields have been carried out to better understand the diversity of *Pythium* species present as well as their sensitivity to common seed-applied fungicides. Multiple species of *Pythium* were routinely observed with varying levels of pathogenicity to both corn and soybeans. Researchers in Ohio[1] and Iowa[2] have reported a subset of *Pythium* species isolated which have differing levels of sensitivity to the commonly used seed-applied fungicides mefenoxam, azoxystrobin, and trifloxystrobin. Although these fungicides continue to offer good levels of protection across the Midwest, when used individually, they may not always inhibit growth of all pathogenic *Pythium* species found within the soil. It is likely that without the use of additional new fungicide modes of action, stand establishment could become more challenging in fields over time.

VAYANTIS PROVIDES UNIQUE MODE OF ACTION

A recently registered fungicide from Syngenta Seedcare branded as Vayantis (picarbutrazox) provides a new level of *Pythium* protection and is now being used on all Golden Harvest® corn hybrids. In combination with CruiserMaxx® Vibrance®, Vayantis enhances protection in fields where unique *Pythium* spp. have become harder to manage. Other seed companies are utilizing another mode of action, in addition to metalaxyl, that was introduced in 2014 and is branded as INTEGO® (ethaboxam). Both Vayantis and INTEGO fungicides have demonstrated improvements in protection, beyond metalaxyl alone. Although due to the diversity of *Pythium* spp. that exist, and differences in sensitivity of those species to different fungicides, there can be noticeable differences in performance between these two products. Syngenta screened a large collection of *Pythium* isolates collected across the Midwest for sensitivity to Vayantis, ethaboxam and mefenoxam as shown in Graph 1. The

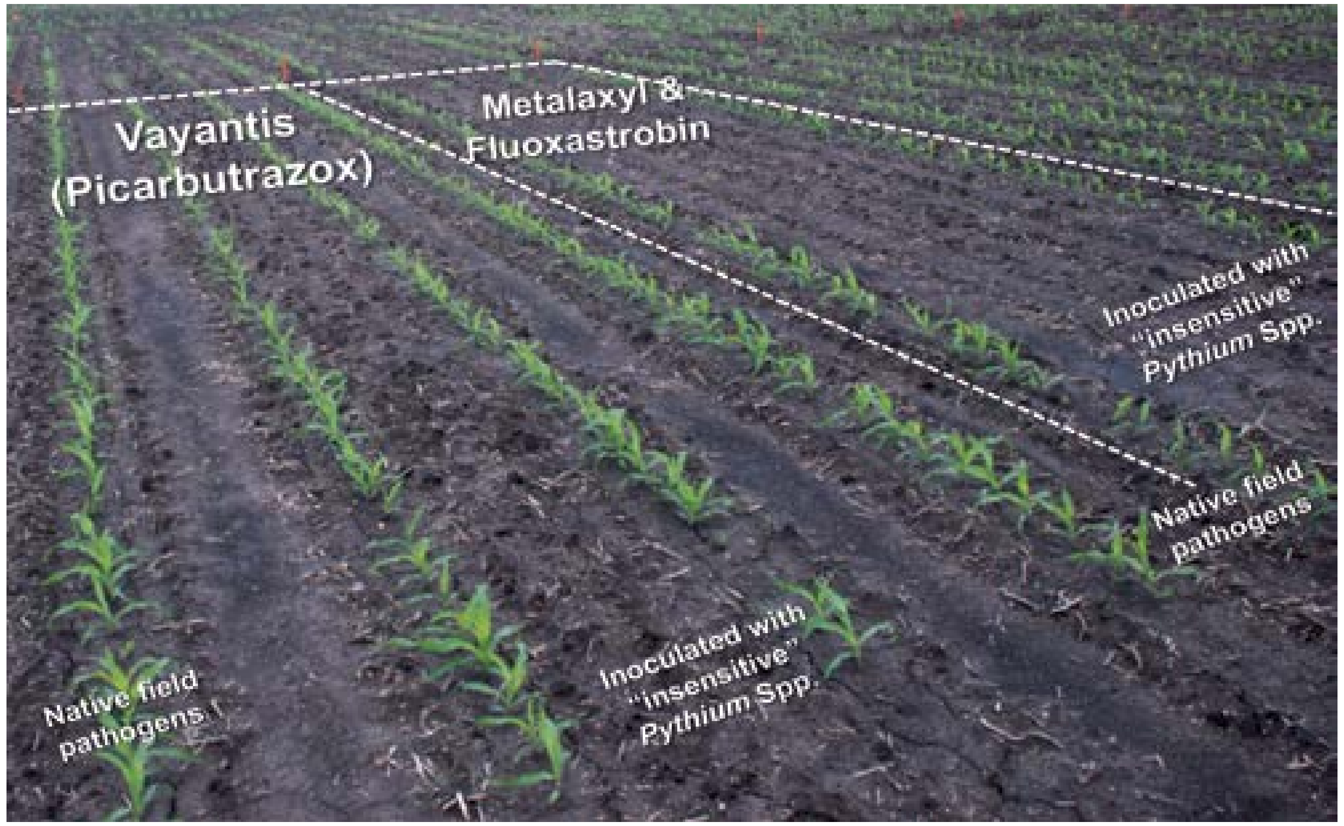


Figure 1. Emergence differences resulting from seed treatment and presence of "insensitive" *Pythium* spp

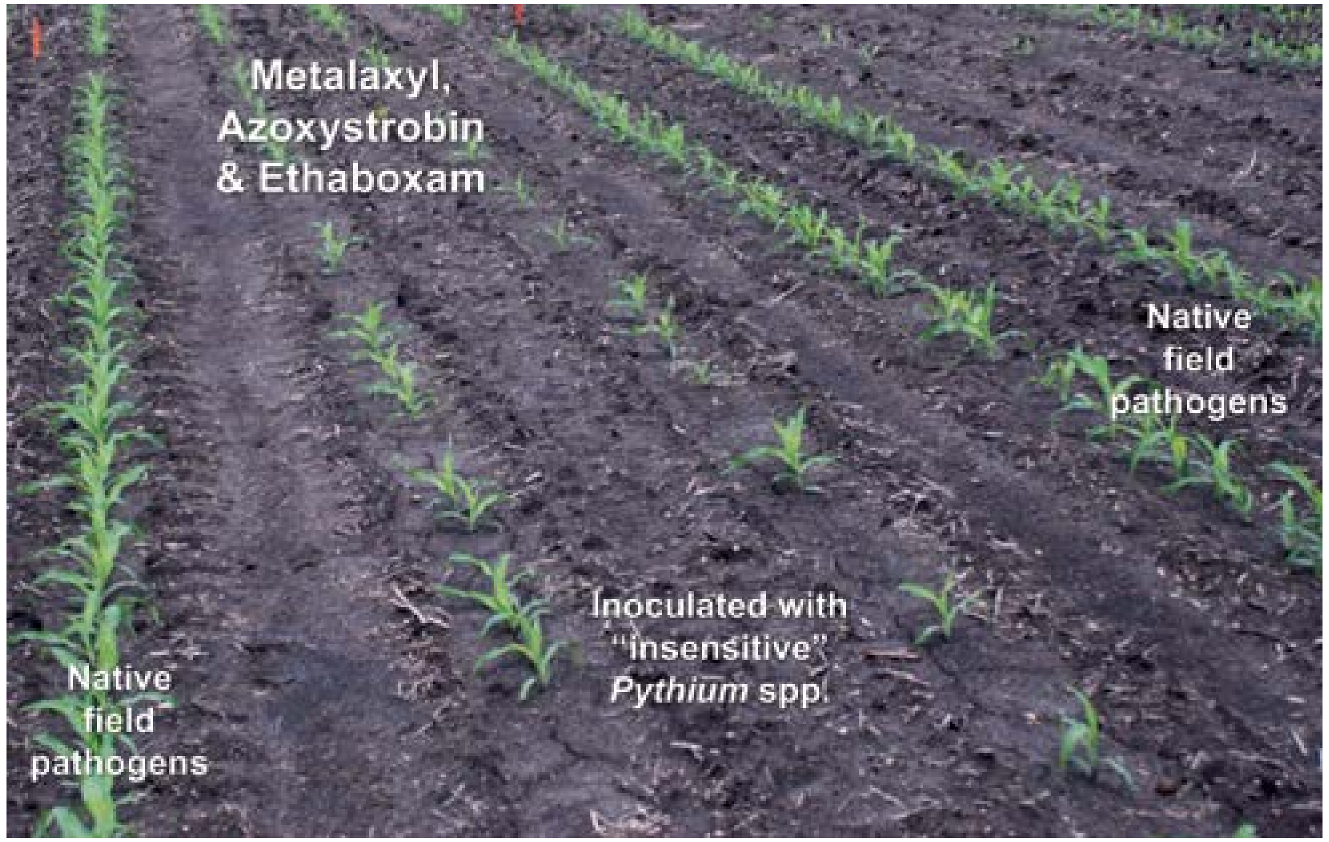


Figure 2. Emergence differences of seed treated with metalaxyl, azoxystrobin and ethaboxam fungicides

mean EC 50 shown represents the effective concentration (EC) at which fungal growth is inhibited by 50%. Lower values observed with Vayantis illustrate the reduced use rate needed to control *Pythium* as compared to the other fungicides. The sensitivity test also illustrates how species such as *P. torulosum* and *P. aphanideramatum* were harder to manage and required higher use rates with ethaboxam, whereas Vayantis offered consistent activity at a much lower use rate across all 18 species commonly found in the Midwest.

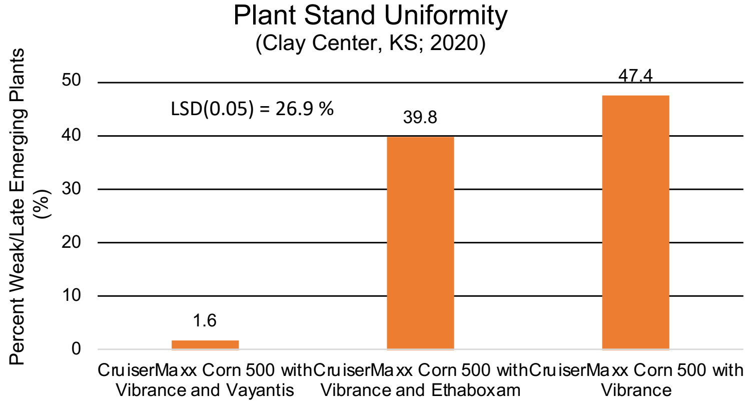
VAYANTIS FIELD TRIAL LEARNINGS

Field trials designed to evaluate stand establishment of seeds treated with different fungicides found similar results as lab screenings when "insensitive" *Pythium* species were present. Figure 1 compares field emergence of seed treated with metalaxyl and fluoxastrobin at rates commonly used in Bayer's Acceleron® seed treatments. Good emergence was observed in rows with native soil pathogens, although few plants survived in rows exposed to insensitive *Pythium* species. In the neighboring plot where seed was treated with Vayantis, good stand establishment was observed in both rows with and without insensitive *Pythium* species being present. In the same trial, emergence of seeds treated with metalaxyl, azoxystrobin and ethaboxam, commonly used in LumiGEN® seed treatments by Corteva Agriscience, had partial stand establishment when exposed to "insensitive" *Pythium* species (Figure 2). Although emergence was improved with ethaboxam, there were fewer emerged plants than when seeds were treated with Vayantis. Neither example, other than those treated with Vayantis, represented a commercially acceptable plant stand and would have required replanting if it was an actual field scenario. There also appears to be some level of "cross-resistance" between ethaboxam and metalaxyl to the *Pythium* isolate present in this field trial. There are no known examples of cross resistance for Vayantis.

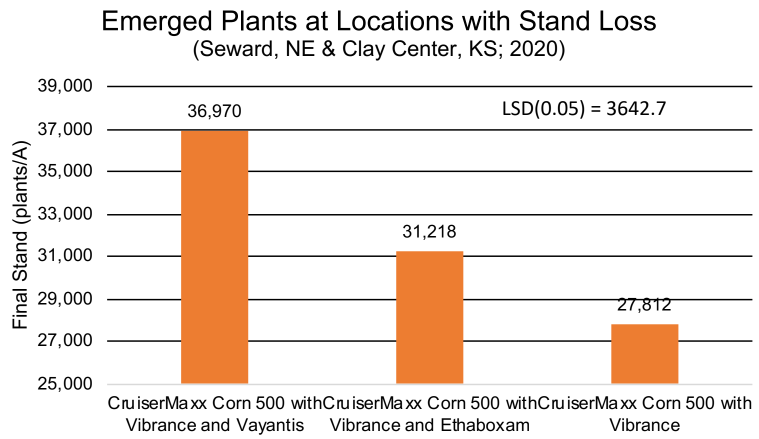
Research trials have repeatedly demonstrated that uniformity of seed emergence and plant growth is almost as equally important as achieving target final population. One Golden Harvest Agronomy In Action research seed treatment trials at Clay Center, Kansas, encountered stressful emergence conditions that resulted in both decreased emergence and uniformity. Seed treated with CruiserMaxx® Corn 500 with Vibrance® containing the oomycetes fungicides mefenoxam and azoxystrobin were compared to seed additionally treated with either ethaboxam or Vayantis. The addition of Vayantis increased plant final stands and decreased the total number of weak plants (plants one or more growth stages behind normal) (Graph 2 and 3). The combination of more plants and improved uniformity resulted in a 20% increase in yield potential in this trial (Graph 4).

SUMMARY

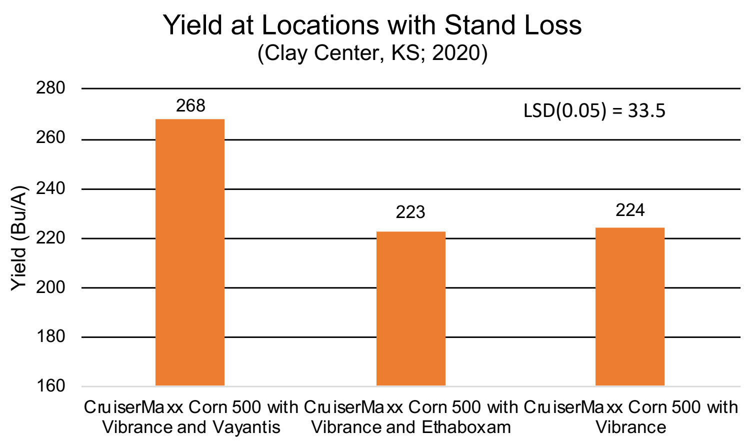
Pythium is one of the leading causes of yield loss in corn. It is commonly the first pathogen seeds encounter each spring and frequently is thought of as the most significant corn seed/seedling disease. *Pythium* commonly causes reduced plant stands, weaker, stunted plants and, ultimately, reduced yield potential. Species of *Pythium* that are less sensitive to some oomycete fungicide chemistries have been observed in Midwestern fields, although the novel new mode of action provided by Vayantis has not been found to be cross-resistant to the same species. Paired with other fungicides that are active against *Pythium*, Vayantis can provide a more reliable way to manage *Pythium*.



Graph 2



Graph 3



Graph 4

CORN ROOTWORM MANAGEMENT

INSIGHTS

- Corn rootworm (CRW) has adapted to decades of management strategies and continues to be destructive.
- Duracade™ trait adds a different tool to the toolbox for rootworm management.
- Diversity in management practices is key for long-term success in managing CRW.

Corn rootworm is the most destructive corn pest in the United States and costs growers more than $1 billion annually in reduced grain yield and control measures. Larvae feed on roots, resulting in underdeveloped root systems, reduced nutrient uptake, weak brace roots and lodged corn (Figure 1). Adult CRW beetles can also interfere with pollination by feeding on pollen and clipping silks, resulting in poor ear fill, and lay eggs in the soil that endanger future corn crops.

Corn rootworm is a difficult pest to manage, to the point that repeated use of the same single management practice will eventually end in disappointment. There is no silver bullet for corn rootworm, but smart planning and hybrid selection are key to building a sustainable, multi-year management plan. Developing a multi-year, field-by-field corn rootworm management plan utilizing different control methods in different years is an important part of addressing one of the most damaging insect pests to corn and ensuring hybrids reach their full yield potential. Understanding if CRW is currently present in fields through scouting or beetle trapping is an important first step in developing management plans. Once the relative risk of CRW is understood, the following management options can be considered independently or in combination as part of a multi-year integrated management plan:

Figure 1. Various levels of corn rootworm feeding

Geographic Distribution of Northern and Western Corn Rootworm and Variants

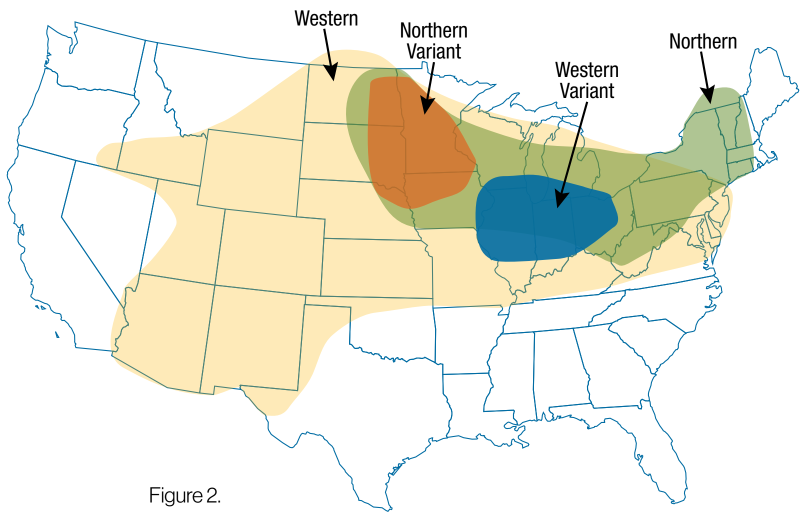


Figure 2.

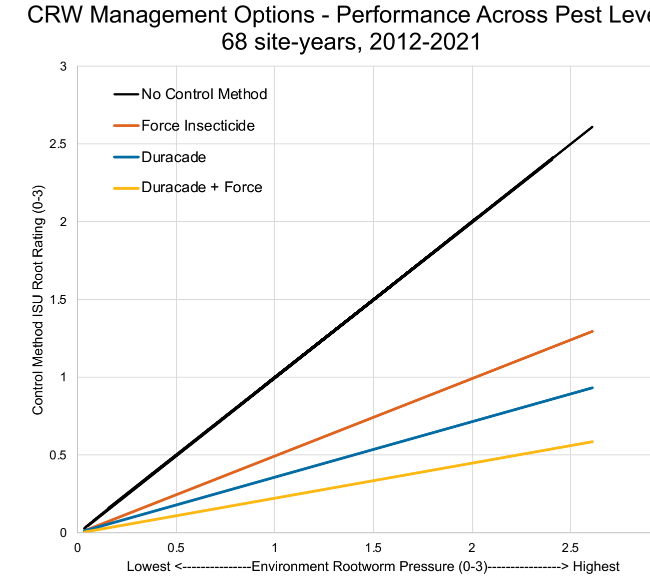
- Crop Rotation – rotate to non-host crops like soybeans to break up CRW's normal lifecycle. Adapted variants of CRW, known as western CRW variant or northern CRW with extended diapause, have changed their lifecycles to overcome single-year rotation (Figure 2). Be aware if present locally and its impact on rotation effectiveness.
- Dual mode of action CRW traits – use different CRW traits like Duracade and Agrisure® Total trait stacks that have more than one CRW trait.
- Soil-applied insecticides like Force® for larvae control.
- Foliar-applied insecticides like Warrior II with Zeon Technology® for adult beetles to minimize silk clipping and reduce egg laying.

Figure 3. CRW damage shown with 2, 1 and 0 CRW modes of action (left to right; Agrisure Duracade, single CRW event, no insect trait)

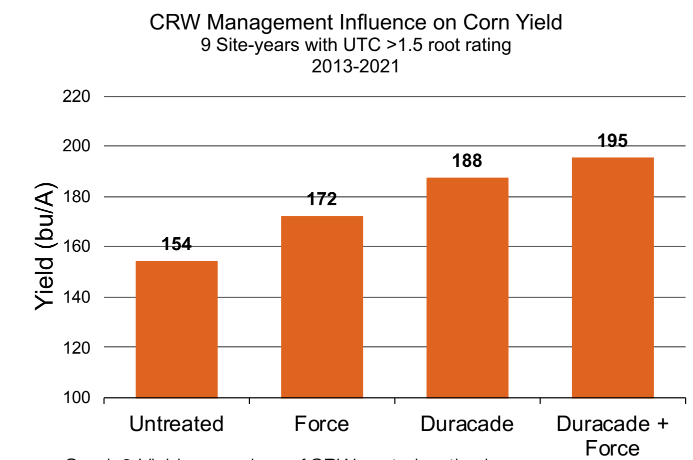
Plans should include the use of different corn rootworm control methods in different years to help minimize the adaptation of corn rootworm to one technology. The plan may need to change each season, depending on pressure, but having it in place gives growers a head start.

The Duracade trait, the most recently registered Bacillus thuringiensis CRW trait, expresses a protein that binds differently in the gut of CRW than any other trait on the market. Additionally, it is always stacked with a second mode of action against CRW, making it a good tool for managing CRW (Figure 3). Agronomy In Action research trials have evaluated the effectiveness of Duracade across multiple years and demonstrated improved root protection (Graph 1) and yield (Graph 2) when used alone or in combination with soil-applied insecticides across many different pest levels.

