Golden Harvest®

AGRONOMY IN ACTION

2024 RESEARCH REVIEW

LOOKING BACK 50 FORGING AHEAD

COMMEMORATIVE EDITION

AGRONOMY HAS DEEP ROOTS WITHIN GOLDEN HARVEST

Welcome to the 2024 Golden Harvest Agronomy in Action Research Review. This year marks the 5th consecutive year of publishing our Research Review as well as the 50th anniversary of the Golden Harvest brand. The number of years we have been delivering agronomic information and providing elite genetics to our customers goes back much further than five and 50 years respectively. We wanted to take a few moments to share how we got to where we are today.

THE FAMILIES THAT WOULD SHAPE THE BRAND

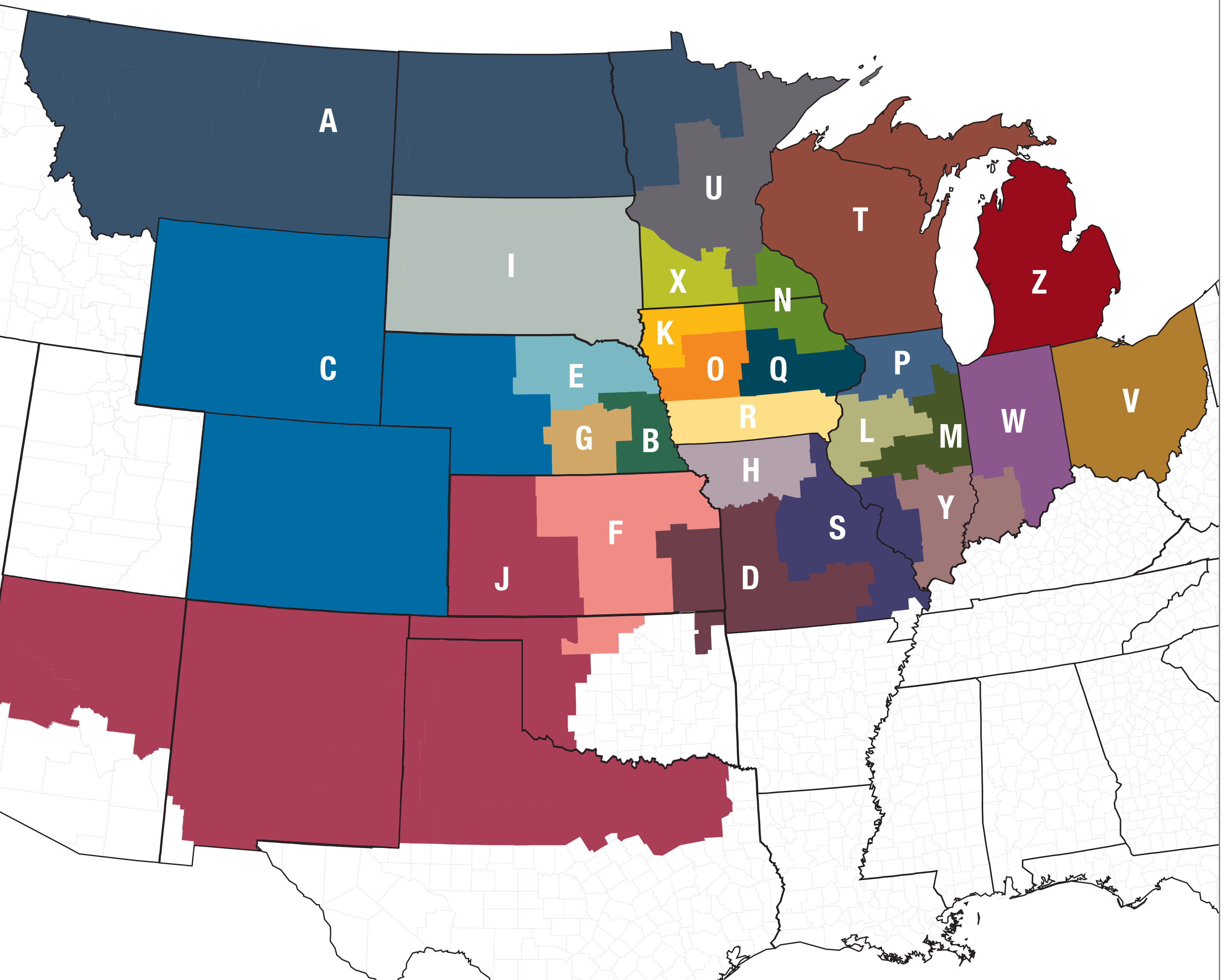
The Golden family, innovators since 1853 and founders of Golden Seed Co. Inc., was the first to package seed in paper bags. J.C. Robinson Seed Co. in Waterloo, NE, was established in 1888, offered 108 varieties of open pollinated seed corn by 1924 and introduced hybrid corn to their growing region in the 1930s. O.J. and Arthur Sommer founded Sommer Brothers Seed Co. in Pekin, IL, with their ten best ears of corn in 1909. Thorp Seed Co. operated one of the first tractors in Illinois in 1917 and applied the first nitrogen sidedress to corn in 1938. Founded in 1924 in Stonington, IL, Garwood Seed Company pioneered the use of a combine for soybeans and was instrumental in improving the pest resistance of early open pollinated corn varieties. Garst and Thomas Hi-Bred Corn Company was founded in 1931 as a family business. The company led the way in developing herbicide-tolerant hybrids, including the first IMI-corn, and was among the first seed companies to offer European corn borer (Bt) control and herbicide tolerance together in one corn hybrid. Columbiana Seed Co. was started in 1932 with 40 acres of seed production in Columbiana, IL. Clarence Akin planted his first acre of seed corn in 1936, officially starting Akin Seed Company.

HOW GOLDEN HARVEST FORMED

In 1973 seven family-owned seed companies previously working with Funk G Hybrids made the decision to end their current partnership and found Golden Harvest Seeds. The families consisting of Akin Seed, Columbiana Seed, Garwood Seed, Golden Seed, J.C. Robinson Seeds, Sommer Bros. Seed and Thorp Seed operated within specific regions, meanwhile exchanging germplasm and marketing under a much larger national brand. Not long after the formation, Akin Seed and Columbiana Seed left the Golden Harvest Brand, reducing it down to five family-owned companies. In 2013 the early contributions of Garst and Thomas Hi-bred Corn Company came to life when the Golden Harvest and Garst corn seed brands were unified under the Golden Harvest brand. The real history of Golden Harvest goes back over 150 years to the individual families that formed it.

AGRONOMY: A CORE VALUE

Delivering agronomic learnings goes back to the roots of each family-owned company that eventually made up Golden Harvest, but wasn't really formalized until the mid-1980s. Golden Harvest agronomists started observing how some hybrids were responding differently to specific herbicides and application timings. The desire to better understand individual herbicide by hybrid interactions led to the development of yearly trials done under the "Agronomy Up Front" moniker in 1984. Over time, protocols were added or dropped. In 2019 additional resources were put into delivering agronomic information and the current name of "Agronomy in Action" was born.



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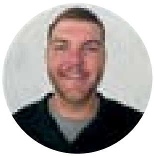
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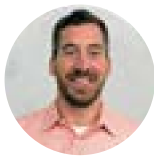
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MAIN MENU

CLICK ON A LINK BELOW TO JUMP TO THAT SECTION

SOIL HEALTH

CORN MANAGEMENT

CORN PEST MANAGEMENT

NUTRIENT MANAGEMENT

SOYBEAN PEST MANAGEMENT

SOYBEAN MANAGEMENT

Agronomy In Action Research Trial Article

EVALUATING SOIL HEALTH

INSIGHTS

- Healthy soils are important for cropping systems and there are multiple ways to measure improvement using on-farm testing methods.
- Lab soil health assessments are valuable to measure soil characteristics and record over time.

Healthy soils function efficiently to support resilient life. In corn and soybean cropping systems, this means optimum cycling and retention of both water and nutrients. There is a lot of interest in shifting farming practices to create more stable and productive systems, but how do we measure progress as a healthier soil is built? There are many methods for measuring changes in soil health and the measurement chosen should be consistent with the prioritized goal.

SOIL HEALTH GOALS

Many short-term soil health goals are biological and chemical in nature. For example, increasing microbial activity or adjusting soil pH may lead to the release of more nutrients available for the plants during the growing season of application. Reaching these goals often involves the addition of soil amendments, but maintaining these goals requires the optimum physical environment. Creating an optimum physical environment is a long-term goal that is achieved as biological and chemical factors come together to affect soil structure and soil function. Changes in cropping practices such as tillage, cover crops or rotation are often required to create an optimum physical environment.

SOIL HEALTH TESTS

There are two ways to compare treatment effects in agricultural soils. Side-by-side comparisons such as test strips or test blocks within a field work well for short-term and in-season measurements. If areas with and without treatment share the same soil type and weather conditions, this reduces environmental variability and gives a better idea of how much change is attributed to the treatment. Before and after comparisons are useful for treatments that take a longer time to take effect and use measurements not sensitive to seasonal variation.

Figure 1

ON-FARM TESTING METHODS

There are a multitude of ways to track soil health progress and a number of these are relatively easy to do on your own.

Slake test

The slake test is an excellent measure of soil health because it ties together chemical, biological and physical measurements into a single indicator. In the ideal chemical environment, abundant root and microbial activity thrive and produce materials for strong aggregation while roots and macrobiota also create tiny channels for water infiltration. Strong aggregation and channels for water keep a clump of soil together when it is suspended in water. Without strong aggregation and water channels, a clump of soil will slake apart when suspended in water (or under a strong rain).

Figure 2. Comparison of two soil samples using the slake test. Less soil moved into solution with the healthier sample on the right. Soil with less structure on the left, more easily dissolved into solution and settled out to bottom of jar.

To use the slake test for a side-by-side comparison, you will need the following:

- Two glass jars large enough to hold a chunk of soil
- Hardware mesh, chicken wire or mesh onion bags
- Two air-dried chunks of soil from different management systems for comparison

Position the mesh to hang inside the glass jars and fill the jars with water. Place the chunks of soil on the mesh and watch to see the difference in how the chunks slake apart. Take a picture of the amount of soil at the bottom of the jars after 10–15 minutes to compare to future years (Figure 2).

Root digs

The shape, color and smell of your roots can tell you a lot about your soil. Roots growing in a healthy environment are white with fine strands and a natural shape. If roots are stunted or bent, it is a sign they have encountered a zone of compaction, such as a side-wall or plow pan. Poor drainage can cause roots to be brown, mushy or smell bad. Roots that are cut off indicate undesirable soil organisms.

"Soil your undies"

While this underwear test is best known as an audience-shocking field day activity, it also does a good job of demonstrating microbial activity in the soil and provides an easy and consistent comparison across sites and years. Simply bury a pair of 100% cotton underwear 4–6 inches deep, leaving the waistband sticking out at the surface. Mark it with a flag and dig it up 60 days later. Compare how much material is left between different fields and take a picture to compare across years. Healthy soils that are teeming with decomposers and quickly cycling nutrients may have only the waistband remaining while dormant soils may keep most of the underwear intact.

Tea bag index

Similar to the "soil your undies" approach, you can also use household items (in this case, tea bags) to approximate microbial activity. Tea, like crop residues, can break down at different rates depending on their carbon to nitrogen ratio (C:N). Green tea bags, which have a lower C:N ratio similar to alfalfa, decay fairly quickly and are used to quantify short term organic matter decomposition. Red or rooibos tea bags have a higher C:N ratio similar to corn stalks and will break down slower. Burying the two types of tea bags for different periods of time in soil can be used to measure mass and carbon loss to quantify decomposition rates. Bury some tea bags (and mark them well) and get an approximation of how quickly your crop residues will decompose and provide nutrients to the crops (Figure 3).