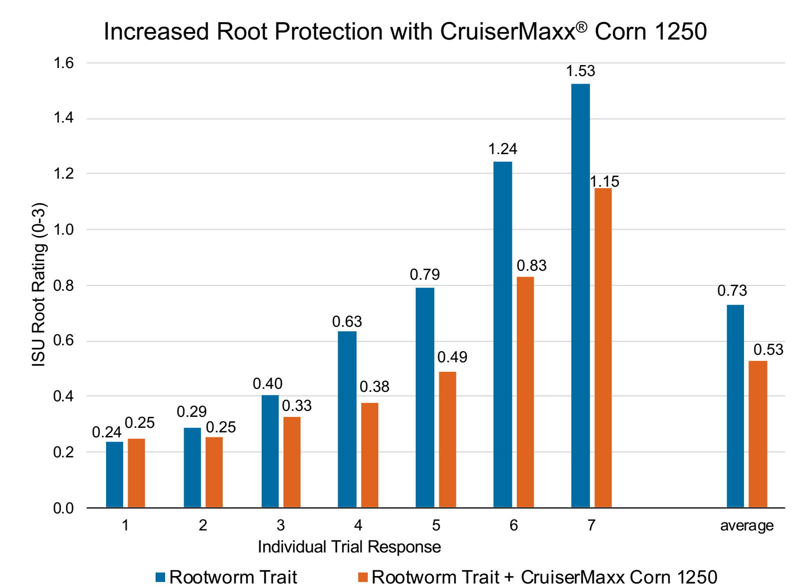
Select Golden Harvest® Duracade hybrids are now available treated with CruiserMaxx® Corn 1250 seed treatment for additional root protection. Corn rootworm trials across 7 locations showed reduced feeding damage at most sites (Graph 3). Whether trying to protect yield or preserve effectiveness of current management practices, effective CRW management will require the integration of multiple control practices, not a singular technology.



Graph 1. CRW root damage comparison of control methods



Graph 2. Yield comparison of CRW control method



Graph 3. Increased root protection with offered with CruiserMaxx Corn 1250 seed treatment

CORN PEST MANAGEMENT
MAIN MENU

MANAGING LOW PRESSURE CORN ROOTWORM

If little to no previous signs of larval feeding or adult beetle populations have been observed and planting corn is selected for areas with western CRW variant, northern CRW extended diapause or corn following corn, consider using at least one of following management practices:

1. Multiple mode of action CRW traited hybrids
2. Non-CRW traited hybrid with Force soil insecticide

If planting first-year corn in areas where CRW has not yet been known to have adapted to corn rotation management, consider using a non-CRW traited hybrid, such as an Viptera™ traited hybrid, that provides broad-spectrum control of above-ground pests. If other soil insects are present, consider adding Force soil insecticide.

OPTIONS FOR MANAGING HEAVY CORN ROOTWORM PRESSURE

1. Crop rotation -- breaking up CRW cycle by rotating to non-host crops, such as soybeans, in fields with a history of high CRW presence or injury should be considered.
2. Traited corn hybrids:
   a. If NO history of root injury on traited hybrids:
      i. Use hybrids with multiple CRW traits
      ii. Scout and consider beetle control with a foliar insecticide to minimize silk clipping and reduce female egg laying
   b. If there is a history of feeding damage to traited hybrid and unable to rotate, use combination of:
      i. Hybrids with multiple CRW traits
      ii. Soil-applied insecticide with traits
      iii. Scout and consider beetle control with a foliar insecticide.
      iv. Seed treatment insecticides

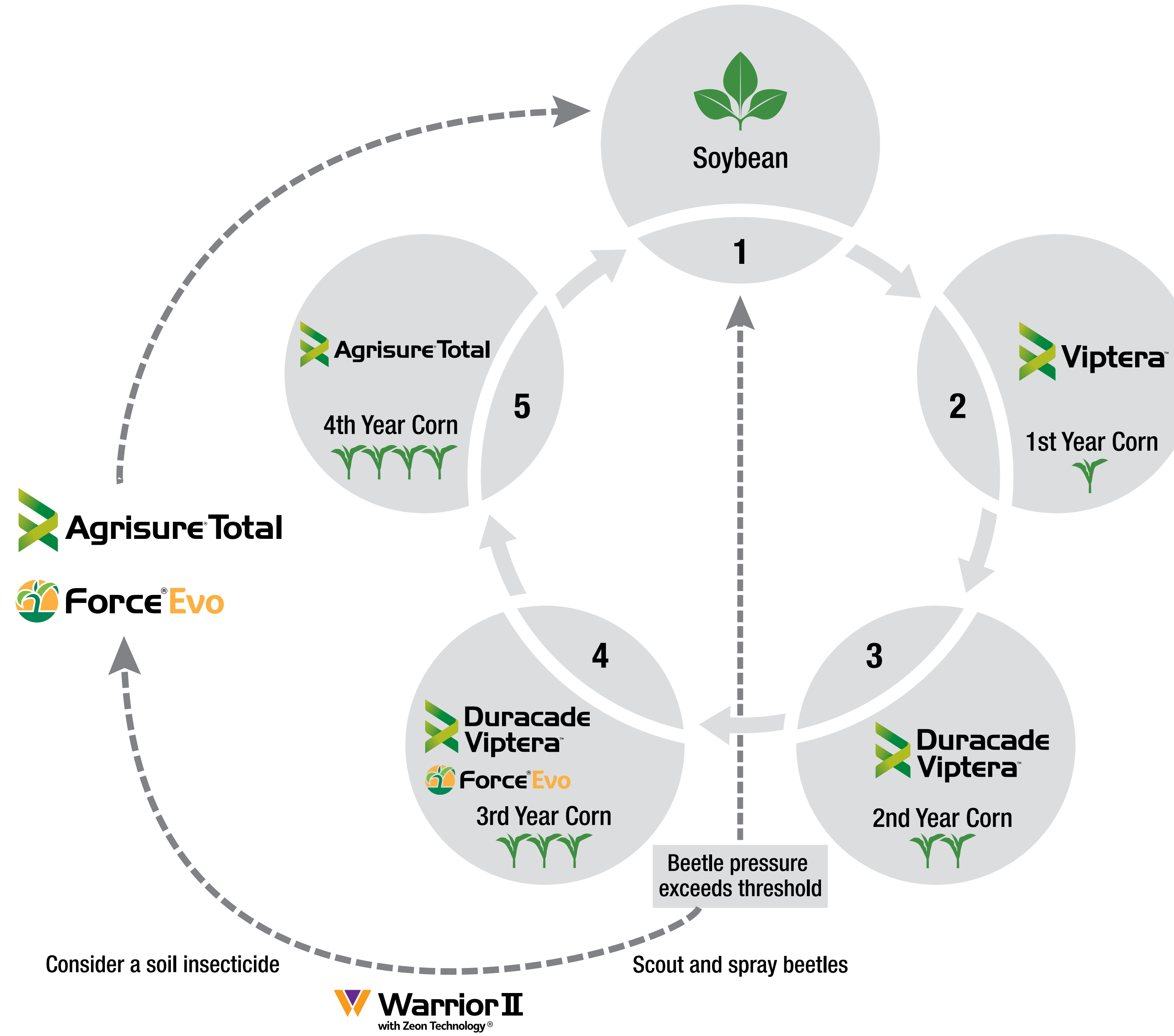
Long-term corn rootworm management requires a multi-year, whole-farm approach. There is an important balance between CRW control, yield protection and resistance management. It is not a one-size-fits-all approach. Effective CRW management will require the integration of multiple control measures, not a singular technology.

CORN ROOTWORM MANAGEMENT TRIAL


Corn rootworm larva


Northern corn rootworm adult


Western corn rootworm adults, female (left) and male (right)



NUTRIENT DEFICIENCY IDENTIFICATION BASICS

INSIGHTS

- Nutrient deficiencies can look like other field issues and may potentially impact corn and soybeans at any time during the season.
- Identifying deficiencies, especially early in the season, may help with management practices to help mitigate the nutrient issues in the future.

IMPORTANCE

Macro and micro soil nutrient deficiencies may be observed due to low soil nutrient levels or presence of environmental conditions that restrict plant nutrient uptake. Diagnosing plant symptoms can be the first step in identifying and correcting future problems. The following is a review of common causes and symptoms of the six essential macronutrients.

Nitrogen: Major component of amino acids, the building blocks of proteins. Important component of chlorophyll which is used in photosynthesis and fuels plant stem, leaf and ear structure growth.

- Pale, yellowish corn plants with spindly stalks
- Corn leaves with V-shaped yellowing on lower (older) leaves starting at tip and progressing down the mid-rib (Figure 1)
- Yellow and premature death of lower leaves, restricted ear and kernel development

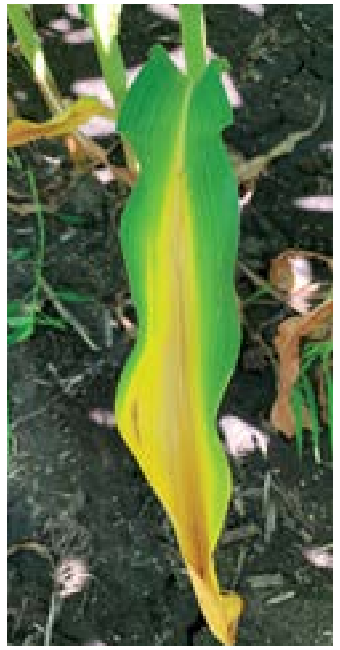


Figure 1. Nitrogen deficiency symptoms in corn

Causes:

- Environmental conditions causing soil nitrogen loss (leaching, volatilization or denitrification)
- Under fertilization
- Sandy soils
- Soybean plants with little or no early root nodulation

Phosphorous (P): Important early in the plant lifecycle to initiate growth and carry out photosynthesis.

- Purple tint that spreads across entire leaf, starting on lower leaves (Figure 2)
- Observed only at early growth stages
- Some hybrids will show similar purpling symptoms even with sufficient P available

Causes:

- Low P testing soils
- Cool soils that are excessively wet or dry, limiting availability
- Compaction

Figure 2. Phosphorous deficiency symptoms in corn

Potassium (Potash or K): Known as the plant health nutrient. Important for regulating plant water use, increasing disease tolerance, stalk quality and standability.

- Yellowing and chlorosis of leaf margins on lower leaves in corn and soybeans (Figure 3)
- Chlorosis of corn leaf tip highly noticeable
- Excessive yellowing and chlorosis of entire lower leaves continue with ongoing deficiency, progressing up the plant
- Upper leaves will remain unaffected due to K being translocated from lower leaves
- Will weaken stalk strength, often causing late-season lodging

Figure 3. Potassium deficiency symptoms in corn

Causes:

- Low K testing soils
- Compaction or other conditions restricting root growth
- Excessively dry soil conditions

Sulfur (S): Has a key role in protein synthesis and many plant functions, including photosynthesis, chlorophyll formation and nitrogen fixation.

- General yellowing of leaves which can be seen in new growth since sulfur is not as mobile within the plant

Figure 4. Sulfur deficiency symptoms in corn

- Stunting, slow growth
- Interveinal chlorosis (loss of green color) in newer growth sometimes (Figure 4)
- Symptoms tend to disappear as soils warm and sulfate mineralization increases

Causes:

- Low soil pH
- Sandy, low organic matter soils
- Cold soil delaying mineralization of S from organic matter

Magnesium

- Yellow to white interveinal striping of lower corn leaves
- Dead, round spots later, with beaded streaking appearance (Figure 5)
- Older leaves may become reddish-purple with tips and margins of leaf later becoming necrotic

Figure 5. Magnesium deficiency symptoms in corn. Source: International Plant Nutrition Institute's (IPNI) Crop Nutrient Deficiency Image Collection

Causes:

- Acidic, low soil pH
- Sandy, low organic matter soils in high rainfall environments
- Can be induced with high potassium availability

Calcium

- Tips of leaves don't unroll and stick together (Figure 6)
- Severe stunting
- Very rarely observed

Causes:

- Acidic or low soil pH levels < 5.0
- Sandy, low organic matter soils

Figure 6. Calcium deficiency symptoms in corn. Source: International Plant Nutrition Institute's (IPNI) Crop Nutrient Deficiency Image Collection

CORN RESPONSE TO INCREMENTAL ZONE-PLACED NUTRIENTS

INSIGHTS

- Place nutrients close to the crop row to minimize risk of loss and increase nutrient availability.
- Focus a fertility program on key nutrients that may be limiting for given yield goals and soil fertility levels.

Crop nutrition is the foundation to achieving maximum genetic yield potential. The Golden Harvest Agronomy in Action research team conducted trials evaluating intensive fertility management practices utilizing precision fertilizer placement and timing. The trial was designed to better answer three main questions:

1. Can zone applying incremental amounts of macronutrients – nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) – and zinc (Zn) in addition to the grower base-applied fertility rates increase yields?
2. Does increasing the rate of nitrogen within the incremental nutrients applied at planting further enhance yield potential?
3. At locations responsive to additional nitrogen, does delaying the application to V6 influence the response?

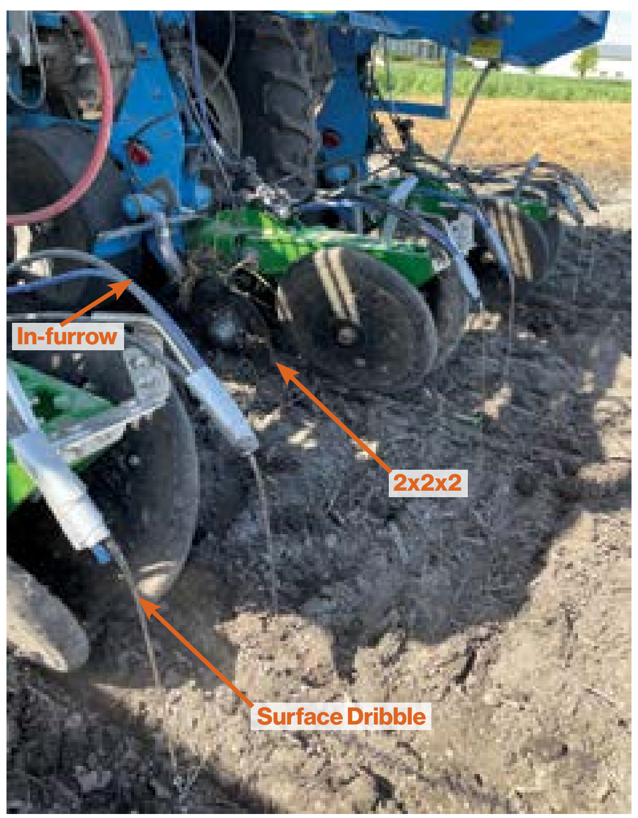


Figure 1. Planter used to apply fertilizer in-furrow, 2x2x2, and surface dribble

To better understand these questions, three incremental zone-placed fertility treatments were compared to the grower-defined base fertility program at nine Midwest locations in 2022. Nutrients, rates and placement of the three treatments are outlined in Table 1.

Precision fertilizer placement was completed using a research planter that can apply 1) seed-safe fertilizer in-furrow on the seed 2) higher rates of fertilizer in a 2x2x2 placement 3) dribble sulfur and/or nitrogen next to the row on the soil surface behind the planter (Figure 1). In-season sidedress nitrogen application was made placing N directly beside the row on the soil surface at the V6 crop stage (Figure 2).

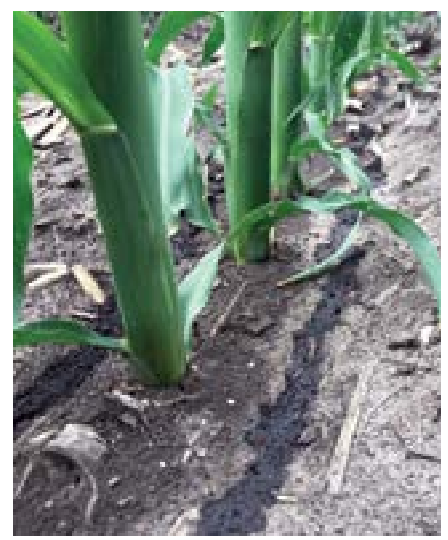


Figure 2. Sidedress surface dribble application placing N along the crop row at the V6 growth stage

Locations varied in soil fertility levels and the base rate of N applied based on local grower management choice (Table 2). All locations had adequate phosphorus and potassium soil test levels except Jefferson, WI, and Malta, IL. Soil P test levels were also below optimum at the Waterloo, NE site, although K level was adequate.

All locations received between 140-200 lbs of N/acre as the base rate except for the two trials at Blue Earth, MN, where the host farmer was only able to apply 30 lbs/acre of nitrogen with their preemergence herbicide program (Table 2). Due to this both Blue Earth locations were N deficient.

CORN HYBRID RESPONSE TO FERTILITY AND THE IMPACT ON YIELD POTENTIAL

YIELD RESULTS

At Blue Earth second location, incremental zone-placed fertilizer increased yields by 11 bu/acre (Graph 1). Since N was a limiting factor, much of the response was likely from the 17 lbs of N/acre rather than the other nutrients applied. Not surprisingly, at the Blue Earth locations, there was a 52-68 bu/acre response when the additional nitrogen (60 lbs/acre) was applied with the planter. Interestingly, although the grower had applied 30 lbs of N/acre and a corn plant takes up less than 20 lbs of N/acre by V3[1], there was still visible growth enhancements from supplemental planter-applied N at that stage (Figure 3). This is an indication that corn plants set their growth trajectory early in the season and it is important to not short crop nutrition during early vegetative growth. Although there were no differences between supplemental N (60 lbs N/acre) application timings at the second Blue Earth location, the planter-applied timing yielded 18 bu/acre more than the V6 timing at the first Blue Earth location (Graph 1).

Jefferson, WI received a more typical preplant N rate (140 lbs/acre) but experienced multiple heavy spring rain

Treatment	Product	Rate (gal/acre)	Placement	Amount of Nutrient Applied (lbs/acre)				
				N	P_2O_5	K_2O	S	Zn
Zone-Placed Incremental Fertility	6-24-6-0.25Zn	5	In-furrow	3.4	13.4	3.4		0.14
	ATS	5	Surface dribble	7			15	
	NACHURS Triple Option®	15	2x2x2	7	22	29	2	
		Total Nutrients Applied		**17**	**35**	**32**	**17**	**0.14**
Zone-Placed Incremental Fertility with Extra Nitrogen at Planting	6-24-6-0.25Zn	5	In-furrow	3.4	13.4	3.4		0.14
	ATS	5	Surface dribble	7			15	
	32% UAN	17	Surface dribble	60				
	NACHURS Triple Option®	15	2x2x2	7	22	29	2	
		Total Nutrients Applied		**77**	**35**	**32**	**17**	**0.14**
Zone-Placed Incremental Fertility with Extra Nitrogen at V6	6-24-6-0.25Zn	5	In-furrow	3.4	13.4	3.4		0.14
	ATS	5	Surface dribble	7			15	
	NACHURS Triple Option®	15	2x2x2	7	22	29	2	
	32% UAN	17	Sidedress	60				
		Total Nutrients Applied		**17**	**35**	**32**	**17**	**0.14**

Table 1. Fertilizer treatments including product used, rate of product, placement of product and amount of nutrients applied for each treatment

Location	Base N Rate lbs/acre	pH	Organic Matter	CEC	P†	K††	S	Zn
			%	meq/100g	ppm	ppm	ppm	ppm
Blue Earth, MN 1	30	5.4	4.5	33	25	188	8	1.3
Blue Earth, MN 2	30	6.1	4.2	30	22	181	6	1.5
Clay Center, KS	150	6.0	1.8	13	29	252	17	1.9
Clinton, IL	200	6.0	3.4	19	47	214	11	1.9
Jefferson, WI	140	7.3	4.8	26	16	158	8	2.3
Malta, IL	200	5.1	4.5	33	19	132	7	2.0
Sac City, IA	180	5.2	4.5	25	67	238	23	6.5
Slater, IA	160	5.4	4.1	35	36	182	6	1.2
Waterloo, NE	200	6.7	2.9	16	10	248	5	1.6

†Weak bray test (20-30 ppm considered adequate) ††Ammonium acetate test (175-250 ppm considered adequate)

Table 2. Soil test values for 9 locations across the Midwest

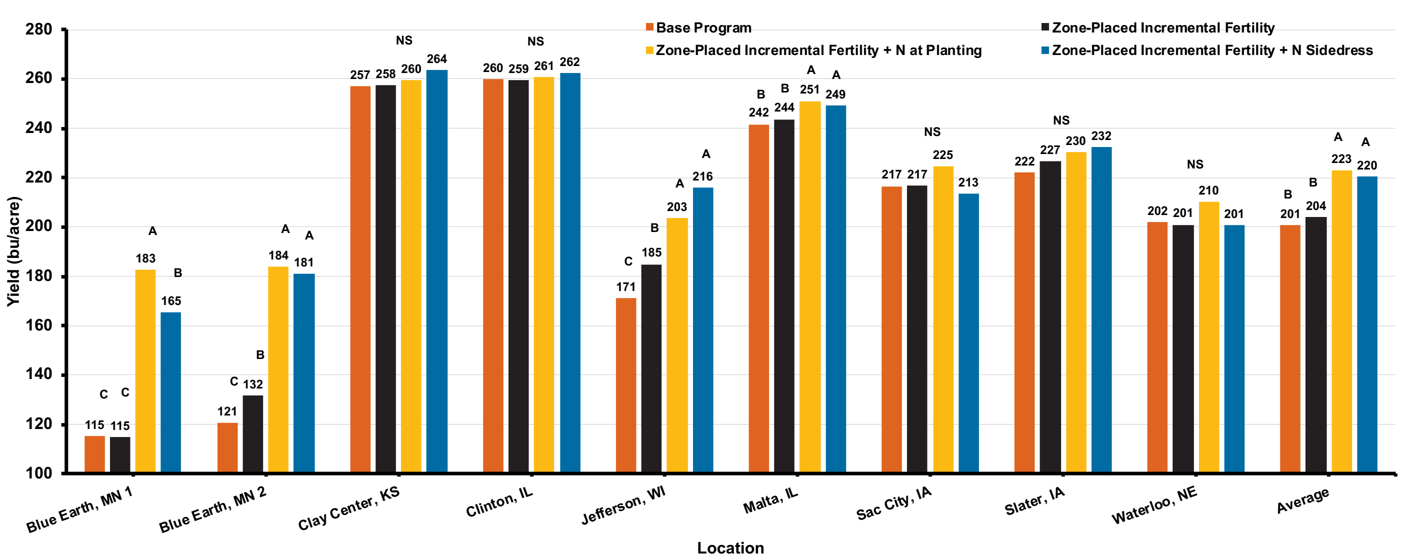
events that resulted in N loss and deficiency symptoms. Incremental zone-placed fertilizer increased yields by 14 bu/acre (Graph 1). The yield response was likely driven by the additional 17 lbs of N/acre from the fertilizer. However, there was likely response to the P_2O_5 and K_2O as well, with soil test levels considered below adequate for both nutrients. Plants at Jefferson that received additional N applied with the planter were significantly taller and more robust during vegetative growth (Figure 4) and yields were increased by 32 bu/acre (Graph 1). Nitrogen applied at sidedress yielded 13 bu/acre greater than if applied with the planter, indicating there was N loss with the early N application from heavy rain after planting (Graph 1). Both Sac City, IA, and Waterloo, NE only saw a response with the early N application yielding 8 bu/acre greater than the base program. Additional N applied with the planter increased yield by 9 bu/acre at Malta, while sidedress N increased yield by 7 bu/acre. Incremental zone-placed fertilizer increased yields by 5 bu/acre and the extra N applied at V6 increased yields an additional 5 bu/acre at Slater, IA (Graph 1).