Figure 3. Burying tea bags in soil to monitor rate of breakdown as indicator of soil biological activity.

LAB TESTING METHODS

Laboratory tests are more convenient if you have a large number of samples and wish to keep a clear quantitative record of changes in your soil.

Soil health assessments

Many commercial soil testing laboratories now offer soil health tests that include a suite of analyses that are used in combination to create a soil health score. These tests aim to characterize the quality of the environment for microbial life and simulate nutrient availability for plants. Through measuring microbial activity and various forms of carbon and nitrogen, these assessments give a good idea of how dependent the crop will be on additional fertilizers and soil amendments or how capable the system will be to support itself.

Soil health assessments provide a more complete picture than a single test, but care should be taken when comparing results across time and against other fields. Many of the components that are measured change throughout the growing season. Comparing spring soil samples from a cold and rootless period in one year to summer soil samples taken during a time of high temperatures and root activity

MAIN MENU

the following year could give the illusion that microbial activity has changed due to practices when it has only increased due to seasonal conditions.

Care should be taken when comparing results across time and other fields or soil types. Many of the components that are measured change throughout the growing season.

Many soil testing labs will provide an overall soil health score based on the combination of test results in the assessment. They will also provide interpretations and recommendations. However, many of these overall soil health scores are not well-calibrated to crop performance, and the lab-provided interpretations should be taken with a grain of salt. Due to texture and environment, not all soils have the capacity to reach a high soil health score relative to other soils. Soil health scores are most useful when comparing a soil type (or texture) to the same soil type without changes in farming practices or the same soil from previous years.

Organic matter fractions

Soil organic matter is material in the soil made up of plant, microbe and animal material. It is present in many forms. Some forms are easily decomposable and quickly contribute to nutrient cycling, while other forms do little beyond existing in the soil. Total organic matter may be a useful measurement for carbon sequestration. However, it is more useful to measure active forms of soil organic matter when trying to determine a soil's potential to support more plant and microbial life. Many commercial labs offer tests for "active carbon" or POXC (permanganate oxidizable carbon), which represents a soil carbon that has been processed by microbes and is likely building soil carbon.

PLFA and enzyme tests

Phospholipid fatty acids (PLFA) are membranes found in organisms and have a different composition for bacteria, fungi and other soil microbes. PLFA analysis can determine the abundance of microbial life and provide a snapshot of microbial community composition. Healthier soils will have a greater abundance of microbial life. Higher ratios of fungi to bacteria are also considered an indicator of a healthier soil. Both measurements will vary over the season as temperature and moisture vary. Different laboratories also use different PLFA markers and may sometimes change markers from year to year. It is important to collect samples under similar conditions and submit samples to a consistent laboratory.

Enzymes are produced by microbes to serve specific functions in nutrient cycling. Looking at microbial activity through enzymes instead of PLFA means asking, "What are they doing?" instead of "Who is there?" Most laboratories measure enzymes involved in carbon, nitrogen and phosphorus cycling. An increase in the presence of these enzymes indicates the community driving these cycles is not only present, but also active. Like all biological measurements, enzyme analysis is also sensitive to changes in temperature, moisture and root activity. Care should be taken when comparing analysis results over time.

Overall, soil health analysis along with soil health improvement is complex, takes time, and requires some form of consistent testing. If you have questions or want help setting goals for your soil health, reach out to your local Golden Harvest Agronomist, Sales Representative or Seed Advisor.

MAIN MENU

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 in offsetting greenhouse gases has placed row crop agriculture at the center of the discussion, as sequestering atmospheric carbon through soil organic matter (SOM) has generated interest. There has been emphasis on maintaining or improving SOM for decades. Its measurement is included in 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

SOM 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 SOM 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).

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.

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: Carbon to Nitrogen Ratios in Cropping Systems, USDA NRCS, soils.usda.gov/sqi

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 an important role 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.

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

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.[1] 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.[3] 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 it 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 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/A corn produces ~9,000 to 10,000 lb/A 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.

Increasing soil organic matter (SOM) is a long-term strategy to positively impact soil properties, such as water infiltration, soil structure and nutrient-holding capabilities.

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: Cover crops 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

SOM 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 HEALTH
MAIN MENU

SOIL COMPACTION AND ITS EFFECT ON CORN GROWTH

INSIGHTS

- Soil compaction reduces the size and amount of pore space, decreasing vertical water movement, soil aeration and oxygen movement.
- Different types of soil compaction include tillage pan/plow layer, planter sidewall compaction and deep compaction.
- The use of proactive measures to mitigate soil compaction is typically the most effective in reducing it long-term.

The temptation to begin field work or planting before soil conditions are ideal happens almost every year, but is even worse when cool, wet springs cause delays. Running across fields with planters or tillage implements when the soil is too wet can cause soil compaction issues.

IMPACT OF SOIL COMPACTION

Compaction increases bulk density of the soil, creating an impenetrable layer of soil that will break apart in flat pieces when digging, as shown in Figure 1. Compaction reduces the size and amount of pore space in the soil, decreasing vertical water movement throughout the soil profile and increasing water runoff.[1] Less soil pore space also reduces soil aeration and oxygen movement, which is important for root respiration and nutrient uptake.

Soil compaction depletes the soil of oxygen, throwing off the balance of "healthy soil." Soil should be about 25% air.[2] Lower ratios of oxygen within soil reduces soil mineralization rates, resulting in reduced nitrogen, phosphorus and potassium availability to the crop through normal microbial processes.

Soil compaction can also alter and reduce rooting depth, which can cause trouble later in the growing season when water becomes scarce and plants are not able to mine the full soil profile for water and mobile soil nutrients.[3]

Figure 1. Compaction layer from tillage on wet soils.

THREE COMMON TYPES OF COMPACTION

Tillage pan or plow layer

Tillage is mainly used to manage residue from prior crops and prepare an even surface for planting. As similar tillage practices are used across years, soil profiles will begin to form a hard, compacted layer across fields at the depth the tillage equipment was run. Disks or field cultivators will form a layer closer to soil surface due to their operating depth, where moldboard plowing creates similar layers at deeper depths. Tillage in wet soil conditions only worsens the effects of tillage pan or plow layers. The resulting layer will restrict water movement and root growth to needed depths for accessing nutrients and moisture.

Planter sidewall compaction

When the openers on a planter "smear" the sides of the seed trench, they create a layer of soil that restricts outward root growth. This "smearing" of the sidewalls of the seed furrow will restrict the root growth through the seed furrow, leading to the development of "mohawk" roots on the corn plant.

Figure 2. Sidewall compaction from wet planting conditions.

Deep compaction

As the name implies, deep compaction forms at a deeper depth in the soil profile and is therefore much harder to eliminate with tillage. Deep compaction typically forms in areas with high traffic with implements loaded to maximum axle weights. The most common cause is grain cart or truck traffic lanes within fields or on end rows. This type of compaction is often the most visible, as the restricted rooting depth can dramatically reduce crop growth as shown in Figure 3.

EFFECT OF COMPACTION ON CORN PLANTS

Roots will grow and develop best in a porous soil, free of compaction. A healthy root system that spreads out and penetrates the soil profile will have large amounts of surface area. This large root surface area allows for efficient uptake of nutrients and water and helps anchor the plant into the soil, decreasing the risk of lodging throughout the growing season.

Compaction restricts root growth and affects nutrient and water uptake throughout the growing season, even if the proper rates of nutrients have been applied to the field and soil moisture is adequate. Roots cannot take up enough nutrients. This leads to plants cannibalizing stalks and increasing the risk of late season lodging because the roots cannot fully develop enough to anchor the plant.

DETERMINING WHEN SOIL IS READY FOR FIELD WORK

Just because the soil surface is dry, doesn't mean that the field is ready for tillage. University researchers recommend digging one inch below the depth of tillage, taking a handful of soil and rolling it into a "worm" shape. If the soil can be rolled into a "worm" that is longer than five inches and does not break apart, the soil is too wet for tillage.[4]

Growers may be tempted to use vertical tillage tools to work the top 2–3 inches of soil to "dry out" the soil to plant sooner. This is not recommended as it will create a tillage pan just below where the seeds will be placed and can restrict water movement through the soil profile. That water will

Figure 3. Deep compaction from grain cart traffic the prior fall.

accumulate at the same depth as the seeds and can cause injury or death to the germinating and emerging seedlings.

MANAGING COMPACTED SOILS

Preventing soil compaction from happening is the best way to manage soils.[5] However, minimizing or controlling soil compaction are the next best options since farmers need to be in the field in less-than-ideal soil conditions. Consider controlled traffic in fields, managing axle loads and tire pressure, and selecting the right equipment for the job.[3] Before deciding on a compaction management tool, it is important to diagnose the existence and depth of compaction.[6]

During the early growing season, corn growing in compacted soils should be monitored for nutrient deficiency symptoms and corrected, if possible. For sidewall compaction, cultivation may be considered to help promote more root growth and help standability. For a tillage pan, a cultivator pass or sidedress N application can help break up the layer if it can be made deep enough.

For late season management, monitor the fields for any potential stalk or root lodging, and plan to harvest those fields early to help minimize losses. To help break up compaction in a field, a deep tillage pass at an angle to the normal cropping rows may be considered in the fall. This will help restore oxygen to the soil profile. In a no-till environment, consider planting an aggressively growing cover crop, such as tillage radish, to break compaction layers. The most important resource to growing a healthy and profitable crop is your soil, so consistent management of compaction is necessary.

SOIL HEALTH
MAIN MENU

BIN BUSTER: TESTING COVER CROPS AND REGENERATIVE FARMING PRACTICES

INSIGHTS

- Healthy soils promote sustainable crop production by increasing plant available water and nutrient use efficiency, reducing agrichemical runoff, and contributing to climate change mitigation.
- While soils can be degraded in an instant, it can take years to realize soil improvement benefits that accumulate over time.
- Enhanced soil health created by regenerative agriculture systems coupled with crop rotations, residue and agrichemical management benefits both growers and the environment.

Regenerative Agriculture (RA) is continually gaining interest, but transitioning to new practices requires investment and carries risk. Outcomes such as improved soil health and carbon capture can take years to fully materialize and be difficult to measure. Many farmers remain uncertain about the adoption of RA practices with the benefits they provide.

Project Bin Buster is a Syngenta initiative created to give farmers reliable data demonstrating the benefits of RA, better understand when benefits can be realized and guide the transition to RA. An integral goal of Bin Buster is to test, recommend and incorporate selected technologies into grower operations with emphasis on grower return-on-investment (ROI). Additionally, the project's vision is to link science-based sustainability outcomes with technology data and eventually incorporate it into grower-friendly decision support platforms.

Bin Buster is currently testing two management practices, cover crops and conservation tillage (no-till, NT; strip-till, ST), with intentions to develop a set of best practices that farmers can draw from and a framework for evaluating their progress.