SUMMARY

Overall, there was smaller responses to incremental zone-placed fertilizer (minus extra N) at most locations and it was difficult to determine which nutrient was responsible for the response. Locations that did have a significant yield increase from zone-placed nutrients without extra N were typically deficient in N. Therefore, the response was likely a result of the small amount of N (17 lbs/acre) included in the fertilizer. Yield increases from the additional 60 lbs N/acre applied either with the planter or sidedress varied depending on location and the timing of crop N demand.

Figure 3. Early growth enhancement from planter-applied nutrients at Blue Earth, MN, in 2022. Base program on the left and zone-placed incremental fertility plus N with planter on right.

Due to trial design, we are not able to determine if the incremental P, K, S and Zn had any influence on the size of the nitrogen response. It is possible that although there was a lack of response to these nutrients at many of the locations, the overall nitrogen response may not have been as great without the supplemental P, K, S and Zn. Phosphorus movement in the soil is minimal and must be close to the root system for uptake through diffusion. Young plants with small roots can struggle to uptake P, especially in conditions that slow plant growth, such as cooler temperatures and dry soils. Zone-placed fertilizer may have increased P uptake and root system development ultimately enhancing the yield response to N. Recently, Purdue University did extensive research evaluating in-furrow and 2x2 starter fertilizer in corn from 2014-2021. They found similar results to our study attributing yield increases primarily to the additional nitrogen rather than other nutrients in the starter.[2]



Graph 1. Effect of intensive fertility management on yield at 9 locations in 2022

Figure 4. Early growth enhancement from planter-applied nutrients at Jefferson, WI in 2022. Zone-placed incremental fertility plus N with planter on left and base program on right.

It is important to understand soil fertility and nutrient uptake patterns in corn. Adding more nutrients does not always mean yields will be enhanced, as demonstrated at both Clinton, IL and Waterloo, NE locations. Crop fertility management should be focused on nutrients that are the limiting factor given yield goals and soil fertility levels.

MANAGING FOR BETTER NITROGEN USE EFFICIENCY

INSIGHTS

- Keeping adequate nitrogen (N) available to the crop all season long involves a systems approach.
- Minimize N loss with optimal N timing, placement and protection with nitrogen stabilizers.
- Urease inhibitors protect against volatilization from surface-applied N.
- Nitrification inhibitors protect against denitrification and leaching by reducing the amount of N in the nitrate (NO_3-) form.

Environmental nitrogen (N) involves a complex cycle that influences plant availability and susceptibility for loss. The goal of nitrogen fertility in corn is to keep adequate nitrogen available to the plant for season-long uptake and utilization.

NITROGEN USE EFFICIENCY

Improving nitrogen fertilizer use efficiency can be accomplished through the 4R Nutrient Stewardship (right rate, right place, right time and right fertilizer source) approach. Applying the correct amount of N based on the environment and yield goals, placing N near the crop rooting zone, timing N applications to crop uptake and using the appropriate N source to minimize N loss is key to optimizing N availability (Table 1).

Fertilizer	Formula	Approximate % as N
Anhydrous Ammonia	NH_3	82
Urea Ammonium Nitrate (UAN)	$NH_4NO_3 + CO(NH_2)_2$	28 or 32
Urea	$CO(NH_2)_2$	46
Ammonium Sulfate	$(NH_4)_2SO_4$	21
Ammonium Nitrate	NH4NO_3	34
Environmentally Smart Nitrogen (ESN)	$CO(NH_2)_2$	44
Diammonium Phosphate (DAP)	(NH_4)2HPO$_4$	20
Potassium Nitrate	KNO_3	14

Table 1. Major sources of N fertilizers

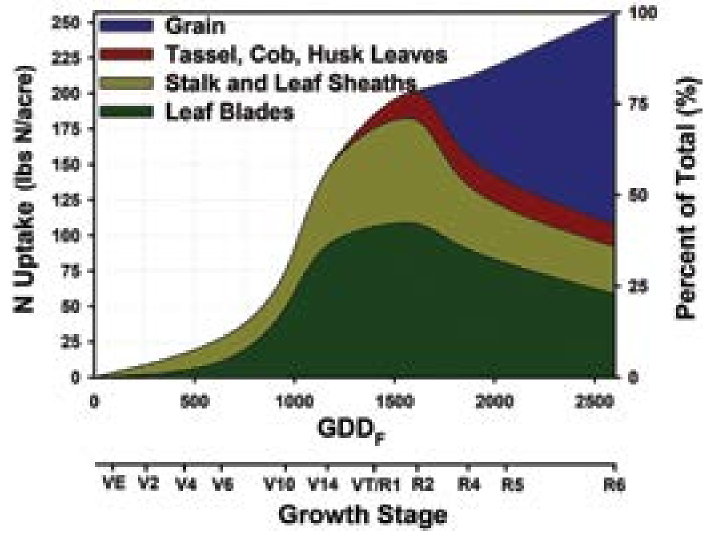


Figure 1. Seasonal N uptake in corn. Peak N uptake occurs between the V8 and VT/R1 growth stages (Bender et al., 2013).

Peak N uptake in corn occurs between the V8-VT/R1 growth stages. During this time, corn takes up 7 lbs. of N per acre per day for 21 consecutive days (Figure 1). Most of the total N amount should be applied during or just prior to this timing. Utilizing slow-release forms of N can help supplement N later in the growing season while minimizing the risk of N loss.

SOURCES OF N LOSS

1. Denitrification

- When soils become saturated and oxygen is unavailable, bacteria convert nitrate (NO_3-) into nitric oxide (NO), nitrous oxide (N_2O), or dinitrogen gas (N_2), which is lost to the atmosphere.
- Conditions conducive to N loss through denitrification include high soil temperature and an increased number of days with saturated soils.
- Ways to avoid denitrification include applying N closer to crop uptake, reducing the amount of N in the nitrate form (NO_3-), and using a nitrification inhibitor.

2. Leaching

- The nitrate (NO_3-) form of nitrogen is negatively charged and therefore does not attract to negatively charged soils, allowing it to move freely with water through the soil profile and potentially be lost through tile lines or reach groundwater.
- Conditions conducive to N loss through leaching include coarse soils (sands), tile drainage and heavy rainfall.
- Ways to avoid leaching include applying N closer to crop uptake, reducing the amount of N in the nitrate form (NO3-) and using a nitrification inhibitor.

3. Volatilization

- When urea-containing N fertilizers are not incorporated by rain or tillage, the urea portion can volatilize into the atmosphere as ammonia gas (NH_3).
- Conditions conducive to N volatilization include moist soil, high relative humidity, high soil pH (>7.0), high soil temperature (>70°F) or frozen soil, crop residue, low cation exchange capacity and poorly buffered soils.
- Ways to avoid volatilization include N fertilizer incorporation (rainfall or tillage), banding UAN fertilizer compared to broadcast and using a urease inhibitor to slow the process of urea hydrolysis.

USING NITROGEN STABILIZERS TO MANAGE LOSS

The inability to control environment and weather most often limits our ability to control nitrogen loss. Under ideal conditions, nitrogen loss can be insignificant. Depending upon the form of nitrogen applied, two different types of nitrogen stabilizers can be used to offset risk of environmentally driven nitrogen loss.

1. Urease Inhibitors

Urea-containing nitrogen fertilizers must first go through a natural chemical process to convert to the plant-available form, ammonium (NH_4+). During this two-step process, urea is first hydrolyzed to ammonia gas (NH_3), which is subject to loss through volatilization

1. Urea Hydrolysis

Urea Fertilizer + Water → (Urease Enzyme) → Ammonia Gas (NH_3) + Carbon Dioxide (CO_2)

$CO(NH_2)_2$ + H_2O

2. Ammonification

Ammonia Gas + Water → Ammonium

NH_3 + H_2O → NH_4^+

Figure 2. Chemical process of urea hydrolysis. Urease inhibitors slow the activity of the urease enzyme.

if applied on the soil surface and not incorporated with tillage or rainfall. Urease inhibitors work by slowing the activity of naturally occurring urease enzymes that are part of the hydrolysis process converting urea to NH_3. Slowing this process increases the opportunity time for a rainfall event to incorporate the fertilizer into the soil before significant N loss can occur (Figure 2). Some of the more common urease inhibitor product names and active ingredients are shown in Table 2.

Urease Inhibitor (Volatilization)		Nitrification Inhibitor (Denitrification/Leaching)	
Product	Active Ingredient	Product	Active Ingredient
Agrotain®	NBPT	Instinct NXTGEN®	Nitrapyrin
Anvol®	NBPT, Duromide	Guardian®-L	DCD
		Centuro®	Pronitridine

Table 2. Common nitrogen stabilizer products

2. Nitrification Inhibitors

In the soil, ammonium (NH_4+) chemically converts to nitrate (NO_3-) through a process called nitrification. Nitrate is subject to loss through leaching. Minimizing the nitrification process can reduce the potential for N loss. Nitrosomonas and Nitrobacter are two naturally occurring bacteria responsible for nitrification. Nitrification inhibitors work by temporarily reducing the population of Nitrosomonas and Nitrobacter bacteria in the soil and/or blocking binding sites on the enzymes within the bacteria where the reaction takes place (Figure 3).

Nitrification

Ammonium NH_4^+ → (Nitrosomonas) → Nitrite NO_2^- → (Nitrobacter) → Nitrate NO_3^-

Figure 3. Chemical process of nitrification. Nitrification inhibitors reduce bacteria populations and/or block enzyme binding sites for the reaction to take place.

Nitrification inhibitors help keep nitrogen in the NH_4+ form longer, reducing risk of leaching or denitrification. Some of the more common nitrification inhibitor product names and ingredients are shown in Table 2.

SUMMARY

Research has shown nitrogen stabilizers, both urease and nitrification inhibitors, to be effective at reducing N loss. However, if conditions are not conducive to the type of N loss they protect against, a yield response to nitrogen stabilizers is unlikely. In addition, if N is overapplied and conditions are conducive to N loss, there may still be sufficient N available when N is not the limiting factor. It is important to use the correct nitrogen stabilizer for the potential source of loss. A urease inhibitor will not protect against NO_3- leaching. Similarly, a nitrification inhibitor will not prevent volatilization loss from surface-applied urea. Understanding a grower's nitrogen program, environment and weather forecast is key to selecting the appropriate nitrogen stabilizer to protect against potential loss and maintain adequate N availability.

Corn plants showing late season nitrogen deficiency

NO-TILL CORN RESPONSE TO P AND S PLACEMENT UNDER HIGH SOIL FERTILITY

INSIGHTS

- Starter fertilizer provides value in high-yield, no-till corn, even when soil test phosphorus (P) and potassium (K) are high.
- Reducing P and K rates should be done cautiously on soils with low nutrient holding capacity based on this trial.
- Banded placement of sulfur (S) may provide additional benefits over broadcast S in fields with low organic matter levels.

INTRODUCTION

Vertical stratification (high nutrient concentration at the surface with decreases at lower depths) of phosphorus (P) and potassium (K) due to repeated surface-applied fertilizers is a great challenge in no-till systems because of the low mobility of these nutrients. While subsurface banding of nutrients can address stratification concerns, research has shown that the advantage of banding over broadcast is minimal when soil P is sufficient.[1,2,3]

Sulfur (S) deficiencies in corn continue to become more common in high-yield situations due to the shift to low-S fuels, as atmospheric deposition had served as an important source, and utilization of fertilizer blends with low S composition. With increased reliance on S mineralized from organic matter, demand can often exceed supply on coarse textured or low organic matter (OM) soils.[4,5] Since mineralization of S is driven by soil temperature, its availability can be delayed or reduced by the cooler soils attributed with no-till. Unlike P and K, S is a highly mobile nutrient. However, can its placement in a no-till setting provide any additional value?

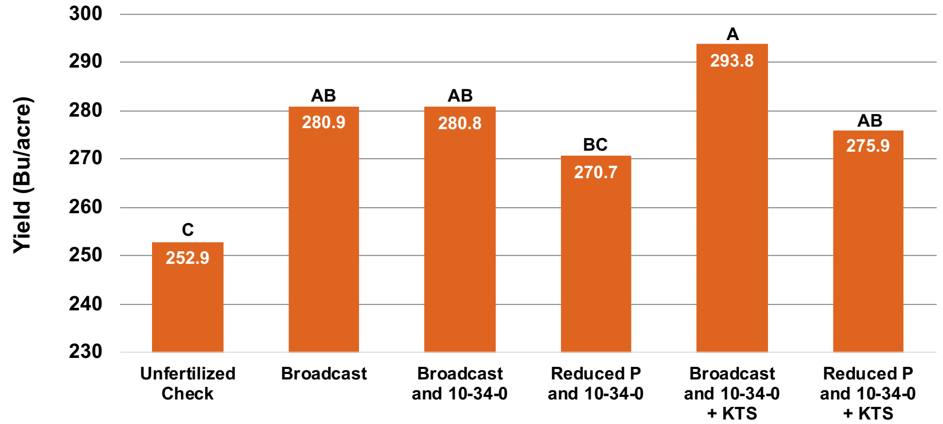
AGRONOMY IN ACTION TRIAL DETAILS

A trial was established in an irrigated, no-till corn-soybean rotation field at Clay Center, KS to answer the following questions:

1) Is there value to starter fertilizer when soil P and K are above sufficient levels?
2) Does reallocating a portion of the amount of N and P applied preseason to a starter application provide positive benefits?
3) Can broadcast P be reduced when soil test P is high and starter fertilizer is used?
4) Does the S application method matter under no-till conditions?

Soil test P and K (0-6-inch depth) were very high at 89 and 305 parts per million (ppm), respectively. Organic matter (OM) was 1.6% and cation exchange capacity (CEC) was 9.7.

Fertilizer treatments were applied either by broadcast in the spring or in 2×2 placement with the planter. Nutrient amounts were balanced for total N, P, K, and S in all treatments (21, 55, 55, and 10 lbs/acre, respectively) except in the reduced P broadcast treatments (21, 45, 55, and 10 lbs/acre, respectively). Fertilizer sources for the broadcast treatments were monoammonium phosphate (MAP, 11-52-0), potash (0-0-60), urea (46-0-0), and ammonium sulfate (AMS, 21-0-0-24). In the reduced P treatment, applied P was reduced 20% from the broadcast combined with 10-34-0 treatment by only reducing the MAP amount. Starter fertilizer consisted of ammonium polyphosphate (10-34-0) at a rate of 7.5 gal/acre for all treatments except the broadcast-only and check treatments. Broadcast fertilizer amounts were reduced accordingly based on starter fertilizer rates being added to maintain equivalent rates to broadcast-only treatments. Potassium thiosulfate (KTS, 0-0-25-17) at a rate of 5 gal/acre was added to 10-34-0 as an alternative S source for some treatments. When this occurred, ammonium sulfate was removed from the broadcast application to keep rates balanced across treatments. No broadcast or starter fertilizer was applied to the check plots. Amounts of total nutrients of each fertilizer source applied within each treatment are provided in Table 1. All plots were side dressed at the V3 growth stage with 150 lbs N/acre of NH_3.



Graph 1. Response of yield to fertilizer addition, allocation and placement at Clay Center, KS. Different letters above bars indicate statistically significant changes (P≤0.10)

RESPONSE TO P FERTILIZER ALLOCATION

Numerical responses to the fertilizer treatments were apparent in the data, but individual plot variability limited most responses from being statistically significant. Fertilizer application either through preseason broadcast or starter significantly increased grain yield by 27.9 bu/acre (11% increase) (Graph 1). This response was likely attributed to N provided in the fertilizer, as pre-plant soil tests only indicated 5 ppm NO3-N (~ 9 lbs N/acre) in the seedling zone and the base field N application was delayed until V3 crop stage. In a study geographically adjacent from this one, greater early growth was observed in plots that received 60 lbs N/acre in addition to starter fertilizer than those that did not (Figure 1). Reallocation of P from broadcast to starter did not affect yield, which is consistent with academic research when soil test P is sufficient.[1,2,3]

Although soil P levels were more than sufficient, numerical reductions in yield were observed when total applied P was reduced (Graph 1). It is important to remember that sufficiency levels on soil test reports indicate the probability of response to additional nutrient applied. Although the very high sufficiency level observed at this site suggests that probability of response is very low, it is not zero. Since CEC at this site is low, opportunity for tie-up of fertilizer P by free cations is reduced, which may explain the response to fertilizer P when soil P was high. Soil K was also very high at this site (305 ppm). It is unlikely that any

Fertilizer Treatment	Total Nutrients Applied (lbs/acre)									
	Dry						Liquid			
	MAP		Potash	AMS		Urea	10-34-0		KTS	
	N	P	K	N	S	N	N	P	N	P
Broadcast	12	55	55	8	10	1	0	0	0	0
Broadcast and 10-34-0	5	25	55	8	10	0	9	30	0	0
Broadcast and 10-34-0 + KTS	5	25	39	0	0	8	9	30	15	10
Reduced P and 10-34-0	3	15	55	8	10	1	9	30	0	0
Reduced P and 10-34-0 + KTS	3	15	39	0	0	10	9	30	15	10
Unfertilized Check	0	0	0	0	0	0	0	0	0	0

Table 1. N, P, K, and S applied by fertilizer source within each fertilizer treatment

responses observed in the trial were associated with or confounded by K, but it cannot be completely ruled out.

RESPONSE TO S PLACEMENT

Banded placement of S typically does not provide any additional advantage over broadcast S, except when soil OM is low.[5] This site, with 1.6% OM exhibited positive, though not significant, responses of ≥5.2 bu/acre to banded application compared to broadcast (Table 1, Graph 1). The limited S supply by organic matter paired with a higher S concentration placed in the root zone with banding compared to broadcast may explain the response. The response to banded S was even more apparent when P and K were not limiting, as yield with banded S increased 13.0 bu/acre as compared to 5.2 bu/acre within reduced P treatments.

SUMMARY

Starter fertilizer is valuable in high-yielding, no-till fields, even when soil P and K are sufficient, due to N responses. This trial did suggest that P fertilization may be advantageous in fields with low nutrient holding capacity (CEC), as opportunity for nutrient tie-up is lower. Banding S in fields with low OM also seems to provide additional value over broadcast, especially when other macronutrients are nonlimiting.

Figure 1. Visual early growth differences in 2022 from the addition of 60 lbs N/acre of surface-applied UAN to 2×2×2-applied starter fertilizer at planting (left) compared to starter only (right). Starter fertilizer contained 17, 35, 32, and 17 lbs/acre of N, P, K, and S, respectively

SULFUR APPLICATION TIMING EFFECT ON CORN RESPONSE

INSIGHTS

- Supplemental sulfur was beneficial to grain yield potential with both application timings at two of eight trial sites.
- Yield responses from sulfur application almost doubled when applied at planting compared to V6 applications when soil test levels were extremely low.
- Differences in hybrid response are likely only to occur when sulfur is extremely deficient in soils.