ACTION

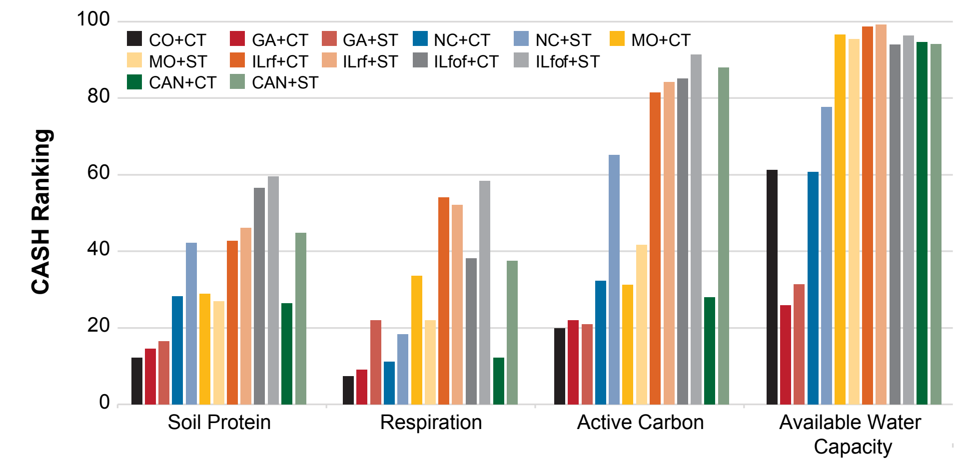
Created by Syngenta Group in 2018, Bin Buster (the name refers to yields so high they burst grain bins) takes place on several farms within a network across North America. At each Bin Buster site, traditional conventional tillage (CT) practices are compared to the conservation practices of strip-till (ST) coupled with cover crops. A soybean-corn rotation was used at Midwest sites (IL, MO); a cotton-peanut-corn-soybean rotation was used on Southeastern sites (NC, GA); and a continuous corn was used at Colorado (CO) and Canadian (CAN) sites. The project measures yield as well as soil health indicators such as active carbon content, organic matter, pH and others (Table 1). Soil and yield data are collected at intervals throughout the growing season and compared to CT and/or baseline data from tillage systems established in either 2021 or 2022.

Bin Buster aims to give farmers an understanding of how RA practices impact soil health across different geographical regions with different soil, climate and cropping systems.

Soil Properties	Indicators
Physical	Soil texture Bulk density Available water holding wcapacity Wet aggregate stability Compaction/hardness interpretation
Chemical	Soil pH Extractable P, K, micronutrients Cation exchange capacity
Biological	Organic matter content Active carbon Short-term C mineralization Total Carbon (C) and Nitrogen (N) Potentially mineralizable N Soil protein index

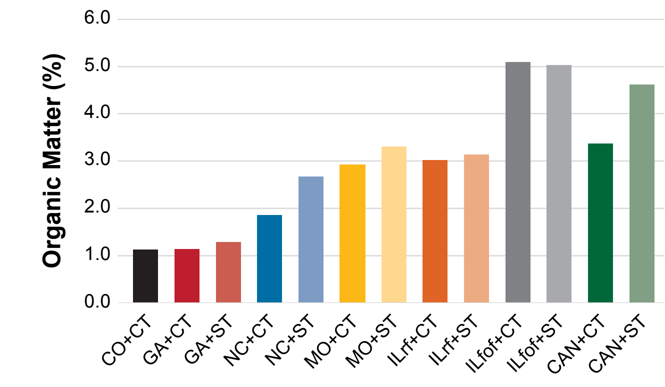
Table 1. Soil health indicators/parameters evaluated by CASH.

First, it hopes to use regular soil sampling to gauge soil variability and RA impact. Second, Bin Buster plans to illustrate which tools are most effective for capturing data and making decisions around future management practices and crop inputs. Finally, it is designed to evaluate which soil health metrics are most impactful.



Graph 1. Regional (state or Canada) + tillage system CASH differences
CT = Conventional tillage system
ST = Strip-tillage system

Leveraging and integrating science-based sustainable soil health results into Bin Buster-generated databases and grower-friendly decision support platforms contributes to adoptable, cost-effective solutions to agronomic, environmental, natural resource and profitability challenges. Bin Buster uses soil health indicator measurements via the *Comprehensive Assessment of Soil Health* (CASH) framework to quantify on-farm soil carbon and its rate of change as a function of farm location, regenerative ag practices (CT, ST) and length of time the system has been adopted (Table 1). Soil health metrics measured by CASH are effective in quantifying soil health improvement as a function of regenerative ag practices, cropping rotations and tillage systems adopted by growers in different regions of the U.S.



Graph 2. Regional + tillage system % organic matter differences
CT = Conventional tillage system
ST = Strip-tillage system

Soil carbon is a critical soil health indicator of other important parameters such as water and nutrient availability, microbial and fungal biodiversity, greenhouse gas emissions and fertility. Approaches to quantifying the improvement in soil health over time will need to vary by farm and region.

OUTCOME

Preliminary results, collected in the 1–2 years after trial plot establishment, already show improvements in selected soil health parameters from the six regionally diverse sites (Graphs 1 and 2). It is relatively early to see steady-state differences among soil properties from adopting strip-till and cover crops, although significant changes can already be seen in active carbon at almost all locations. As more years of data are collected, relative differences are expected to become more distinguishable among tillage and cropping practices such as cover crops used in this field study. It typically takes multiple years of adoption to start seeing significant results in soil health indices. Over time, Bin Buster will gauge the impact on yields and the trajectory of soil health changes, to understand whether the benefits of RA continue to accumulate or if they plateau after a certain period.

Enhanced soil health created by these regenerative agriculture systems, crop rotations and agrichemical management can have benefits for growers as well as the environment. These benefits could come in the form of remediation of degraded land, improved water quality, reduced trips across the field, sustained productivity and profitability.

EFFECT OF UNEVEN EMERGENCE ON CORN YIELD POTENTIAL

INSIGHTS

- Yield decreased 0.6 to 1 bu/A for every 1% increase in delayed emergence in these trials.
- Yield and gross revenue decreased 0.26% and $1.30/A, respectively, for every 1% increase in late emerging plants.
- Ear flex potential of a hybrid did not influence the response to delayed emergence.