INTRODUCTION

The occurrence of sulfur deficiency in corn has increased in recent years, largely due to reductions in atmospheric deposition from air emission standard improvements. High organic matter (OM) soils can also help maintain adequate soil sulfur levels as it is mineralized into a plant-available sulfate form. Predicting plant-available soil sulfur levels can be challenging due to delayed mineralization with cooler temperatures. Insufficient spring soil sulfur levels will often reach a sufficient level from mineralization prior to reaching peak demand after pollination. Once mineralized, the sulfate form can also be leached out of rooting zones following periods of excessive rainfall. Soil tests can be used to evaluate soil sulfur levels but may not always account for in-season mineralization or other sources of sulfur such as irrigation water.

2021 CORN SULFUR TRIALS

SULFUR DEFICIENCY IN CORN TRIAL

Sulfur response trials were established at 9 locations across Illinois, Iowa, Kansas, South Dakota and Nebraska in 2021. In addition to understanding frequency of response to sulfur, the trials were designed to evaluate application timing and hybrid response differences. Two hybrids, G10D21 and G10L16, were planted at each location to better understand response differences among hybrids. Sulfur treatments were applied as at-planting and

Figure 1. Twenty pounds per acre of sulfur applied at planting (left) compared to none (right)

V6 timings in separate plots and compared against a non-sulfur treatment. Sulfur applied at the time of planting was surface dribbled 3-inches to each side of the row behind the closing wheel of the planter. Applications at V6 growth stage were applied in a band at the base of the plant on both sides of each row. Ammonium thiosulfate (ATS) 12-0-0-26S, a form of sulfur that is easily applied in a liquid form, was applied at 20 lbs/acre, which simultaneously provided 9 lbs/ac of nitrogen at each timing. All plots not receiving sulfur at planting were treated with 9 lbs/ac of nitrogen in the form of urea ammonium nitrate (UAN) at the same timing. UAN was also applied to all treatments at the V6 timing at a rate that provided an equivalent 50 lbs/ac of total nitrogen to all treatments. Every plot received a total of 59 lbs/ac of nitrogen via the two timings so that nitrogen within ATS did not bias results.

Treatments were replicated 4 times in a randomized complete block design at each trial site. Leaf tissue samples were collected from the ear leaves of all plots and evaluated for sulfur content at the R1 growth stage. Plots were harvested using a research combine to assess grain yield and moisture.

CORN YIELD RESPONSE TO SULFUR

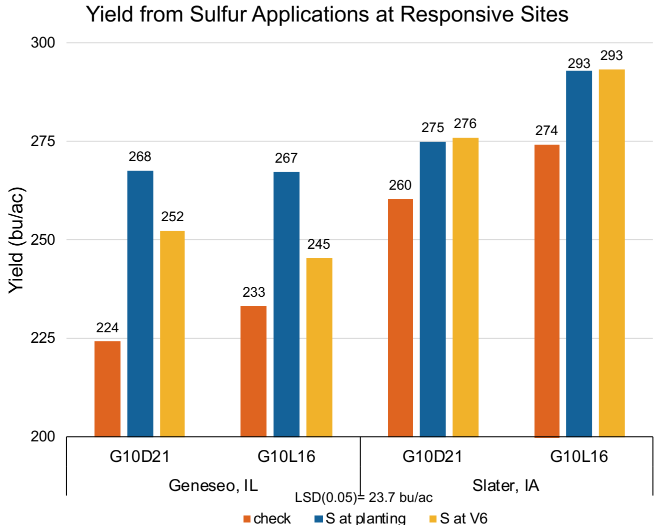
Yield response to sulfur ranged from 0-38 bu/ac across the 2021 trial locations. Of the 7 trials harvested, Geneseo, IL, and Slater, IA, responded significantly more than other locations (Table 1). Both at-planting and V6 application timings responded similarly at Slater with 16.6 and 17.2 bu/ac respectively, although little to no deficiency symptoms were present at the site. Deficiency symptoms were noticeable in non-sulfur treatments throughout most of the spring at Geneseo, which had the lowest soil sulfur test values of all sites.

Sulfur deficiency symptoms were not visible in corn emerging from treatments that received sulfur at planting, whereas treatments delayed until V6 timing showed symptomology for several weeks following the layby applications at Geneseo. Although there was a 20 bu/ac response to the V6 sulfur application at Geneseo, there was an incremental 18.5 bu/ac (38.7 bu/ac total) gained when applications were applied at time of planting. Although the largest yield response at Geneseo was observed with at-planting applications, R1 ear leaf tissue tests indicated higher concentrations of sulfur in plots treated at V6 timing. This may be in part from a reduction in yield components (kernels per row and rows per ear) that were being determined at V5-V8 growth stages while still under stress. This likely reduced the ability to use up available sulfur throughout grain fill, resulting in higher concentrations remaining in the ear leaf than the at-planting applications.

RESPONSE TO SULFUR AVERAGED ACROSS HYBRID			
Location	**Check**	**20 lbs S at V6**	**20 lbs S at-planting**
Clay Center, KS	278.8	274.0	274.8
Clinton, IL	240.8	243.2	237.0
Geneseo, IL	228.7	248.9*	267.4*
Keystone, IA	271.2	270.6	272.5
Sac City, IA	250.3	261.0	252.4
Slater, IA	267.3	284.5 **	283.8**
Seward, NE	286.3	281.7	283.4

Table 1. Individual location response to sulfur application at-planting or at V6

* = significant $p < 0.05$
**= significant $p < 0.10$



Graph 1. Hybrid response to sulfur application timing at responsive sites

HYBRID RESPONSE TO SULFUR

At the Slater trial, hybrids responded similarly to sulfur applications with yield increases ranging from 5.5-7% across the two hybrids (Graph 1). At Geneseo, the V6 application timings improved G10D21 yields by 12% whereas G10L16 appeared to be less responsive to the same application timing with only a 5% yield increase. Early application timings increased G10L16 by 14.6%. However, G10D21 again appeared more responsive with a 19.3% yield increase from at planting applications. As both hybrids yielded similarly within specific sulfur application timings at both locations, it would suggest that G10D21 is slightly more sensitive to sulfur deficiency than G10L16 when sulfur is extremely limiting as it was at Geneseo.

DRIVERS FOR SITE RESPONSIVENESS

Soil and R1 tissue samples from plots not receiving sulfur applications were compared across locations to better understand the lack of responsiveness at sites other than Geneseo and Slater in 2021. Soil tests taken at planting provide a snapshot into plant available sulfur at that point in time but are unable to reflect sulfur that may become available later in the season from sources such as OM mineralization or irrigation water. Normally tissue testing would occur with small plants to allow time to take corrective measures, although in this trial they were taken at R1 to gauge if other sources of sulfur may have mitigated early soil deficiencies. Graph 2 illustrates the relationship of early soil test levels and the R1 tissue test results. Very low soil sulfur levels (5 ppm) and lower soil organic matter content increased odds of seeing responsiveness at Geneseo. Soils with sulfur levels greater than 10 ppm have historically been considered nonresponsive, although Slater had soil levels of 15 ppm and resulted in a significant response. Both Seward, NE, and Clay Center, KS, also had lower soil sulfur levels but had higher leaf tissue test values later in the season and were non-responsive. This may have been in part due to in-season sulfur being partially supplemented through irrigation well water. University of Nebraska irrigation well water surveys found a median value of 35.1 pounds sulfur per acre foot of water sampled, which could have been enough to supplement soil deficiencies.[1] Bridgewater, SD, Keystone and Sac City, IA, locations all had initial soil sulfur levels greater than 20 ppm and soil OM levels greater than 3.5%, greatly reducing chances of responsiveness. In addition, the Sac City location has a long history of manure application, which can contribute to higher amounts of in-season sulfur mineralization. Like yield, sulfur R1 tissue test levels did not increase with either application timing at Clinton, IL. Potentially excessive sulfate leaching occurred at Clinton from multiple periods of excessive rain early in the season, reducing effectiveness of sulfur applications.

SUMMARY

Sulfur deficiency is becoming more common in corn production today. As environmental emissions of sulfur continue to be cleaned up, mitigating sulfur deficiency will become increasingly more important. The extremely complex nature of plant-available sulfur being influenced by temperature, moisture, OM and soil pH levels will continue to make economic sulfur application decisions difficult in the future. Due to similar sulfate and nitrate behaviors in the soil, management strategies such as application timings will need to be similar. Soil and plant tissue sampling can help identify when sulfur may be deficient and identify where economic responses are more likely to occur.

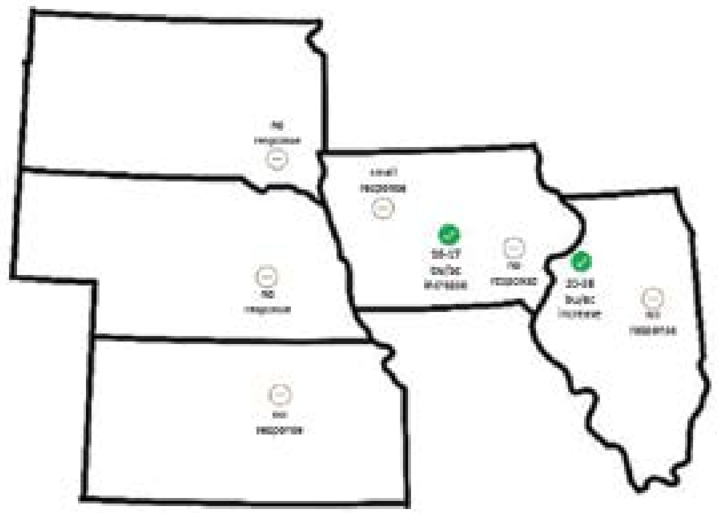
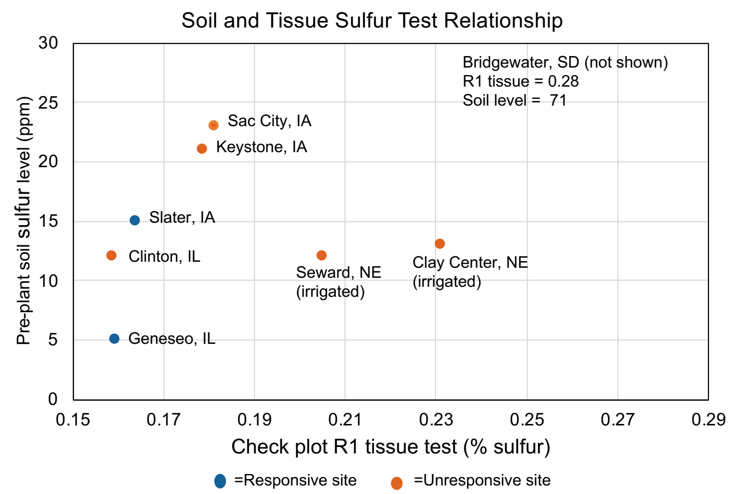


Figure 2. Trial sites in 2021 and average sulfur response



Graph 2. Relationship between early soil and R1 tissue sampling sulfur test results

Figure 3. Sulfur application timing trial at Geneseo, IL in 2021

VALUE OF SOIL ORGANIC MATTER

INSIGHTS

- Soil organic matter (SOM) is a critical contributor of nutrients for crop growth.
- SOM positively affects many soil properties, such as nutrient holding capabilities, water holding capacity and infiltration, soil structure and resistance to erosion.
- Building SOM is a long-term strategy and is focused on increasing organic inputs and moderating microbial activity.

INTRODUCTION

Recent public interest around offsetting greenhouse gases has placed row crop agriculture at the center of discussion, as sequestering atmospheric carbon through SOM has generated interest. There has been emphasis on maintaining or improving SOM for decades. Its measurement is included on most soil test results, yet it generally garners little actionable attention since it is used sporadically for nutrient recommendations. However, as nutrient decisions are impacted by high fertilizer costs, understanding the role of SOM can help support fertility management decisions.

THE BIOLOGY BEHIND SOIL ORGANIC MATTER

Soil organic matter consists of a variety of materials and nutrients, with carbon being the most abundant (58%). It is much more complex than just the residues that remain in the soil after harvest. It also includes any soilborne organisms (dead or living) and their by-products, exudates from roots, and animal manures. The inorganic fraction of soil contains minerals, air and water. Although SOM only represents a small percentage of the overall volume of soil, it is critical to soil functionality and plant health. A single teaspoon of soil can contain up to one billion living organisms that are responsible for key soil processes, such as decomposition, nutrient cycling or bioavailability, and nitrogen fixation, among others.

Decomposition is the primary critical process of soil organic matter dynamics and nutrient release. It occurs when microbes consume residues, using the carbon and nitrogen for energy and metabolic function, and release nutrients as by-products or through microbial death and decomposition.

The ratio of carbon and nitrogen (C:N) determines the quality of various organic material to microbes, and dictates the rate of decomposition, with lower ratios preferred. This explains why corn residue (C:N ratio of ~60:1) is much more persistent in the field than smaller grasses like cereal rye residue (30:1) (Table 1).

Organic Material	C:N Ratio
Sawdust	500:1
Corn residue	60:1
Cereal rye (post-anthesis)	37:1
Cereal rye (pre-anthesis)	26:1
Alfalfa (mature)	25:1
Beef manure	18:1
Alfalfa (young)	11:1
Hairy vetch	11:1
Poultry manure	10:1

Table 1. C:N ratios of various organic plant and animal materials; Data source for table: Carbon to Nitrogen Ratios in Cropping Systems, USDA NRCS, soils.usda.gov/sqi

Soil microbes use carbon and nitrogen at a ratio of approximately 24:1, meaning organic materials with a ratio below 24:1 are more easily decomposed, or mineralized, which releases previously unavailable nutrients. When ratios are greater than 24:1, nutrients are immobilized, meaning microbes are scavenging nutrients from other areas (e.g., soil nitrates) to aid in decomposition since the nitrogen in organic material is not in adequate supply to meet the microbe's nutrient needs. The C:N ratio, soil temperature and water availability are the key mechanisms that affect microbial activity responsible for residue decomposition and subsequent nutrient availability.

COMPONENTS OF SOIL ORGANIC MATTER

A general C:N ratio can technically be calculated from a soil test report, but that number doesn't provide much insight. That's because there are multiple organic matter pools in the soil, and they differ based on their resistance to decomposition: active, slow and stable pools. Each individual pool has important roles in the function of soils.

1. Active Soil Organic Matter Pool

This pool mainly consists of "fresh" plant residues and animal manure. Although it only represents ~5-20% of overall SOM, it is very important to crop nutrition. This is because organic matter in this fraction has low C:N ratios that is very desirable to soil microbes, meaning this pool serves as an important nutrient source to crops. This SOM pool has a turnover time of months to years, meaning it can recycle nutrients quickly. However, it can also be degraded the fastest if organic materials are not replenished at the same rate of decomposition. Although it seems logical that crops with low C:N ratios would be preferred, this can actually lead to faster depletion. Because of this, a balance of crops with low and high C:N ratios will provide consistent nutrient release.

2. Slow Soil Organic Matter Pool

This pool has a decomposition rate that ranges from years to decades and can include fresh organic matter and some that has gone through partial decomposition.[3] Its unique characteristic is that it is either chemically or physically protected from microbial decomposition. Chemical protection typically occurs when it has been decomposed to a point, and it is energy-intensive for microbes to continue decomposing it. Physical protection occurs when microbes cannot access the organic matter. Exudates from plants and microbes acts as a "glue" that binds soil particles together, thus forming a physical barrier between the microbes and organic matter fragments (Figure 1). This process is called aggregation, and is a critical process that creates soil structure, which improves water infiltration, root penetration, and resistance to erosion.[2]

3. Stable Soil Organic Matter Pool

This is the largest SOM pool (~60-90%), and its rate of turnover is much, much slower (hundreds to thousands of years) than the active and slow pools.[1] Stable SOM, commonly called humus, has been degraded to the point where it has very little nutritive (energy) value to soil microbes. In fact, it is so decomposed that is has likely survived hundreds, if not thousands, of microbial ingestions. This pool is responsible for the "black" color associated with high SOM content, as it is organic matter

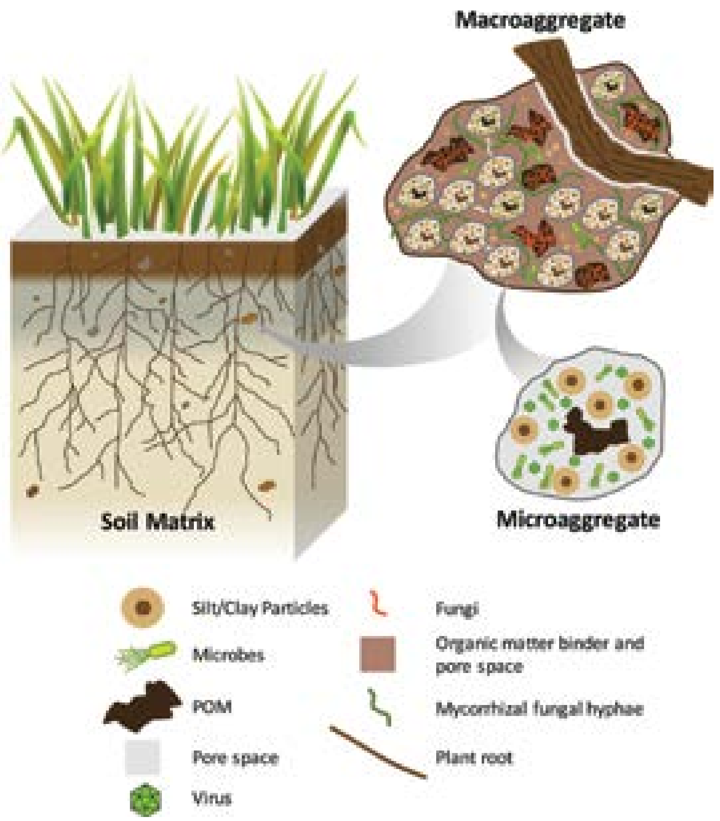


Figure 1. Composition of soil aggregates. POM, particulate organic matter; Source: Wilpiszeski et al., 2019[4]

coatings on clay particles. Although it may sound like an insignificant pool, stable SOM provides incredible value to critical soil chemical processes. Most importantly, this pool affects the soil's cation exchange capacity (CEC), which is the ability to hold nutrients, because SOM has 4 to 50 times higher CEC than clay particles (the other soil component that influences CEC). In addition to nutrient-holding capacity, this also makes a soil more resilient to rapid pH changes and improves water holding capabilities.

RELATIONSHIP BETWEEN SOM AND GREENHOUSE GASES

It can be difficult to see the parallel between carbon in SOM and greenhouse gases in the atmosphere. The link between the two is plant growth. In simple terms, plants remove carbon dioxide from the atmosphere for photosynthesis. A portion of this carbon can then potentially be converted to stable carbon (as SOM), resulting in the sequestration of atmospheric carbon. In general, one pound of sequestered carbon in the soil (1.7 lbs SOM) offsets ~3.6 lbs of carbon dioxide.

BUILDING ORGANIC MATTER IN SOILS

Increasing SOM is a long-term goal, as it can take several years before changes can even be scientifically detectable. To increase SOM by 1% in the top six inches, ~20,000 lb/acre of organic matter above microbial demand would need to be added. For context, 200 bu/acre corn produces ~9,000 to 10,000 lb/acre of residue, and only a small portion is ultimately converted to stable SOM under optimal conditions. This simple estimate demonstrates how many crop cycles would be needed to obtain a larger SOM increase.

Building SOM happens through two main principles: 1) addition of more organic materials, and 2) moderating microbial activity. While the importance of microbial activity for nutrient availability was previously discussed, overactivity of microbes can actually have negative effects, as a by-product of their physiological activity (respiration). The carbon dioxide ultimately escapes back to the atmosphere. Management practices that promote building organic matter include:

- **Tillage reduction:** Tillage stimulates microbial activity, which accelerates OM decomposition, and aerates the soil, which oxidizes OM and releases carbon dioxide. Tillage also breaks aggregates, leaving previously protected organic matter exposed for decomposition or susceptible to loss via erosion.
- **Cover crops:** They increase the period of growing season where carbon dioxide is removed from the atmosphere and converted to organic carbon as plant biomass. They also sequester free nutrients, which can

generally be easily mineralized and released due to their favorable C:N ratios. Legume cover crops exhibit lower C:N ratios due to their nitrogen fixation capabilities.

- **Minimal residue removal, if at all**: Baling cornstalks for feed use is very tempting, especially when forage value is high. However, continuous residue removal substantially reduces the amount of organic matter available for conversion to SOM. Tillage paired with residue removal greatly accelerates SOM loss.

SUMMARY

CARBON TO NITRO RATIO IN SOIL

Soil organic matter plays a critical role in nutrient cycling, water infiltration, soil structure, and nutrient-holding capabilities. Improving SOM in soils is a long-term strategy and can be difficult when SOM is already high. However, soils with improved SOM can be a tremendous nutrient resource to plants and be more resilient to extreme weather due to improved water infiltration and holding capabilities.

SOIL FERTILITY CONSIDERATIONS FOLLOWING A DROUGHT

INSIGHTS

- Drought conditions can influence soil properties. Soil testing can help to accurately estimate nutrient availability.
- For every 1 bushel of corn produced, 0.38 lbs of P2O5 (phosphorus) and 0.27 lbs of K2O (potassium) are removed.
- Drought can reduce nitrogen and sulfur mineralization and plant availability, potentially influencing availability the following year.

INTRODUCTION

Many areas of the Midwest experienced periods of drought throughout the 2021 growing season (Figure 1). Drought conditions not only influence plant growth and crop performance but can also influence soil properties and nutrient availability. As farmers look to 2022, there is concern about the increased fertilizer prices that may cause them to reconsider their fertility program. There are a few methods to monitor the soil-water interactions to make the best fertility recommendations for next year.

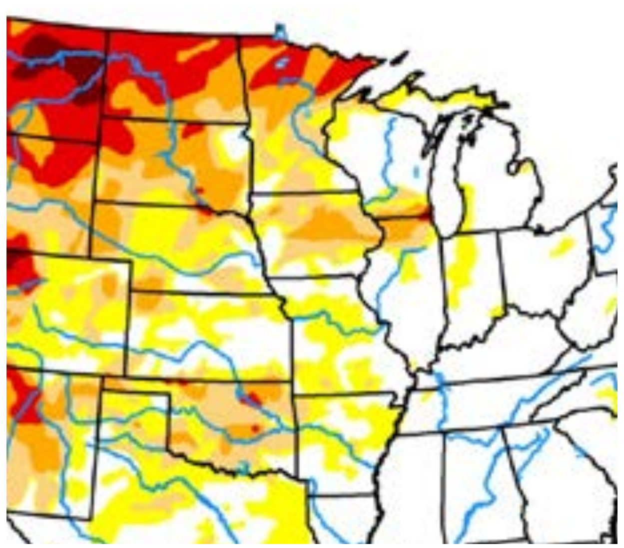


Figure 1. Drought-stressed areas on Sept. 28, 2021
Source: https://droughtmonitor.unl.edu/

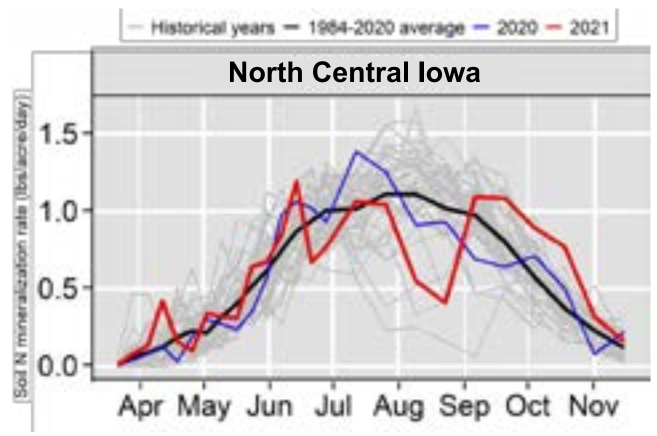


Figure 2. Nitrogen mineralization rates in north central Iowa
Source: Iowa State University FACTS, https://crops.extension.iastate.edu/facts/soil-n-mineralization

DROUGHT IMPACT ON SOIL NUTRIENT INTERACTIONS

Drought conditions reduce soil mineralization, decreasing the availability of nitrogen and sulfur from organic matter. This predominately influences the current crop. Figure 2 shows the average rate of mineralization (black line) in north central Iowa in 2021 and the drop in the red line correlates to the lack of precipitation during that time. Under these dry conditions, plant nutrient uptake is also reduced for nitrogen and sulfur since they translocate with water.

Without water, nitrogen and sulfur leaching is reduced, potentially improving their availability for the next crop. As a result, soil nitrates accumulate in soils in drought conditions. These can remain until the following year, but heavy rainfall in the spring can cause leaching and make the nitrogen unavailable to the new crop.

Immobile soil nutrients, such as phosphorus and potassium, do not leach under wet soil conditions, and are predominately removed from the soil through soil erosion and plant uptake. Both of these nutrient loss mechanisms are often reduced in drought conditions, potentially resulting in above-average potassium and phosphorus available the following year. The exception to this can be soil availability from windblown sediment if there is not sufficient residue cover, such as from heavy tillage management. These water-nutrient interactions can be complex and unpredictable, but there are some management solutions.

Figure 3. Soil sampling with soil probe

CROP NUTRIENT REMOVAL CONSIDERATIONS

The amount of nutrient uptake under drought conditions can vary based on the timing and the severity of the drought. If dry weather occurs early in the season or for only a short period of time, there may be no negative impact on yield. In this case, nutrient uptake may be consistent with previous years. In a severe drought, crop growth may be stunted and productivity reduced. In these scenarios, the crop likely extracted fewer nutrients from the soil which may be available for the following year.

Using the yield of the field, the amount of nutrients removed from the soil can be estimated. For every 1 bushel of corn produced, 0.38 lbs of P2O5 and 0.27 lbs of K2O are removed. Using this method when yields are significantly different than previous yields, can help make more accurate fertility recommendations.

MORE INFORMATION ON HOW REMOVAL RATES IMPACT ROTATIONAL CROPS

SOIL TESTING FOLLOWING DROUGHT

Soil sampling for nutrients is one of the most reliable ways to know the nutrient availability of a field (Figure 3). When soil sampling, always collect the depth of the sample that the soil lab recommends. Fertility recommendations are based on nutrient calibration curves for a specific sample depth, typically 0-6-inches or 0-8-inches, so anything shallower or deeper than those recommended depths will skew results. In dry soils, taking a deep enough sample can be especially challenging. Also, in dry conditions, nutrients are often concentrated in the top few inches of the soil profile without water to move them downward. As a result, a shallow soil sample would likely have high soil test values and underestimate fertility recommendations.

In a drought, just as there is increased variability in yield potential, there is also increased soil variability across a field. The different landscape positions, water-holding capacity, nutrient uptake and mineralization will all vary across a field, resulting in extreme nutrient concentrations. Often soil test values in dry conditions can seem out of the ordinary or may have samples that are outliers compared to the rest of the field. To combat this, consider increasing the density of soil samples collected in a field following a drought. It may also be beneficial to compare to previous soil sample results. Patterns of results from normal precipitation years compared to sample results from dry years can show trends and help make accurate fertility recommendations.

DISCUSSION

In a drought, mobile nutrients such as nitrogen and sulfur may be less available to the crop. However, with reduced leaching potential, there is often increased concentration of these nutrients for the following year. Immobile nutrients such as potassium and phosphorus may also be more available following a drought if yields were reduced and there was less crop nutrient uptake. The nutrient availability may be unpredictable, so use yield to estimate the crop removal and proper soil sampling techniques for 2022 nutrient management planning.

SOURCE CORN: A BIOSTIMULANT FOR CORN

INSIGHTS

- SOURCE Corn improved grain yield by an average of 4.1 bu/acre across five trials (range of 3.1 to 5.6 bu/acre).
- Hybrid selection did not affect the response of yield to SOURCE Corn.
- Root biomass differences due to SOURCE Corn were not consistently observed.

INTRODUCTION

Microbial or biostimulant products that can be tank mixed with fertilizer or pesticides have been utilized more often in recent years. These products typically target soil biological or chemical processes in an effort to improve plant nutrient availability. However, there is still much uncertainty in many of these products regarding their true yield impact and fit with different farmer management practices.

SOURCE Corn, developed by Sound Agriculture, is a foliar product that has shown to positively increase grain yield by ≥ 4 bu/acre in a university trial.[1] The active ingredient, maltol lactone, is expressed by plant roots, which stimulates soil microbes that have nitrogen-fixing or phosphorus-solubilizing capabilities, which increases availability of these nutrients to the plant.

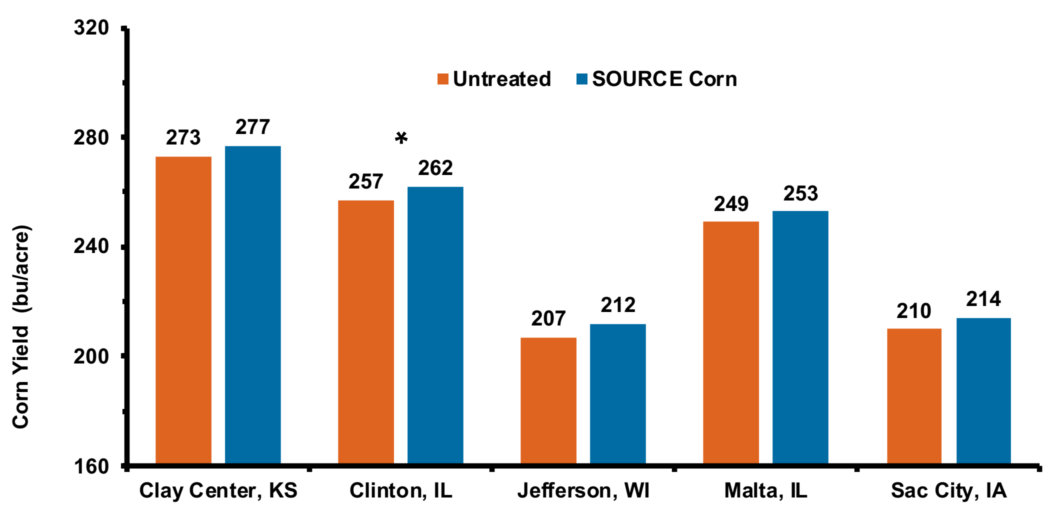
TRIAL DETAILS

Experiments were conducted at five Agronomy In Action sites to assess the agronomic impact of SOURCE corn. Within each location, two different fertility scenarios, "standard" and "intensive," were established to test whether base fertility levels would influence hybrid yield response to SOURCE Corn. The standard fertility practice consisted of the farmer's fertility program at each site. The intensive fertility treatment consisted of the farmer's normal fertility program and an additional planter-applied application of 70 lbs/acre N, 36 lbs/acre P2O5, 32 lbs/acre K2O, 15 lbs/acre S, and 0.15 lbs/acre Zn applied through a combination of in-furrow, 2×2×2, and surface dribble application methods.

Four hybrids with varying degrees of root architecture were selected to test for possible hybrid interactions. SOURCE Corn was applied as a broadcast spray treatment at the V4 growth stage at a rate of 0.7 oz/acre with non-ionic surfactant (0.25% V/V rate) and water as the carrier.

SOURCE CORN EFFECTS ON YIELD

When averaged across hybrids, fertility regimes and locations, there was an average response of 4.1 bu/ac resulting from SOURCE corn applications with individual location results ranging from 3.1 to 5.6 bu/ac. Clinton, IL, (4.3 bu/ac response) was the only location observing a statistically significant response of the five trial locations (Graph 1).



Graph 1. Response of corn yield to SOURCE Corn at five responsive Agronomy In Action sites averaged across two fertility regimes. Asterisk denotes significant differences at P≤0.10

FERTILITY LEVEL INFLUENCE ON SOURCE RESPONSE

Incremental fertilizer applications were applied as a subplot to understand if base fertility levels influenced the response to SOURCE Corn. All sites except Clinton, positively responded to intensive fertility (2.0 to 41.4 bu/acre). At these sites, the response to SOURCE Corn did not differ between standard and intensive fertility treatments. At Clinton, there was a 9.3 bu/ac response to SOURCE Corn within the grower- applied base fertilizer rate, but no response when incremental fertility was added (Table 1).

DIFFERENTIAL HYBRID RESPONSE TO SOURCE

No incidences occurred where yield of a particular hybrid responded differently to SOURCE Corn, and this was consistent in both fertility scenarios. To assess if SOURCE Corn affected any root characteristics, root digs of G10L16 were conducted at multiple locations. This hybrid was selected based on having a below-average root biomass rating. Despite this, no visual responses were observed at any location between the control and SOURCE Corn plants (Figure 1).

SUMMARY

SOURCE Corn had varying levels of impact on grain yield (3.1 to 5.6 bu/acre), though only one location, Clinton, exhibited a statistically significant response. Any yield increases were not a product of root mass increases, as no distinguishable changes were visually observed. Neither high fertility nor hybrid had any influence on the response to SOURCE Corn. On-farm experiments are the best indicator to determine the true value to an individual farm operation.

Figure 1. No distinguishable root biomass differences observed between the control (left) and plants treated with SOURCE Corn (right) of G10L16

Fertility Scenario	Treatment	Clay Center, KS	Clinton, IL	Jefferson, WI	Malta, IL	Sac City, IA	Average
Standard	Control	270.5	255.2	186.3	245.7	209.1	230.0
	SOURCE Corn	274.1	264.5	191.6	244.7	212.9	234.1
	Yield Response	**3.6**	**9.3***	**5.3**	**-1.0**	**3.8**	**4.1**
Intensive	Control	274.9	259.2	227.3	252.8	211.7	241.8
	SOURCE Corn	279.5	258.6	233.3	260.5	214.2	245.8
	Yield Response	**4.6**	**-0.6**	**6.0**	**7.7**	**2.5**	**4.0**

Table 1. Response of corn to SOURCE under standard and intensive fertility. Asterisk denotes significant response at *P*≤0.10

MISCONCEPTIONS OF MANURE NUTRIENT AVAILABILITY

INSIGHTS

- Manure can be an important part of a soil fertility program, especially as fertilizer prices rise.
- Available nutrients in a manure source should be analyzed carefully and planned accordingly with soil sample information.

INTRODUCTION

Manure is a key part of a crop fertility program for many farmers and may become a component of more fertility programs as fertilizer prices rise. If managed correctly, manure can help reduce input costs. However, there are factors of manure nutrient availability that should be understood.

MANURE TYPE AND NUTRIENT LEVELS

Nutrient analysis of a manure source can vary depending on the animal source (Figure 1), how it is stored, water dilution and the bedding and diet of the animal. It is recommended to have the manure source regularly tested by a laboratory (typically offered through university agriculture programs) for more precise measurements of nutrient levels. There are some resources available online to help provide average ranges of manure nutrient percentages, as well as the percent moisture of various manure sources. Knowing the moisture percentage of a manure source is helpful to calculating the quantity of nutrients applied at a given rate because water has a diluting effect on the final nutrient concentration of manure.[1]

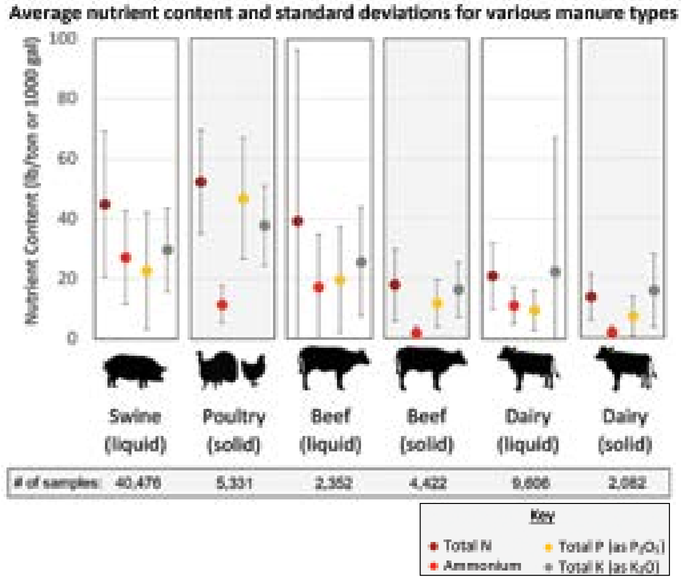


Figure 1. Nutrient ranges of different manure types from nutrient analysis
Source: Melissa Wilson, University of Minnesota Extension[3]

MANURE NUTRIENT EFFICIENCY

Nutrients from manure can be found in both organic and inorganic forms, so they may not always be as readily available to plants as commercial fertilizers. Some nutrients, such as potassium and certain nitrates, may be obtainable from the soil quite rapidly, but the availability of other nutrients may take much longer. When building a nutrient management plan using manure, 100% of the nutrients should not be considered available in the first year.[2] It can take up to four years for nitrogen, phosphorus and potassium to be fully available for the crop when applied as manure. As a rule of thumb, 80% of potassium and 90% of phosphorus are likely available during the first year.[1]

Predicting nitrogen availability can be more complex as it is dependent on both animal species and application method.[1] Nitrogen from raw manure is available as ammonium, which is immediately available to plants, and in an organic form, which must be mineralized into ammonium before being useful. Ammonium also has the potential to convert to ammonia and be lost through volatilization. Incorporating manure as quickly as possible greatly reduces the amount of nitrogen lost with volatilization. Due to delays in mineralization, it should be expected that a portion of plant-available nitrogen from manure will not be available until one year after being applied. Table 1 illustrates how second-year nitrogen credits could range from 15-25% of the total nitrogen applied, depending on method of application and animal species.

MANAGEMENT CONSIDERATIONS

Soil Sampling

Soil testing and understanding current soil nutrient levels is important. If a field has high phosphorus and/or potassium levels, caution should be used in applying excessive amounts of manure. Excess levels of phosphorus and potassium in a manure application can interfere with the uptake of copper and/or zinc, which may lead to deficiencies in the crop, such as decreased moisture uptake (zinc) and decreased stalk strength (copper). Excess potassium may also interfere with the uptake of boron and magnesium. This may also be a cause for concern, as boron is important for cell structure, pollination and grain-fill, while magnesium plays a key role in chlorophyll and enzyme production. Thus, a deficiency in these may lead to stunted crop growth and increased drought stress.

	Injection with knife or coulter	Injection with sweeps	------Broadcast + Incorporate------ 0-12 hours (including double disks)	12-96 hours	>96 hours
		----------------N available/ year	-----------------		
Beef					
yr 1	50%	60%	60%	45%	25%
yr 2	25%	25%	25%	25%	25%
Dairy					
yr 1	50%	55%	55%	40%	20%
yr 2	25%	25%	25%	25%	25%
Swine					
yr 1	70%	80%	75%	55%	35%
yr 2	15%	15%	15%	15%	15%
Poultry					
yr 1	n/a	n/a	70%	55%	45%
yr 2	n/a	n/a	25%	25%	25%

Source: Melissa Wilson, University of Minnesota Extension[3]

Table 1. Manure nitrogen availability and loss affected by method of manure application and animal species

Soil sampling is also important in years following the manure application to understand the plant-available nutrients. Different soil types and soil properties can affect the rate of mineralization of the nutrients in the manure.

Manure Sample Testing

Manure sampling is very insightful to understanding the nutrient content to ensure accurate application rates. Nutrient value in manure can vary based on factors such as type of storage, so multiple samples throughout the storage system are recommended. Another solution to the variability is to agitate manure in the storage system prior to application for a more even distribution of nutrients.

A possible concern to keep in mind from manure applications is the potential for a liming effect to occur. This tends to be a more common occurrence in feedlot manures, as they are more likely to contain higher levels of calcium carbonates – a common additive to feedlot cattle diets. To determine the percentage of calcium carbonate equivalent more precisely in manure, it is recommended to request an effective calcium carbonate (ECC) commercial fertilizer test to aid in determining optimal application rates.

Application Timing and Method

The timing of a manure application influences the amount of nitrogen loss in a cropping system. If the application occurs on a warm day or in dry soil conditions, there can be significant nitrogen loss to volatilization which reduces the amount of nitrogen available to the crop.

How quickly manure is incorporated and the method used can have dramatic impacts on nitrogen loss rates. As an example, plant-available nitrogen in year 1 from swine manure can be as high as 80% when injected with sweeps and as low as 35% if broadcast and incorporated 4 days later.

Table 1 outlines the variability of nitrogen availability by animal species and application method.

SUMMARY

Manure has high nutrient value and soil health benefits, but proper management, such as application rate, timing and placement is important. Consistently collect manure samples to understand the nutrient content and soil samples to know the appropriate application rate.

CAN SOYBEAN BLENDS HELP MINIMIZE RISK?

INSIGHTS

- Identifying blended combinations that outyielded individual soybean varieties was difficult.
- Diversifying genetics and matching varietal characteristics to the field environment are the best ways to manage for yield stability without limiting yield potential.

INTRODUCTION

In addition to individual agronomic, disease and pest tolerance scores, Golden Harvest® soybean varieties are characterized for their suitability to various soil types/conditions (e.g., drought-prone, poor drainage, highly productive, etc.). By leveraging this knowledge, can soybean varieties be effectively paired based on their agronomic and disease tolerance ratings that outperform their traditional varietal counterparts?

Figure 1. White and purple flower colors in a blended soybean treatment in Malta, IL

2022 SOYBEAN VARIETY SEED BLEND TRIALS

Four soybean varieties were selected within a 1.7-1.9 relative maturity (RM), 2.5-2.9 RM and 3.0-3.3 RM range for evaluating the concept of blending soybean seeds. Sets of varieties were planted at Agronomy in Action research sites based on the RM normally grown at the respective location. Varieties for blending were selected with similar RM and differentiating adaptability to various soil classifications with the intent that companion varieties could be beneficial when in-season environmental changes occur. Individual varieties were compared against the same variety blended at a 50:50 ratio with a similar maturity companion variety (Figure 1). The four individual varieties were blended in all possible combinations, resulting in six unique varietal blends per RM group. All blending was done manually, not by the planter.