Uniform corn plant emergence is a critical step towards maximizing genetic yield potential. When uneven emergence occurs, late emerging plants are at a disadvantage in competing for resources (e.g., water, nutrients), resulting in smaller ears. If emergence is delayed even further, those plants often are barren, yet are still competing against productive plants for resources. While several factors that cause uneven emergence are manageable (e.g., consistent planting depth, proper seed-to-soil contact), there are still uncontrollable microenvironmental factors (e.g., soil moisture and temperature) that are difficult to fully account for, especially in highly variable fields. This article discusses what to expect for corn yield when emergence is uneven due to these microenvironmental factors.

TRIAL DETAILS

Agronomy in Action Research trials were conducted at nine sites to quantify the effect of uneven plant emergence on yield. Two Golden Harvest® corn hybrids with differing ear flex ratings were planted at each location to understand if the response to uneven emergence would vary. Hybrids used included G00A97 brand (semi determinant) and G02K39 brand (flex) at early relative maturity (RM) sites (Blue Earth, MN, Bridgewater, SD, Grundy Center, IA and Janesville, WI), and G10D21 brand (semi determinant) and G11V76 brand (semi flex) at late RM sites (Clay Center, KS, Clinton, IL, Malta, IL, Slater, IA and Waterloo, NE).

The trial evaluated varied levels of uneven emergence based on a percentage of delayed plants at the following targets:

1. Untreated Check (uniform emergence)
2. 10% Delayed Plants
3. 20% Delayed Plants
4. 30% Delayed Plants

Delayed emergence of individual plants was achieved by coating selected seeds with a polymer to delay germination. The polymer was originally designed for synchronizing male-female inbred pollination in seed corn production fields. A minimum number of GDUs is required for polymer breakdown, resulting in delayed water absorption by seeds and subsequent germination. In this trial, it was applied as an overtreatment to the base seed treatment in which delayed emergence was desired and blended at appropriate ratios with seeds without a polymer (Figure 1).

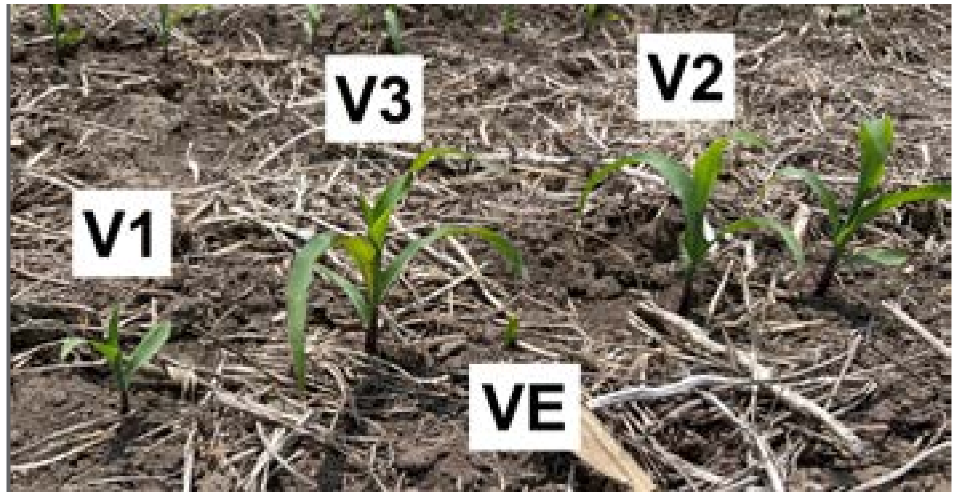
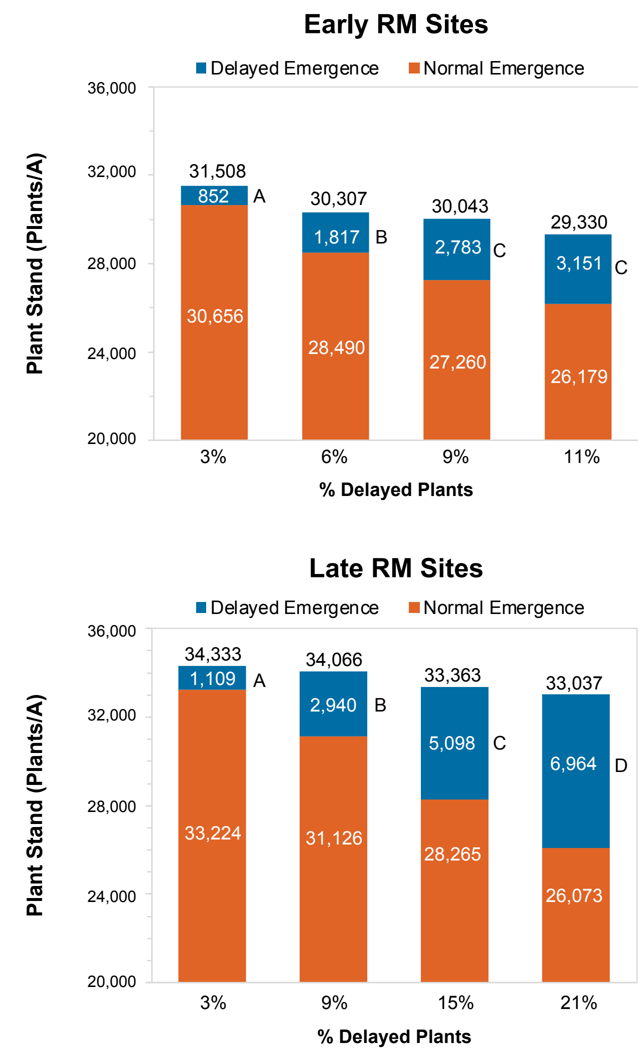


Figure 1. Range of growth stages caused by the seed polymer and cool, dry soils at Waterloo, NE planted on May 2. Photo taken on May 23.