RESULTS

Blending varieties did not provide consistent yield advantages across locations in any of the maturity sets tested in this study (Table 1). One blend, GH1763E3 and GH1973E3S brands, did outyield both individual varieties at one site; however no other blends showed any yield advantages at any site.

Although this study showed limited yield improvement of blended varieties, there may be situations where it is advantageous. The greatest challenge, though, is the difficulty of identifying those combinations, as it would require additional testing. Since a soybean product lifecycle is only a few years, the window for a blended product being commercially available would be very short (~1-2 years). Because of this, selecting a single variety that matches the environmental conditions within a given field likely provides the best opportunity for yield stability.

CONCLUSIONS

Identifying soybean varietal combinations that provide yield benefits over their individual counterparts is difficult and rare, as evidenced in this study. Diversifying genetics and matching proper soybean varieties to the field provide the best opportunity to achieve yield stability and not cap yield potential.

RM Set	Base Variety	Base Variety Yield	Yield When Blended With			
			GH1763E3	GH1802E3	GH1922E3	GH1973E3S
			bushels/acre			
Early RM (Blue Earth, MN, Jefferson, WI, Sac City, IA)	GH1763E3	56.0	-	62.0 (ns)	57.8 (ns)	64.8 (1 of 3)
	GH1802E3	68.0	-	-	66.1 (ns)	66.3 (ns)
	GH1922E3	59.1	-	-	-	65.2 (ns)
	GH1973E3S	62.7	-	-	-	-
RM Set	**Base Variety**	**Base Variety Yield**	**Yield When Blended With**			
			GH2505E3	**GH2610E3**	**GH2818E3**	**GH2922E3**
			bushels/acre			
Mid RM (Clinton, IL, Malta, IL, Slater, IA, Waterloo, NE)	GH2505E3	76.3	-	72.6 (ns)	74.3 (ns)	75.2 (ns)
	GH2610E3	74.3	-	-	76.5 (ns)	76.4 (ns)
	GH2818E3	76.9	-	-	-	78.2 (ns)
	GH2922E3	77.2	-	-	-	-
RM Set	**Base Variety**	**Base Variety Yield**	**Yield When Blended With**			
			GH3043E3	**GH3132E3**	**GH3373E3S**	**GH3392E3S**
			bushels/acre			
Late RM (Clay Center, KS, Clinton, IL, Slater, IA, Waterloo, NE)	GH3043E3	74.5	-	77.6 (ns)	74.6 (ns)	69.8 (ns)
	GH3132E3	74.8	-	-	73.8 (ns)	74.3 (ns)
	GH3373E3S	72.6	-	-	-	72.3 (ns)
	GH3392E3S	73.0	-	-	-	-

Table 1. Yield comparisons between blended and unblended varieties in three RM sets averaged across sites. Values in parentheses indicate number of sites where blend yield was significantly greater than base yields of both individual varieties ($P \leq 0.10$).

PLANTING DEPTH EFFECTS ON SMALL AND LARGE SOYBEAN SEED SIZE

INSIGHTS

- Soybean seed size has little to no effect on overall emergence and yield potential.
- To maximize soybean emergence, focus on consistent seeding depth and planting into favorable soil conditions.

Purchasing soybeans by seed count is still a relatively new concept within the seed industry. Historically seed was priced per 50-lb bag, independent of seed size. Small differences in seed size influenced the number of actual acres that could be planted per unit. Purchasing smaller seeds could in some cases reduce the dollar per acre cost since there were more seeds per bag. Purchasing seed by count may take away the opportunity to sometimes get more seed per bag but does allow growers to more accurately determine the number of seeds needed to plant a given area. With either method, small-seed soybeans will continue to be sold. In most situations seed size has not influenced germination, seedling vigor or yield potential. Although, since small seed has less stored reserves, maintaining a consistent planting depth may be more important. The Agronomy in Action Research team took a closer look at the importance of soybean seed size and planting depth at three sites in 2022.

WHAT INFLUENCES SEED SIZE

Environmental conditions during the seed filling period play an important role in determining the number and size of soybean seeds.[1] Growing conditions during the R5 and R6 growth stages have a large influence on the size of seed that a plant produces. Weather events that stress plant growth during this time can impact soybean yield potential greatly. Available moisture is the most important factor, as dry conditions can reduce the size of seeds and the number of seeds per pod. Extreme moisture stress can lead to the plant aborting flowers and small pods before they have a chance to produce seed.

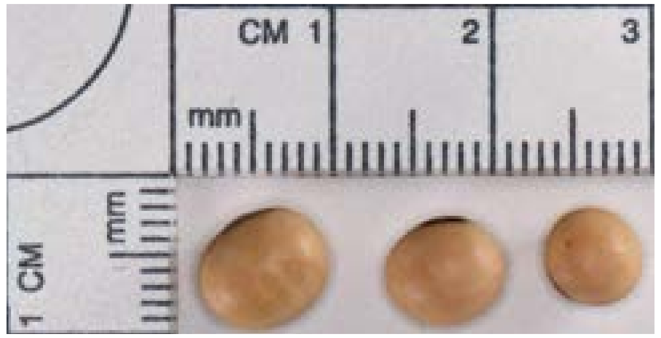


Figure 1. Soybean seed size differences

SOIL CONDITIONS AND PLANTING DEPTH

Soil conditions at planting and prior to emergence will typically have a larger influence on emergence than seed size. As a soybean germinates, the hypocotyl elongates and pulls the cotyledons through the soil to the surface. This process requires a great deal of energy by the seed. Crusted or compacted soil which further stresses emergence can sometimes create slight advantages to large seeds that have more stored energy reserves. Planting soybean seed too deep or in undesirable soil moisture conditions can create additional stress, leading to further stand and yield loss.

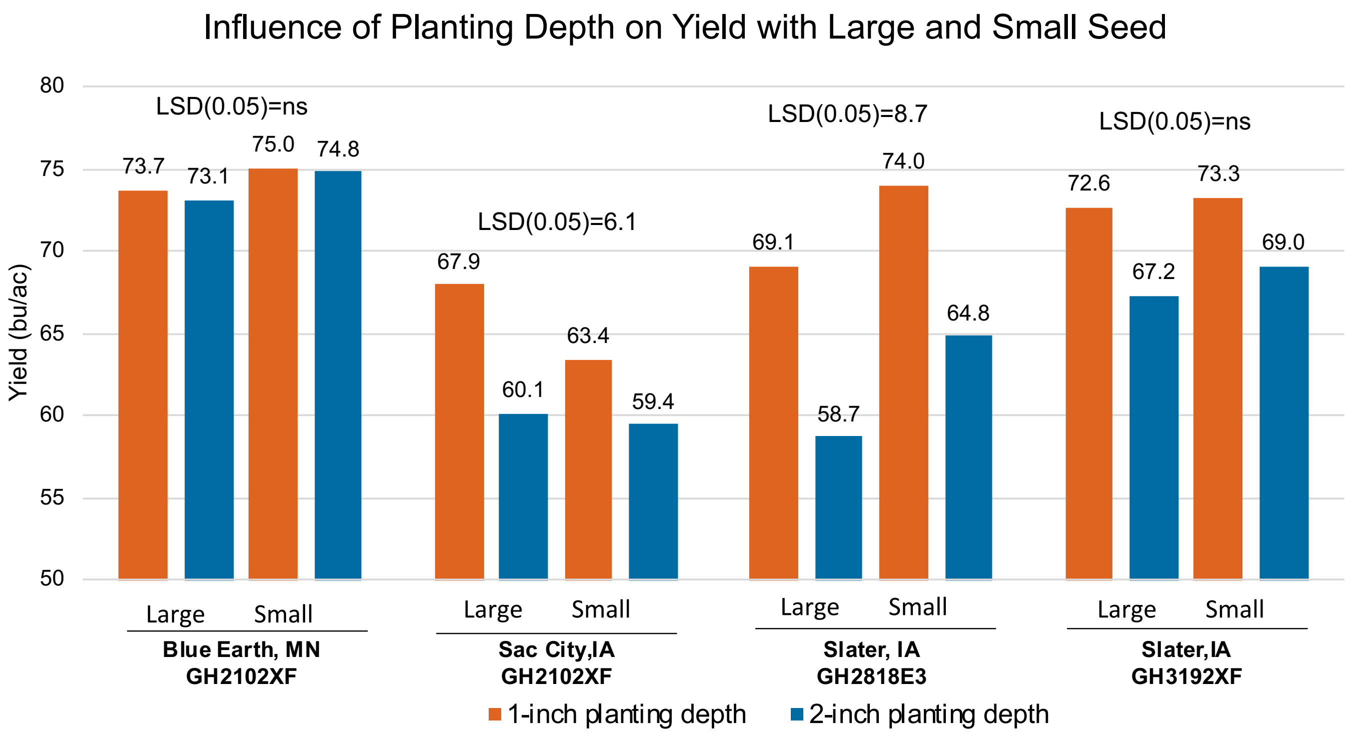
2022 SEED SIZE BY PLANTING DEPTH TRIALS

To investigate further, trials were established in Iowa and Minnesota to understand the effect that seed size and planting depth have on soybean yield. Large and small seed sizes of the same soybean variety were chosen and planted at one- and two-inch depths. A single variety was chosen for each location except for Slater, IA, which included a second variety of differing relative maturity (RM). Each combination of seed size and planting depth was replicated four times at a location. Plots were harvested at maturity with a research combine to collect grain yield and moisture.

DISCUSSION

There was no difference in stand establishment or yield at Blue Earth, MN, which had good conditions for emergence shortly after planting. Heavy rainfall and soil crusting was common in and around both the Sac City and Slater, IA trialing locations in the spring of 2022. Stressful emergence conditions resulted in improved emergence and yields when planting both seeds sizes shallower (1-inch) at these locations (Graph 1). Within the 1-inch planting depth there was insignificant yield differences between small and large seed sizes, which most of the time favored smaller seed sizes. Although the 2-inch seeding depths were statistically lower yielding at two of four trials (Sac City and Slater), there was no advantage to planting larger seed at that depth (Graph 1).

Results from this trial suggest that seed size does not influence overall yield. Inconsistent planting depth and challenging emergence conditions after planting can have far larger impacts on yield potential than seed size. To maximize soybean emergence, focus on seed depth and soil conditions shortly before, during and shortly after planting. Excess soil moisture can lead to crusting and soil compaction issues that can affect soybean emergence and reduce stands, ultimately lowering yields. Selecting varieties based on yield potential and needed pest resistance traits are far more important considerations than seed size when determining profitability.



Graph 1. Influence of planting depth on yield with large and small soybean seed size

ON A ROLL – TIMING EFFECT OF ROLLING SOYBEANS

INSIGHTS

- Rolling soybeans can ease concerns from rocks and residue damaging harvest equipment.
- Schedule rolling operations in the heat of the day and by V1 growth stage to prevent injury.

Rolling soybeans is a practice that has become increasingly common in recent years (Figure 1). The practice has become popular enough that manufacturers continue to develop and improve equipment designed specifically for rolling soybeans. Use of a roller is more common in small grains, grasses or alfalfa to improve seed-to-soil contact.

Figure 1. Land roller. Photo by Jodi DeJong-Hughes, UMN Extension

REASONS TO ROLL

The most common reason to roll soybeans is to ease issues related to harvest. Harvesting soybeans requires the combine head to follow the contour of the ground. Obstacles like rocks can cause extensive damage if taken into the combine, so a roller can help push those rocks into the soil and avoid the combine. Use of a roller can also flatten tough corn stalks and root balls from the previous season in no-till systems. Additionally, some producers are attempting to injure soybean plants early to increase branching, offering more opportunities for nodes, pods and increased yield.

TIME TO ROLL

Timing is an important consideration when deciding whether to roll soybeans.

Growth Stage

- Care should be taken to avoid rolling soybeans in the hypocotyl arch or hook stage of emergence, as these are susceptible to damage.
- If soybeans have emerged, growth stages from VC to V2 are the preferred rolling timing to reduce the threat of stand loss.
- Rolling at V3 or beyond is not recommended because plant injury could reduce yield potential.

Soil Conditions

- Rolling prior to emergence in wet soils can cause crusting, decrease emergence, limit water infiltration and cause compaction issues.
- Fields rolled in good soil conditions prior to emergence but receiving hard rains shortly after can also be more susceptible to crusting and emergence issues.
- A damp soil surface can cause soil and soybean plants to stick to the roller, causing stand reduction from uprooting plants.
- Rolling soil destroys soil structure at the surface, which can increase the risk of soil loss to erosion by wind and water.

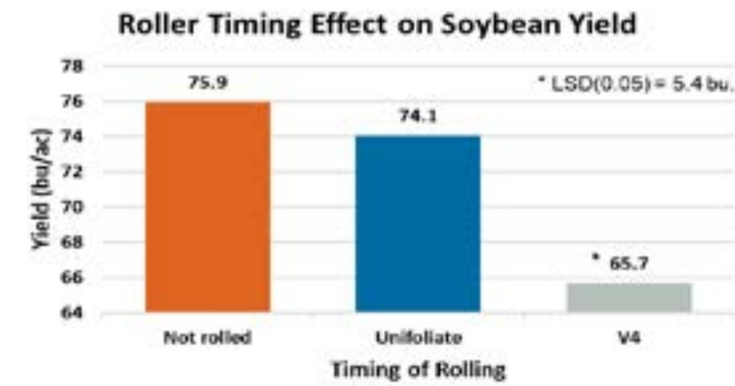
Time of Day

- Soybean plants are less turgid and more flexible if rolled in the afternoon heat of the day as it reduces concern of breaking plants off.
- Avoid early morning or late-day rolling to prevent snapping or breaking plants and causing stand loss.

2022 AGRONOMY IN ACTION RESEARCH TRIAL

The Agronomy in Action Research team investigated the effect of rolling soybeans at different growth stages. A trial was established at Slater, IA, to evaluate the effect of rolling soybeans at two timings, unifoliate and V4, with four soybean varieties (Figure 2). Treatments were replicated through the trial. Soil conditions were appropriate for rolling at each treatment timing.

Plots were harvested at maturity, and grain yield in addition to moisture were collected at the time of harvest. Yield data showed no significant difference between rolling at the unifoliate timing compared to plots that were not rolled (Graph 1). There was a significant loss of 8.4 bu/ac by delaying rolling to the V4 timing (Graph 1). The yield decrease was the result of injury to plants that were too large with rigid stems that consequently broke off (Figure 2). This suggests that delaying rolling operations past the unifoliate to V2 growth stage can have a significant impact on soybean yield potential due to stand loss. There were no significant differences in yield between the four soybeans varieties in each of the treatments.



Graph 1. Yield results from average across varieties for each treatment roller timing

SUMMARY

While rolling soybeans can lower risk of rocks or corn stalk roots at harvest time, consideration should be given to soil structure and erosion concerns. It is critical to schedule soybean rolling operations accordingly. The time of day and growth stage of soybean plants appear to be the most important factors when making rolling decisions. Rolling soybeans past the V2 growth stage could have significant consequences on yield potential.

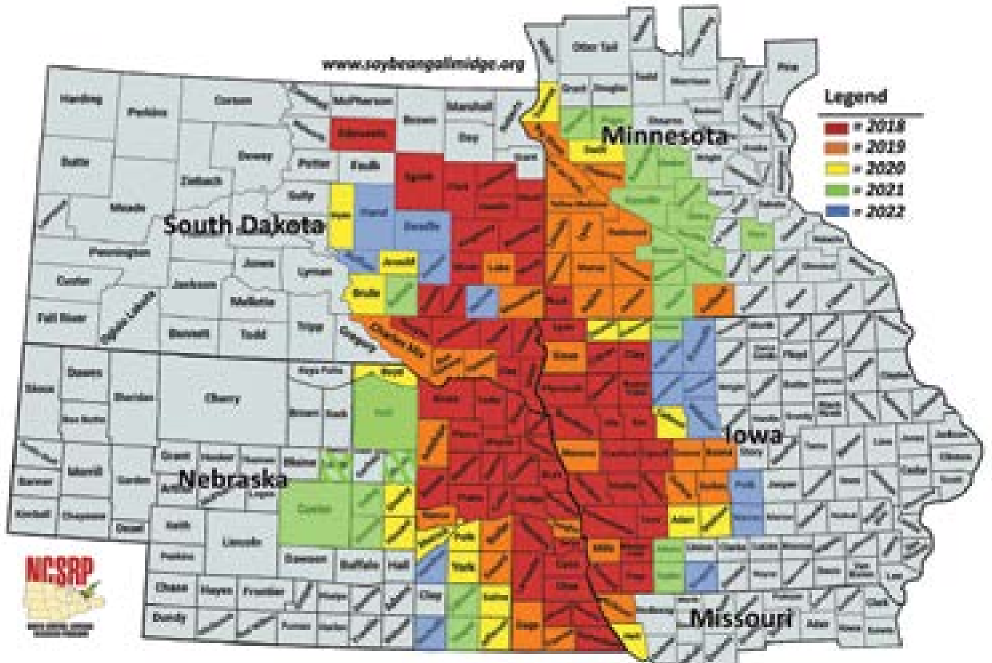
Figure 2. Row on left after rolling vs row on right not rolled at V4 timing, Slater, IA, 2022

SOYBEAN GALL MIDGE

JUSTIN MCMECHAN – Department of Entomology, University of Nebraska-Lincoln

INSIGHTS

- Plants are most susceptible to soybean gall midge (SGM) at the V2 stage and beyond, exhibiting symptoms of wilting around 20 days post adult emergence.
- There are no known "sure fire" management techniques, but mitigation measures such as mowing densely vegetated field edges, spring tillage, late planting and insecticides (foliar and seed treatments) can help lessen impact.



Source: Soybean Gall Midge Alert Network

Figure 1. Counties with soybean gall midge detection in 2018 – 2022 . 155 counties have been documented as infested as of 8/18/2022. 15 new counties.

INTRODUCTION

There is a vast amount of research taking place on soybean gall midge but large gaps in knowledge remain due to the recent discovery of this new pest. Although it can't be confirmed, orange larvae suspected to be SGM were first observed in a field in northeast Nebraska in 2011. Since 2018, larval detection of SGM have been detected in 155 counties in 5 states in the Midwest (Figure 1). In 2019, SGM was described as a new species in the insect Order Diptera (True Flies: Family Cecidomyiidae (Gall Flies)) as *Resseliella maxima* Gagne (Figure 2). Soybeans are the most studied host, however, sweet clover, alfalfa, dry bean, and lima bean are other known hosts.

Figure 2. Adult female SGM. Source: A.J. McMechan, University of Nebraska-Lincoln

LIFE CYCLE AND FEEDING

SGM adult activity is continuous throughout the growing season after first adult detection making it difficult to determine the number of generations per year. Field-collected data on adult emergence from overwintering (previous-season soybean) and current-season soybean fields indicates that the generation time is approximately 30 days (Figure 3). The life cycle begins in the soil when the overwintering 3rd instar (developmental stage) larvae (Figure 4b) in silken cocoons pupate in the spring and subsequently emerge as adults in early- to mid-June. After mating, females lay eggs in natural cracks and crevices at the base of soybean plants below the cotyledonary nodes. The eggs hatch and the first larval stage feed within the stem towards the base of the plant. SGM have a total of three instars; the 1st and 2nd are whiteish colored and small and the 3rd instar is bright orange and comparatively large (Figure 4). These orange larvae then fall off the plant and pupate in the soil. After the transformation to adult is complete, they emerge and repeat this cycle.

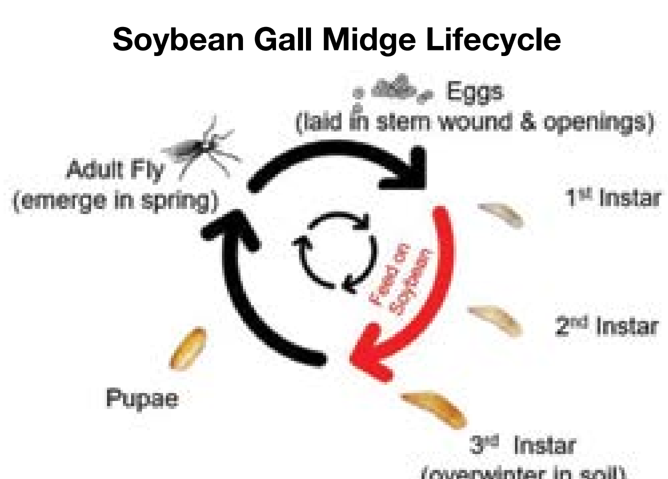


Figure 3. Soybean gall midge life cycle

Figure 4. Field view diagram. Source: A.J. McMechan, University of Nebraska-Lincoln. (a) 3rd instar larvae are orange; (b) 1st and 2nd instar larvae are white; (c) sporadic feeding damage (dead plants) in a field

Figure 5. Stem expansion – stretch marks and tissue damage

Scouting Considerations:

- Confirmed hosts of SGM include alfalfa, sweet clover, dry bean, and lima bean.
- SGM are observed to work their way in from field edges which are often the hardest hit field areas.
- Plants are most susceptible at the V2 stage or later (cracks and fissures in the ground may be necessary for egg laying).
- Wilted plants and darkened stems (at ground level) are the most notable symptoms (Figures 4c and 5).
- Split the soybean stem and look under the stem epidermis to look for larvae (Figure 4a).

MANAGEMENT

Information gathered from university and industry research in 2019 and 2022 has revealed key points:

- Duration of adult emergence ranges from 3-45 days and this is the stage to target with foliar insecticides. Every 28-32 days there may be new flushes of adults from either the overwintering population or in-season generations.
- Infestation by SGM appears to take place around the V2 soybean growth stage.
- Monitoring SGM adult activities utilizing adult emergence cages is part of an emergence network across NE, IA, SD and MN with activity reported on soybeangallmidge.org
- Planting date can have a significant effect on infestation. When planting occurs after May 22, however, more data is needed to determine the stability of this tactic.
- Fall and spring tillage have not been consistent with some site-years showing little to no effect from tillage.
- Mowing dense vegetation around fields had a slight effect on infestation.
- Utilization of a seed treatment with an insecticide had some effect but results have been inconsistent between sites and years. Evaluation of insecticidal seed treatments remains ongoing.
- Foliar applications of a pyrethroid like Warrior II with Zeon Technology® or pyrethroid containing Endigo® ZC showed some efficacy up to 11 days after first adult emergence but has not been consistent.

SOYBEAN SEED TREATMENTS ADD PROTECTION AGAINST PESTS

INSIGHTS

- All seed treatments are not created equal.
- Understanding seed treatment active ingredients is important to know which pests are controlled and treatment that is needed.
- Seed treatments are the first line of defense against pests. Yield lost to seedborne pests can never be recovered.

Treatment Combinations	Seed Treatment Active Ingredients	
	Insecticide	Fungicide
Untreated Check	NA	NA
Vibrance® Trio	None	Mefenoxam, Fludioxonil, Sedaxane
CruiserMaxx® Vibrance	Thiamethoxam	Mefenoxam, Fludioxonil, Sedaxane
CruiserMaxx® APX	Thiamethoxam	Mefenoxam, Fludioxonil, Sedaxane, Picarbutrazox
CruiserMaxx APX with Saltro®	Thiamethoxam	Mefenoxam, Fludioxonil, Sedaxane, Picarbutrazox & Pydiflumetofen (Saltro)
CruiserMaxx APX with Saltro followed by Miravis® Neo at R3	Thiamethoxam	Mefenoxam, Fludioxonil, Sedaxane, Picarbutrazox & Pydiflumetofen (Saltro)
Acceleron®	Imidacloprid	Metalaxyl, Fluxapyroxad, Pyraclostrobin
Acceleron with ILEVO®	Imidacloprid	Metalaxyl, Fluxapyroxad, Pyraclostrobin & Fluopyram (ILEVO)

Table 1. Active ingredients in seed treatments

PEST MANAGEMENT WITH SEED TREATMENTS

Farmers are planting soybeans earlier to capture the full growing season for additional soybean yield potential. In some areas of the Midwest, growers have been planting soybeans as early as late March or early April. Often the soil is cooler and wetter during early planting windows, resulting in slower soybean germination and emergence. As the length of time a soybean seed is sitting in the ground increases, so does the vulnerability of the seed to pests.

Seed treatments protect soybeans against pests such as insects, diseases and nematodes. Common insect pests include aphids, bean leaf beetles, leafhoppers, seedcorn maggots, white grubs and wireworms. Diseases such as fusarium, phytophthora, pythium and rhizoctonia often impact soybean yield.

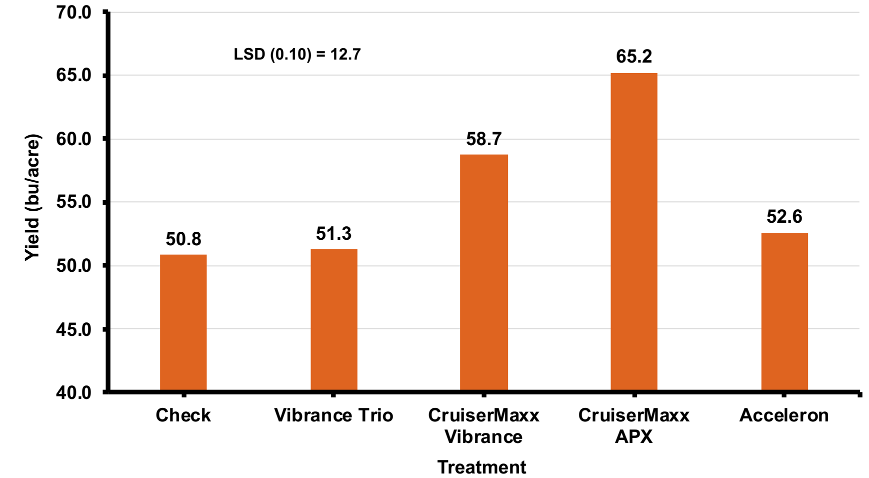
SOYBEAN SEED TREATMENT TRIALS

Golden Harvest Agronomy in Action Research conducted trials at eight locations in the 2022 growing season to evaluate the value of seed treatment options across a range of environments. Eight different insecticide and/or fungicide combinations were evaluated for differences in stand establishment and yield. Treatments were designed in a way to understand the incremental yield response when additional active ingredients were added (Table 1). Vibrance® Trio seed treatment is solely comprised of fungicides, whereas CruiserMaxx® Vibrance seed treatment contains the same 3 fungicides with the addition of CruiserMaxx (Thiamethoxam) insecticide. CruiserMaxx® APX seed treatment contains the same insecticide/fungicide rates and active ingredients, along with an additional fungicide (Picarbutrazox) to provide a second mode of action for managing pythium and phytophthora species. Acceleron®, an insecticide and fungicide combination, was also included as a competitive check to compare relative performance. Saltro® and ILEVO® fungicides were added to select treatments when sudden death syndrome (SDS) was present.

SOYBEAN SEED TREATMENT EVALUATION TRIAL

Trials established at Blue Earth, MN, Clinton, IL, Slater, IA, and Waterloo, NE, experienced relatively little observable insect or disease pressure throughout the season, resulting in very small yield differences between treatments at those locations (data not shown). Larger treatment differences were observed at other locations and results were highly dependent on specific pests present.

Figure 1. Bean leaf beetle feeding on soybean cotyledons and unifoliate leaves at Clay Center, KS in 2022



Graph 1. Effect of seed treatment on soybean yield at Clay Center, KS in 2022

LOCATION WITH INSECT AND PHYTOPHTHORA PRESENT

The Clay Center, KS, site experienced a substantial number of overwintering adult bean leaf beetles (BLB) soon after emergence causing significant defoliation (Figure 1). All treatments lacking a seed-applied insecticide were easily recognizable prior to crop canopy due to the early feeding damage. The insecticide component in CruiserMaxx Vibrance and CruiserMaxx APX provided excellent control of BLB feeding compared to Vibrance Trio, which did not include an insecticide. Plants treated with CruiserMaxx Vibrance and CruiserMaxx APX were visually healthier and more robust early in the growing season (Figure 2). Plants emerging from seed treated with Acceleron, which uses imidacloprid insecticide, had less BLB damage than non-insecticide treatments, but slightly more damage than observed in plants where seed treatments included Cruiser® insecticide. Overall, adding insecticide to fungicide increased yield by 7.4 bu/acre when comparing Vibrance Trio to CruiserMaxx Vibrance seed treatment, largely due to BLB presence (Graph 1).

Soils at Clay Center warmed rapidly after planting, but remained saturated from early rains, resulting in ideal conditions for phytophthora to develop. Phytophthora symptoms were observed in plots planted to a susceptible variety neighboring the seed treatment trial, suggesting that phytophthora was likely also present in the more tolerant variety within the seed treatment trial. Phytophthora presence likely produced the 6.5 bu/acre CruiserMaxx APX advantage over CruiserMaxx Vibrance and the 12.6 bu/acre advantage over Acceleron seed treatment (Graph 1).

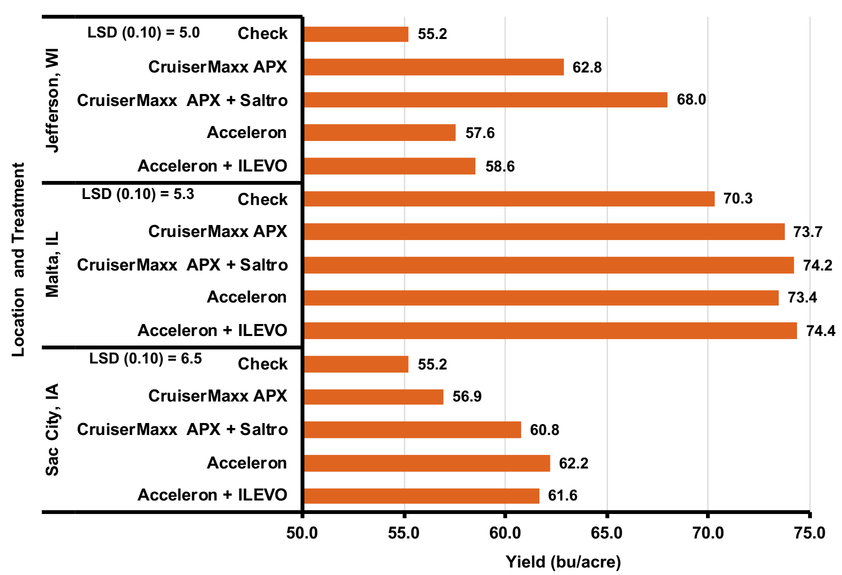
Figure 2. Seeds treated with Vibrance Trio on the left and CruiserMaxx Vibrance on the right at Clay Center, KS in 2022

Figure 3. Seed treatment trial at Jefferson, WI in 2022. Orange boxes highlight plots treated with Saltro

LOCATIONS WITH SDS FOLIAR SYMPTOMS

Soybean plants at Jefferson WI, Malta, IL, and Sac City, IA, all showed varying levels of foliar symptoms of SDS. Jefferson had the most severe SDS symptoms, and plots that were treated with Saltro could be visually distinguished from plots that were not (Figure 3). Saltro provided excellent control against the interveinal chlorosis symptomology of SDS whereas ILEVO reduced symptoms some, but not as consistently across replications.

Adding Saltro to CruiserMaxx APX increased yield 5.2 bu/acre, whereas adding ILEVO to Acceleron only added 1 bu/acre at the Jefferson site (Graph 2). Although present,



Graph 2. Effect of seed treatment on yield at location where SDS was present (Jefferson, WI, Malta, IL, and Sac City, IA) in 2022

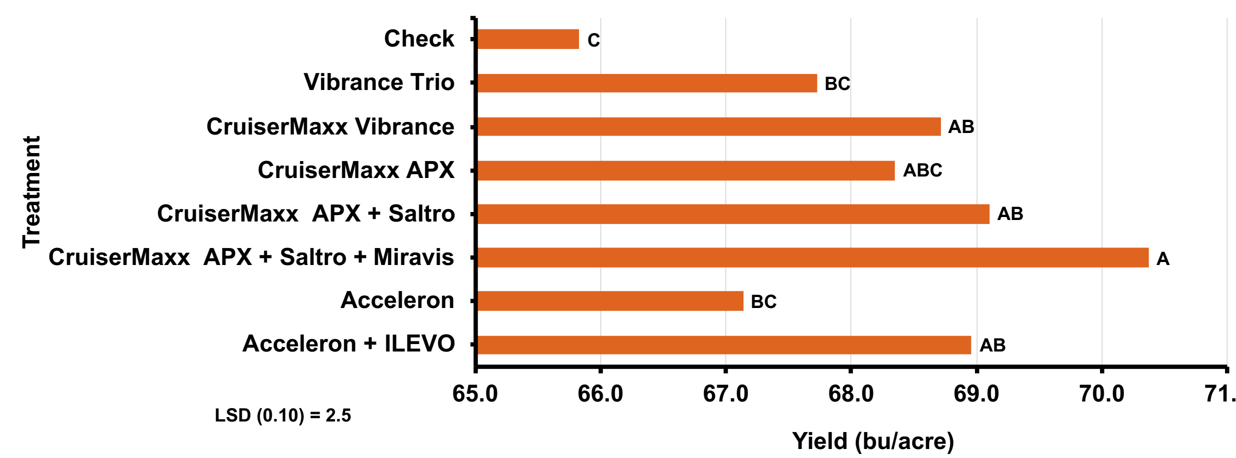
SDS symptoms were less visible at Sac City and Malta locations. Due to low SDS presence, less differences in yield were observed when Saltro or ILEVO was added to their respective treatments (Graph 2).

SUMMARY

When including the four sites without pest presence and averaging across all eight locations, incremental yield benefits from adding insecticide and new fungicides are still seen. On average, adding a base fungicide and then an insecticide increased yield by 1.9 and 1 bu/acre, respectively. Benefits from Saltro decreased when averaged across locations since five of eight locations did not have SDS present, although added 0.5 to 5.2 bu/acre at locations with symptomology. Ultimately the highest yield potential was seen when the complete seed treatment package (CruiserMaxx APX + Saltro) was used in combination with Miravis® Neo foliar fungicide applied at R3 to provide a season-long disease protection program (Graph 3).

Results from this study show the benefits of protecting the seed with specified seed treatments when specific pests are present. In-season pest pressure is not always known by the time seed treatment decisions need to be made. Since pest presence is highly dependent on that year's weather events, seed treatments may not always show responses. As a result, understanding relative risk of specific pests and matching that to the best combination of treatment options is important in determining profitability. Yield losses from seedborne pests can be significant so protecting seed investment with seed treatments is important.

Figure 4 . Seeds treated with CruiseMaxx APX on the left and CruiserMaxx APX + Saltro on the right at Jefferson, WI in 2022



Graph 3. Effect of seed treatment and foliar fungicide on yield averaged across 8 locations with and without pest pressure in 2022

IRON DEFICIENCY CHLOROSIS IN SOYBEANS

INSIGHTS

- Soil properties and other environmental factors are responsible for iron deficiency in soybeans.
- Iron deficiency chlorosis (IDC) is a complex issue for soybean farmers, especially in calcareous soils (soils with excessive lime).
- Selecting varieties more tolerant to IDC is the best available management practice, although other management practices can help lessen severity.

Iron (Fe) is an essential nutrient and an important component of nodulation, nitrogen fixation, and enzymes that form chlorophyll. A lack of iron within soybean plants is often referred to as iron deficiency chlorosis (IDC) and is easily recognized due to reduced leaf chlorophyll, chlorosis and subsequent yellowing of leaves. IDC symptoms begin to appear within a few weeks after soybeans emerge, with interveinal chlorosis showing on the first trifoliate. Iron does not readily translocate within the plant, causing new growth to be impacted first when deficiencies continue. Unique to other deficiencies, soybean leaf veins will remain green as the remainder of the leaves begin to yellow. Under severe IDC, edges of leaves will become necrotic and start to die (Figure 1).

IDC symptoms tend to appear in irregular shaped areas across fields causing significant reduction in yield potential of affected areas. Substantial yield reductions have been reported across many areas where soybeans are grown but are more prevalent in Western Minnesota, Northwestern Iowa, Nebraska, North Dakota, and South Dakota where calcareous or sodic (alkali) soils are most common.

COMMON CAUSES FOR IDC

Although the name IDC implies it is caused by low soil iron levels, it is the result of soil conditions that decrease iron uptake by soybean roots. Most soils likely have sufficient iron concentrations, however, not all of it is readily available


Figure 1. Iron deficiency chlorosis in soybeans

to plants. Soybean IDC is mostly observed in areas with high calcium carbonate and/or high salinity soil levels.

Calcareous soils developed from calcium carbonate parent material commonly have pH levels that range from 7-8.5, making them highly conducive to IDC symptoms. Within fields predominately having calcareous soils, IDC symptoms will often appear first in wetter areas where parent calcium carbonate more readily dissolves into a solution that releases carbonate (CO_3^{-2}). This acts as a strong base that increases soil pH. If soil nitrate levels are also high, soybeans will preferentially uptake soil nitrogen and subsequentially release additional carbonates that further increases pH within the soil root rhizosphere (root zone) and exacerbate IDC symptoms. Although IDC symptoms are commonly observed in high pH soils, this can be a poor predictor. Symptoms are not always seen in elevated soil pH areas with lower carbonate and salinity levels.

Soils with high pH levels oxidize iron into a ferric state (Fe^{3+}) which binds iron tightly to soil components, making it less soluble and able to move to nearby roots. Soybeans depend on iron being in a ferrous state (Fe^{2+}) for uptake and transport into the plant. Acidification from plant roots helps reduce iron from the Fe^{3+} to Fe^{2+} form, making it more


Figure 2. IDC ratings being taken in soybean research plots

available for plant uptake. IDC symptoms in high pH soils can be worsened by other nutrient deficiencies as well as cool growing conditions that slow growth and development. If Fe deficiency is not severe, and environmental conditions improve, resumed root growth will normally allow plants to absorb sufficient Fe and recover.

MANAGEMENT PRACTICES

1. Variety Selection

Golden Harvest has significant research efforts to characterize varieties for IDC tolerance (Figures 2 and 3). Soybean variety tolerance is the most important strategy in managing this complex issue. Varieties characterized as having high tolerance to IDC are generally more "iron efficient" or better able to reduce Fe^{3+} to the Fe^{2+} form in soil around roots, making it more available for plant uptake.[1]

Although some IDC symptoms may be visible on tolerant and susceptible varieties in severe situations, tolerant varieties will have less symptomology and yield loss. Susceptible varieties can sometimes provide a better option in fields not prone to IDC, making it important to map areas that have shown IDC symptoms and use this insight for making future variety selection decisions.

2. Apply Iron Chelates to Soil

Iron chelates are often added as a soil amendment to increase the solubility of iron in the soil and deliver it to the


Figure 3. Single row variety differences in IDC research plots. Northwest Iowa 2022

plant to minimize IDC symptoms. Chelated forms of Fe have shown to help correct IDC and protect yield potential with varying levels of effectiveness in different soil pH.[2] Fe-EDDHA fertilizer is considered to be the most stable of the chelates and has shown to increase grain yield of soybeans on calcareous soils.[1] Research has also shown that the most effective chelate application timing and placement for reducing IDC is Fe-EDDHA chelate fertilizer in-furrow at planting, even though no iron chelate treatment completely eliminates chlorosis.[1] The success of chelate application relies heavily on the buffering capacity (ability to maintain stable pH) and pH of the soil.[3] Return on investment (ROI) of applying an iron chelate should always be considered before using on a large scale.

Foliar Fe applications have shown to "regreen" chlorotic symptoms in some studies but were less effective in severe IDC field conditions. While leaves appeared less chlorotic, previous research showed that foliar Fe may not reach the plant roots and therefore yield potential may decrease later in the season.[3] Again, ROI should be evaluated for foliar Fe products before using broadly.

3. Manage Areas with High Soil Nitrate Levels

Excess soil nitrates in IDC-susceptible soils have been shown to increase the severity.[2] Soybeans commonly use symbiotic relationships with rhizobia to form nitrogen-fixing nodules on roots, but when soil nitrates are available in soil, they will take up nitrogen directly from the soil. When taking up nitrogen directly from the soil, soybean roots release bicarbonates which further increases soil pH and reduces Fe uptake. This can be highly visible in fields with tire track compaction (Figure 4). Previous research showed that soil nitrates were lower in compacted tracks than in adjacent uncompacted soil.[2] It is believed that the compaction decreases soil porosity, thus increasing soil saturation which increases soil denitrification. Denitrification within compacted areas helped minimize IDC in those areas. Using an oat companion crop interseeded within soybeans has also been found to help manage high nitrate soils since they scavenge soil nitrogen and excess soil moisture, thus decreasing bicarbonates that increase pH in the soybean root rhizosphere.[3]

4. Adjust Seeding Rate and Row Spacing

Increasing soybean seeding rate has shown to minimize IDC symptoms in some cases. Increased seeding rates result in more plants, which develop additional roots. Because soybeans acidify the rhizosphere, the increased root mass helps to further acidify the root zone, reducing more iron from the Fe^{3+} to Fe^{2+} form which is a more plant-available form. Research shows that increased seeding rate can reduce chlorosis, although yield responses also depended on other environmental conditions.[4,5]

Narrow row spacings (<30-inch) generally increase seed-to-seed spacing, producing a similar outcome to reducing seeding rates. Due to this, much larger seeding rate increases may be needed to help minimize IDC symptoms when planting narrow-row soybeans.

5. Minimize Additional Plant Stress

Any additional stress will only exasperate IDC symptoms. Help minimize additional plant stress with specific management practices as needed to avoid the following:

- Nutrient deficiencies
- Diseases
- Nematodes
- Herbicide injury
- Severe compaction which damages soybean roots

SUMMARY

IDC is a complex field issue that requires a robust management strategy. Since it generally occurs due to various stresses and not simply due to low soil Fe, it is challenging to mitigate. In areas where IDC is a concern, selecting a soybean variety with tolerance to IDC is one of the best methods to protect yield potential.

Figure 4. Green compacted wheel tracks with lower soil nitrate levels showing in IDC affected area of soybean field

UNDERSTANDING SOYBEAN VARIETAL RESPONSES TO FUNGICIDE AND ENHANCED FERTILITY

INSIGHTS

- Fungicide application increased soybean yield by 1.3 bu/acre across all sites under low disease pressure.
- Enhanced fertility did not significantly increase yield, especially when soil phosphorus (P) and potassium (K) were sufficient.
- All soybean varieties responded similarly to fungicide and enhanced fertility.
- It is more probable that fungicides will provide greater return than enhanced fertility when soil P and K are sufficient.