Graph 1. Response of plant stands and runt plants to delayed emergence at early RM (top) and late RM (bottom) sites. Different letters indicate differences between delayed plant levels, *P*≤0.10.

PLANT STANDS AND RUNT PLANTS FROM DELAYED EMERGENCE

Emergence of seeds treated with the polymer, on average, ranged from one to six days later, although longer delays were not uncommon. For example, delays up to ten days were observed at Waterloo, NE due to abnormally low rainfall and poor soil moisture. Stand counts were taken at the V3 growth stage to give adequate time for complete emergence and still be able to detect the number of runts or plants one or more growth stages behind.

Actual levels of delayed plants differed between the early and late RM sites (Graph 1). At the late RM sites, the observed delayed emergence levels were 9, 15 and 21% compared to the check plots without a polymer having 3% delays. Delayed emergence at early RM sites were 6, 9 and 11% compared to check plots having 3% delays.

Dry soil conditions at Waterloo resulted in a bigger spread in emergence of polymer coated seeds resulting in multiple growth stages occurring simultaneously (Figure 1). Significant variability in ear size was observed with the different emergence timings (Figure 2). Ears with fewer kernel rows were observed when emergence was delayed ≥ 7 days. Early RM sites were planted on or after May 10, which had warmer soils that likely accelerated polymer degradation, thus reducing the amount of overall delayed plants. Due to rapid GDU accumulation at early RM sites, there was also less variability of delay timings as seen at the Waterloo site.

YIELD RESPONSE TO DELAYED EMERGENCE

Small decreases in final stand were seen when the targeted number of delayed plants increased but in general final plant stands were similar across treatments. Due to this, it is safe to assume that yield loss at locations was primarily due to delayed emergence rather than reduced final stand. In general, yields decreased as the percentage of delayed plants increased (Graph 2). On average yields were reduced by 0.58 bu/A and 1.1 bu/A for every 1% increase in delayed emerging plants at the late RM and early RM locations respectively. Although the targeted number of delayed plants were the same at late RM and early RM locations, there were fewer overall delayed plants at early RM locations, yet yields were more severely reduced for every increase in delayed plant present at those sites.

As an example of the potential economic loss, when you look at 9% of plants being delayed, there was an average loss of 5 bu/A across early and late RM locations from delays which is equivalent to $25 per acre (assuming $5.00/bu grain value).

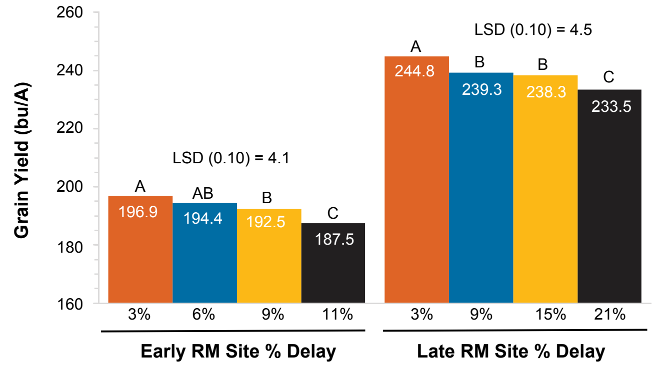
Regression analysis found yield potential decreased linearly as the percentage of delayed plants (defined as ≥ 1 growth stage behind) increased (Graph 3). Specifically, it predicted a 0.26% decrease in yield for every 1%

increase in plants delayed. This would result in a reduction in revenue of $1.30/A with each 1% delay increase (assuming $5.00/bu grain value). This brief economic analysis underscores that there can be significant revenue penalties if uneven plant emergence occurs.

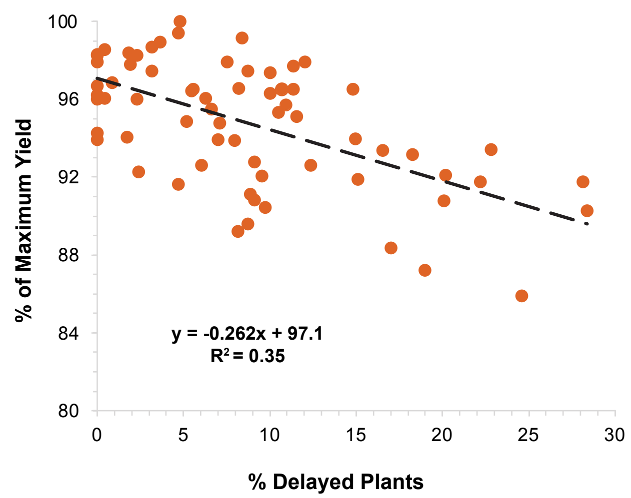
The ear flex ability of the hybrid did not statistically affect its response to delayed emergence. It was hypothesized that yield losses would be less with flex hybrids due to their ability to better respond to interplant competition. However, the data did not support this, as individual hybrid responses to varying delayed plant emergence levels were statistically similar. This indicates that growers should not expect that using a hybrid with some degree of ear flex will lessen the detrimental effect of uneven emergence if it occurs.

SUMMARY

This trial demonstrated that stand uniformity can have a significant effect on corn yield, especially in fields planted at high populations, due to interplant competition. The results also showed that hybrids with greater ear flex potential did not consistently minimize the effects of delayed or inconsistent plant emergence compared to hybrids with less ear flex. Although we cannot control the environmental factors that contribute to uneven emergence, proper planting management (residue management, seeding depth, seed-to-soil contact), selection of seed with good early vigor and planting into soils at or above 50°F will collectively help maximize uniform plant emergence.



Graph 2. Response of yield to delayed emergence averaged across two hybrids at the early RM and late RM sites.