INTRODUCTION

The 2021 Agronomy In Action Research trials found that soybean fungicide application followed by enhanced soil fertility were the two most responsive management variables out of multiple agronomic and plant nutrition variables evaluated. However, the magnitude of those responses was found to be location dependent. Previous trials were also not designed in a way to understand if responses can be variety specific. Historic data continues to support corn hybrid-specific responses to both fungicide and zone-placed fertility, although less is known about variety specific soybean responses. Agronomy In Action researchers carried out trials in 2022 to better understand if soybean fungicide and fertility management practices should also be based on variety.

2022 SOYBEAN MANAGEMENT TRIAL DETAILS

Research trials were conducted at eight Agronomy In Action sites in 2022. Replicated trials were designed to evaluate response to fungicide and enhanced fertility as well as the two factors combined. The host farmer standard fertility practices were applied across the entire trial and additional fertilizer was applied to specific blocks within the trial to create "enhanced fertility" treatments. Enhanced fertility blocks consisted of the baseline fertilizer in combination with NACHURS Triple Option® at 15 gal/ac (22 lbs/acre P2O5, 29 lbs/acre K2O, and 2 lbs/acre S) applied through the planter. Planter fertilizer applications were applied using a 2×2×2 placement to provide nutrients in proximity of developing roots while also avoiding direct contact with seed and avoiding potential germination issues from high salt content. Higher-than-normal starter fertilizer rates were meant to mimic zone fertilizer placement used in strip-till or other precision placement practices. Soil test P and K levels at each site are provided in Table 1.

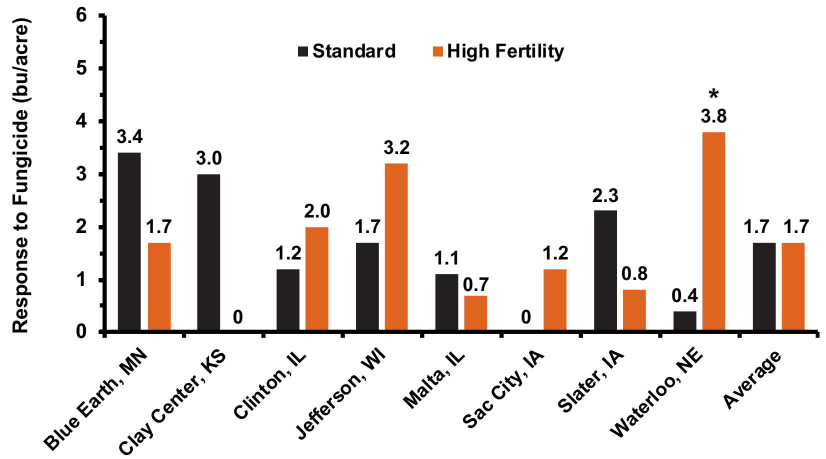
Location	Phosphorus		Potassium	
	PPM	Sufficiency Level	PPM	Sufficiency Level
Blue Earth, MN	33	VH	197	L
Clay Center, KS	29	H	252	VH
Clinton, IL	53	VH	248	VH
Jefferson, WI	11	L	231	M
Malta, IL	38	VH	157	M
Sac City, IA	83	VH	344	VH
Slater, IA	17	M	132	L
Waterloo, NE	5	VL	270	VH

Table 1. Soil test P and K levels at eight Agronomy In Action sites, 2022

To test for varietal response to fungicide and fertility, 10 varieties with ranging agronomic characteristics, disease tolerance scores, and herbicide tolerance traits (Enlist E3® soybeans and XtendFlex® soybeans) were selected for each maturity group (MG) region. Fungicide application blocks were established in both normal and enhanced fertility areas and received a broadcast application of Miravis® Neo fungicide at the R3 growth stage at a rate of 13.7 oz/acre.

ENHANCED FERTILITY RESPONSE

Enhanced fertility did not have a statistically significant effect on soybean yield at any site, and numerical increases were less than 1 bu/acre at seven of eight sites. Although soil P and K were sufficient at six of eight sites, those with very low or low soil P or K still did not respond to the enhanced fertility. The lack of yield response at sites with high soil test P was not surprising, as university research supports this trend.[1,2,3] Though the lack of response at the low P or K sites was surprising, it may have been caused by random field variability.



Graph 1. Yield increases with fungicide application with standard and high fertility at eight Agronomy In Action sites in 2022. Asterisk denotes statistically significant response at $P \leq 0.10$

FUNGICIDE APPLICATION RESPONSE

Averaged across all locations there was a 1.7 bu/ac response to R3 fungicide application, although responses ranged from 0 to 3.8 bu/ac depending on location and fertility levels (Graph 1). This average response was smaller than expected but was likely related to low disease pressure at most locations throughout pod fill stages. In comparison, fungicide applications produced a 3.7 bu/acre increase across nine Agronomy In Action sites in 2021. Although disease pressure was generally low, delayed plant senescence within treated plots was observed at many locations which likely extended pod fill and potentially contributed to smaller yield gains (Figure 1).

Figure 1. Delayed leaf senescence in plots where Miravis Neo fungicide was applied (left) compared to the untreated control (right) at Waterloo, NE, 2022

Soil fertility level did not appear to affect the response to fungicide at most locations, as both standard and high fertility blocks averaged a 1.7 bu/acre response to fungicide when comparing across all locations (Graph 1). Locations with medium to very high base fertility levels did not show a clear trend that further enhancing the fertility would help improve overall fungicide response. Inconsistent differences observed in responses between individual locations was likely noise resulting from natural field variability rather than fungicide. There was a numerical yield advantage to fungicide response in enhanced fertility blocks as compared to base fertility rates at Jefferson, WI (*NS*), and Waterloo, NE ($P \leq 0.10$), where soil P test levels were low to very low at 11 and 5 PPM, respectively (Table 1). Observations at these two locations could suggest that the magnitude of a fungicide response may have been limited by insufficient base soil fertility.

The response of individual soybean varieties to fungicide application was consistent in all MG regions (10 varieties within each zone, 30 total tested) (Table 2). Individual variety responses to fungicide were inconsistent within each MG region, indicating that variety-specific responses are difficult to pinpoint, if they exist. For example, GH2722XF brand had a -0.2 bu/ac average response to fungicide across all locations, yet two of three sites exhibited ≥1.9 bu/acre yield responses. If one chooses to prioritize fungicide applications, it should be done based on field disease pressure, and not variety driven.

MG Region	Variety Brands	Base Yield	Response to Fungicide
Mid I - Early II (Blue Earth, MN, Slater, IA, Sac City, IA)	GH1442XF	65.6	0.7
	GH1472E3	65.9	1.6
	GH1762XF	66.5	1.6
	GH1763E3	63.3	1.7
	GH1802E3	71.1	2.1
	GH1973E3S	65.9	2.9
	GH2011E3	65.5	1.4
	GH2083E3S	65.2	2.9
	GH2102XF	69.9	1.7
	Average	**65.6**	**1.9**
Mid II - Early III (Clinton, IL, Malta, IL, Slater, IA, Waterloo, NE)	GH2562XF	69.9	2.1
	GH2610E3	71.2	2.1
	GH2653XF	79.3	1
	GH2722XF	71.7	-0.2
	GH2818E3	74.3	2
	GH2922E3	73.5	2.1
	GH3043E3	83.2	1.6
	GH3132E3	75.2	2.4
	GH3192XF	70.2	1.2
	GH3373E3S	81.1	1.5
	Average	**75**	**1.6**

Table 2. Response of individual varieties to fungicide application in two MG regions

CONCLUSIONS

Fungicide application increased soybean yields by 1.7 bu/acre across eight Agronomy In Action sites with low disease pressure. Overall fungicide response did not appear to increase with enhanced fertility, but may play a role in response when adding supplemental fertility if base nutrient levels are deficient. Enhanced fertility by itself did not increase yield, likely due to sufficient soil P and K levels at six of eight sites. These results indicate that fungicide application has a greater likelihood to produce more return than additional P and K fertilization when soil test levels are already sufficient.

SOYBEAN MANAGEMENT TRIAL

COMMON SOYBEAN DISEASES

INSIGHTS

- There are multiple, common soybean diseases that may be encountered during a growing season, and many are described here with symptoms and some management tips.
- When managing most soybean diseases, variety selection is a critical component.

STEM CANKER

Stem canker is a disease in soybeans found widely where infections occur, resulting from multiple fungi in the genus *Diaporthe*. Diaporthe-Phomopsis disease complex is also responsible for Phomopsis seed decay, pod and stem blight as well as stem canker. The fungi can survive in residue or in the soil for several years. Seed infection can sometimes be responsible for spreading, but most often results from infested residue. There are also multiple weed species such as black nightshade, curly dock, morningglory and others that can serve as hosts for the disease, although they will not often show symptoms. Infection requires extended periods of moisture and can occur across a wide range of temperatures. Fungus spores will splash on plant tissue from rain events and infect during early vegetative stages even though symptoms will not be visible until later reproductive plant stages.

Symptoms

Correct diagnosis can be difficult due to multiple diseases that can cause similar symptoms. Key symptoms include:

- Patchy, dead plants later in the season with dried leaves still attached to petioles.
- Reddish-brown lesion spots that start small at base of stem branching and expand to form slightly sunken cankers – lesions may expand over several nodes or girdle stem, killing the plant (Figures 1 and 2).
- Sometimes top dieback can occur when canker forms on upper 4-6 internodes, killing only the top of the plant.
- Interveinal chlorosis and necrosis of leaves may occur, similar to sudden death syndrome and brown stem rot.


Figure 1. Stem canker


Figure 2. Stem canker zonal lines near canker lesion

POD AND STEM BLIGHT

Soybean pod and stem blight is caused by the Diaporthe-Phomopsis disease complex and is found throughout most soybean-producing areas of the U.S. Other common, associated diseases are Phomopsis seed decay and stem canker. This disease favors wet conditions for development and survives similarly to stem canker.

Symptoms

- The characteristic sign of pod and stem blight is the linear rows of black specks on the stem – these black specks are pycnidia, the fruiting structures that contain the spores for the fungal pathogen (Figure 3).
- The pycnidia will only be present on plant tissue that is dead.
- Pods may become infected showing scattered pycnidia too and will have infected seed – the infected seed will appear shriveled, cracked and have a white, chalky mold on it.


Figure 3. Stem blight

Disease	Roots	Exterior Stem	Interior Stem	Leaf Symptoms
Stem canker	healthy	dark red-brown canker at node that can extend over several nodes; lesions often not entirely around stem	discoloration or browning near lesion. Thin, dark irregular pattern lines inside mature plant lower stems	interveinal chlorosis and necrosis; typically leaves remain attached to plant
Brown stem rot	healthy	healthy	brown discoloration in pith (center of stem)	interveinal chlorosis and necrosis
Fusarium wilt	brown vascular tissue	healthy	brown vascular tissue	leaves yellow and wilt, remain attached
Phytophthora stem rot	root discoloration	dark brown lesion beginning at the taproot and extending up several nodes on the stem and surrounding the entire stem	brown internal discoloration on plants at any stage	leaves yellow and wilt, remain attached
Sudden death syndrome (SDS)	root discoloration and rotting; internal browning of tap root	healthy	brown or gray discoloration in below outer stem layer but pith is white	interveinal chlorosis and necrosis of leaves; leaves drop after death
Tobacco streak virus	healthy	dark red-brown canker at node(s) - not always present	brown discoloration of the pith at node(s)	healthy; bud proliferation and plants stay green after maturity
White mold (Sclerotinia stem rot)	healthy	white cottony mold stuck to lower stem; black, hard sclerotia may be present	black sclerotia embedded in stem tissue	leaves wilt and turn grayish green between veins, remain attached
Symptom expression table recreated from Cropprotectionnetwork.org "Stem Canker"				

Table 1. Symptom expression summary table of soybean diseases

BROWN STEM ROT

Brown stem rot (BSR) is caused by the fungus *Cadophora (Phialophora) gregata*, of which there is an A and B genotype. Infection occurs through plant roots before colonizing vascular tissue, stems and leaves. Genotype A causes both stem and leaf symptoms. Genotype B usually only results in stem symptoms. Foliar symptoms are suppressed when temperatures are high, often making it difficult to determine the cause of dying plants. The BSR fungus survives in infected soybean residue, but unlike SDS, it doesn't form any long-term survival structures.


Figure 4. Brown stem rot foliar symptoms

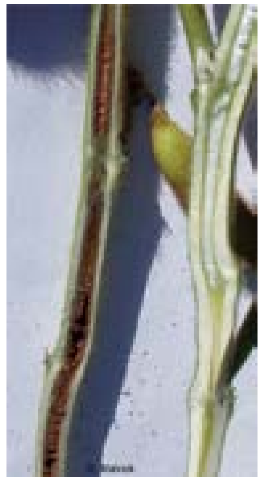


Figure 5. Brown stem rot (left) healthy stem (right); Source: D. Malvik, Univ. of Minnesota

Symptoms

- Foliar symptoms have interveinal yellowing and browning of leaves similar in appearance to SDS (genotype A only) (Figure 4).
- Dark, brown and discolored pith that extends from lower stem upwards, but sometimes appears only at nodes (Figure 5).
- Diseased plants will retain leaves after death, whereas SDS-affected plants typically drop leaves rapidly.
- Roots will not be affected, whereas SDS will show root infection.
- Diseased plants often occur in clusters of individual plants among healthy plants.

Management

- Variety selection
- Crop rotation
- Burying residue via tillage
- Managing soybean cyst nematode (SCN), if present

SOYBEAN MANAGEMENT
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SUDDEN DEATH SYNDROME

Sudden death syndrome (SDS) in soybeans is caused by *Fusarium virguliforme*, a soilborne fungal disease. It is one of the most significant disease pathogens impacting soybean performance. *F. Virguliforme* overwinters on crop residue and infects the plant's root system early in the season, although symptoms rarely occur until late in the season after toxins from the disease begin to move up throughout the canopy. The risk of SDS infection is greatest when there is significant early season moisture followed by mid-summer rains saturating the soil. Poorly drained, compacted and SCN-prone soils are favorable for this disease.

Symptoms

- Chlorotic spots between veins on the leaves begin to form in the uppermost canopy.
- Yellow spots coalesce to form chlorotic yellow-brown interveinal leaf scorching similar to BSR (Figure 6).
- Uniquely different from BSR, SDS-infected plant leaves fall off early and leaf petioles remain attached to the plant.

Figure 6. Sudden death syndrome

- Lower stem infection will result in cortex (outside edge of split stem) turning gray-brown in color, while inner pith of stem remains a normal green-white appearance.
- Fuzzy, powdery white or cobalt blue growth appearance on outer surface of roots can be observed under wetter soil conditions. Distinctly different from BSR, which does not affect roots.

Management

Since infection occurs much earlier than actual symptoms, in-season fungicide applications have limited value, however there are multiple options for minimizing future infections:

- Variety selection
- Seed treatments such as Saltro® fungicide
- Improving soil water drainage
- Minimizing stresses such as compaction
- Delay planting of high-risk fields until soils warm
- Manage SCN
- Harvest in timely manner

CHARCOAL ROT

Charcoal rot, also called dry weather wilt, affects soybeans throughout the U.S. and is caused by the fungal pathogen *Macrophomina phaseolina*.

Microsclerotia, the survival structures of the pathogen, overwinter on dry soil or infected plant residues. The disease infects the roots of soybean plants early in the growing season and remain latent until favorable conditions occur for disease development. Environmental conditions favorable for charcoal rot development are high temperatures and dry soil conditions during the reproductive stages.

Symptoms

- Appear as patches of stunted plants later in season after R1 crop stage.
- Yellowing leaves followed by wilting and browning leaves that eventually die.
- A unique identification key is that dead leaves remain attached to the plant, unlike SDS-affected plants that drop leaves but retain the petiole.
- Lower portion of the stem and tap root will have a light gray or silver discoloration.

Figure 7. Charcoal rot

- Tiny black specks of microsclerotia are visible on the outside as well as inside of lower stem and root with an appearance of fine charcoal powder sprinkles (Figure 7).

Management Tips

- Select soybean varieties that are less susceptible to charcoal rot.
- In fields with history of charcoal rot, avoid high populations to help conserve soil moisture and make sure fertility levels are adequate to reduce plant stress.
- Crop rotation to small grains may help reduce inoculum, however corn is susceptible to charcoal rot and does not help to reduce infected residue.

CERCOSPORA LEAF BLIGHT AND PURPLE SEED STAIN

Cercospora leaf blight is caused by the fungus *Cercospora kikuchii*, a close relative of frogeye leaf spot. Warm, humid conditions of 80°F greatly increase fungal sporulation. The pathogen overwinters on crop residue and/or seed. Yield loss may occur if the disease infects leaves early in the season, but the loss is usually less than 10%. Seed discoloration may result in dockage in sale price if more than half the load is discolored.

Symptoms

- Infection not usually visible until R4.
- Leaf symptoms range from light purple small spots to larger, irregularly shaped patches on the upper surface (Figure 8).

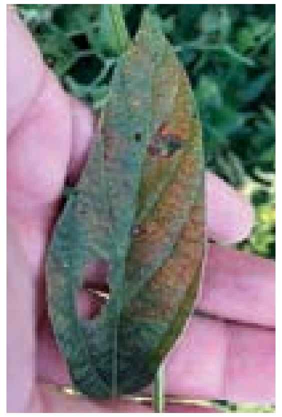

Figure 8. Cercospora leaf blight

Figure 9. Cercospora seed stain

- Leaves develop a purple to bronze discoloration that can resemble a sunburn appearance on the uppermost leaves – the color will deepen and may take on a leathery appearance.
- Infected pods often show a noticeable purple discoloration or staining of the seed; however symptomology may not be present even though seed is infected (Figure 9).

Management

- Rotating to crops other than soybeans and incorporating residue may help reduce inoculum and future disease.
- Plant tolerant varieties
- Consider an application of Miravis® Neo, Miravis Top, or Trivapro® fungicide at R1-R3 to help control Cercospora and consider a second application at R3-R5.

FROGEYE LEAF SPOT

Frogeye leaf spot (FLS), caused by the fungus *Cercospora sojina*, can be easily mistaken for other diseases or herbicide injury. There is a chance for significant yield impact from this disease when it appears during or just after flowering and favorable environmental conditions are present to allow continued development. Late-season occurrence (post-R5.5) usually has minimal yield impact. Frogeye leaf spot also has growing cases of resistance toward the QoI (Group 11) class of fungicides (strobilurins are the most well-known type in this class), making it imperative to be conscientious about fungicide choice and use.


Figure 10. Frogeye leaf spot

Symptoms

- Produces circular lesions, beginning as small, circular and dark water-soaked marks on the leaf tissue, but will become larger, more angular, and lighten in color throughout the season, fading from gray to brown to tan, and surrounded by a thin, purple margin (Figure 10).
- Lesions may also be found on the pods and stems, where they will sometimes appear more oblong on pods and elongated on stems than on the leaves.
- Tiny, dark fruiting bodies may be seen in the center of the spots.
- Severe infection can cause premature defoliation.
- Infection is most prevalent from R1-R7 (flowering through early maturity), mostly impacting the upper canopy of the crop, but can be seen in earlier growth stages.

Management

- Plant a Golden Harvest® soybean variety containing the Rcs3 gene, the only gene currently available that is resistant to all strains of the frogeye leaf spot fungus.
- Residue management may help mitigate future impacts of a previously infected field.
- Tillage and crop rotation may help break up and lessen overwintering host residues in the field.
- Consider using a fungicide with multiple, effective modes of action, such as Miravis® Top fungicide, to help manage strobilurin-resistant FLS infections.

WHITE MOLD

Sclerotinia stem rot, more commonly called "white mold," is a very common and widespread soybean fungal disease caused by *Sclerotinia sclerotiorum*. Losses from this disease may be extreme depending on the year and the amount of inoculum in the soil. White mold infections occur at flowering and thrive in saturated wet soils, high humidity and temperatures lower than 85°F. White mold symptoms aren't prevalent until later in the season and may be harder to manage at that point in time. It is important to identify as early as possible to manage effectively.

Symptoms

- Gray-to-white lesions at nodes will later develop into fluffy white growth on soybean stems (usually developing R3-R6) (Figure 11).
- Dark black sclerotia appear along the stem or bean pods.
- Bleached or light-colored stems occur as soybeans become dry or die.
- Dead brown leaves attached to stem are seen after severe disease progression.

Management

- Plant Golden Harvest soybean varieties with favorable Sclerotinia white mold ratings.
- Improve air movement within canopy to minimize development by choosing varieties with upright growth, increasing row width and reducing seeding rates.
- Consider crop rotation of 2-3 years to corn, small grains or forage legumes.
- Control broadleaf weeds which can serve as alternate hosts.
- If fields have a history of this disease or experience prime, consistent environmental conditions for disease growth, consider a fungicide application of Miravis® Neo or Miravis Top fungicide close to the R1 growth stage.


Figure 11. White mold

ADDITIONAL RESOURCES

GOLDEN HARVEST SEEDS AGRONOMY ARTICLES

GOLDEN HARVEST SEEDS YOUTUBE CHANNEL

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