Graph 3. Relationship between % of maximum grain yield and % of delayed plants (≥ 1 growth stage behind plot median).

Figure 2. Ear size resulting from uneven emergence at Slater, IA. Dates indicates an individual plant emergence date. Trial planted on May 2, 2023.

MANAGING CONTINUOUS CORN YIELD PENALTY

INSIGHTS

- Growing continuous corn comes with agronomic challenges that can significantly decrease yield if left unmanaged.
- Managing residue, fertility and pest pressure is critical to maximizing yield potential in continuous corn.
- Placing continuous corn on more productive fields has been found to help minimize yield penalty.

CHALLENGES OF GROWING CONTINUOUS CORN

The number of continuous corn acres in the U.S. fluctuates each year depending on variables such as grain prices, input costs and the previous growing season. Yield penalties associated with lack of crop rotation (continuous corn) are a common concern and can be caused by multiple related issues:

1. Increased residue
2. Reduced stand establishment
3. Decrease soil nitrogen (N) availability
4. Elevated disease pressure
5. Increased insect pressure

With proper management, growers can reduce the continuous corn yield penalty and increase profit potential.

MANAGING RESIDUE

Corn residue from previous years can create multiple issues such as reduced nutrient availability and soil temperature as well as increased soil moisture and pest pressure. The high carbon to nitrogen ratio of corn residue can immobilize soil nitrogen making it less available that season. Colder and wetter soils can slow emergence and increase risk of seedling disease and stand loss. Cooler spring soils can also delay mineralization and availability of other nutrients such as sulfur (S). Residue can also harbor pathogens from previous years that can develop into diseases. Corn residue has even been believed to have an allelopathic effect that

Figure 1. Heavy residue cover in continuous corn field that can reduce stand establishment, decrease nitrogen availability and increase pest pressure.

can slow early season growth of the following corn crop. At planting, heavy levels of residue create a physical barrier for seedlings to grow through (Figure 1).

As corn yields continue to increase, so does the amount of stover accumulation. A 180 bu/A corn crop accumulates 4.3 tons of stover per acre. As yields increase to 300 bu/A, the amount of stover accumulation can be over 7 tons/A.[1]

There are different ways to manage residue such as removing it by baling corn stalks. However, removing residue can also remove nutrients such as N and potassium (K) that must eventually be replaced. Another option is to incorporate residue into the soil with tillage to speed up residue breakdown. Sizing residue into smaller pieces increases the surface area for microbes to break down biomass faster. Vertical tillage or chopping stalks with a mower can size residue but also requires an extra pass in the field. Attachments for corn heads can size the residue while harvesting. Chopping corn heads, residue managing stalk rolls and aggressive stalk stompers are all combine attachments that can create more surface area for microbes to enter. There are also biological products on the market that either contain physical microbes or catalysts to increase the activity of microbes already present in the soil to accelerate the decomposition process.

Figure 2. Difference in remaining residue and plant health during the following growing season after harvesting with OEM stalk roll on left compared to residue sizing stalk roll on right (Vogel and Below 2019).

A study conducted at the University of Illinois showed a 7% increase in residue decomposition overwinter when using a sizing stalk roll compared to the original equipment manufacturer (OEM) stalk roll (Figure 2). The 7% increase in residue degradation resulted in a 10 bu/A increase in yield suggesting that reducing the amount of residue from the previous crop can mitigate continuous corn yield penalty.[2]

FERTILITY MANAGEMENT

Corn stover contains a much higher amount of carbon than nitrogen (60:1) relative to other crop residues like soybeans (20:1) which break down much faster. Soil microorganisms need a C:N ratio diet of 24:1 to be able to survive and stay active. In cases where residue C:N ratios are greater than 20:1, such as with corn, soil microorganisms will seek out additional nitrogen to consume the extra carbon. This results in soil nitrogen being immobilized and unavailable until those microbes die. Due to this, continuous corn requires between 40–50 lbs/acre more nitrogen than rotated corn. Broadcasting N directly on corn residue further increases risk of N immobilization. Delaying N applications closer to time of planting and applying in a band near the row can help reduce immobilization and increase plant availability.

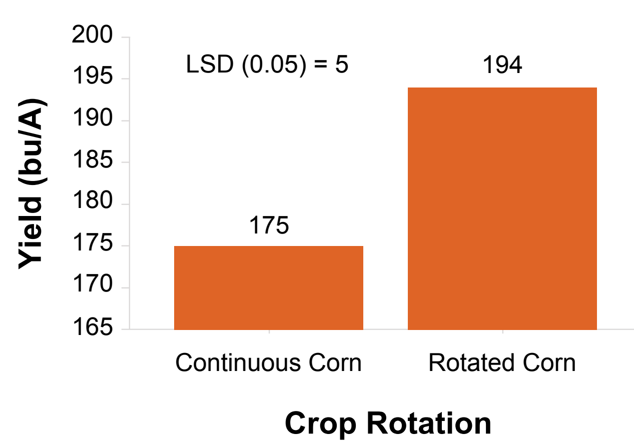
Corn residue also slows soil warming in the spring which reduces root growth, slows the rate of diffusion and slows soil mineralization. Nutrients that are taken up by the plant through diffusion, such as P and K, may become deficient early in the season. Using a starter fertilizer and placing nutrients near the root zone provides immediately available nutrients to the plant. As soils warm, organic matter mineralizes to supply the bulk of plant S needs. However, with cooler soils mineralization is slowed and can cause early season sulfur deficiency in continuous corn. Apply at least 15 lbs/A of S around planting time to avoid S deficiency problems.

PEST CONTROL

Insect pests such as wireworms, seedcorn maggots and white grubs can become more problematic with heavy residue situations. Using a premium seed treatment will help protect seed and seedlings against insect pests.

Many crop diseases overwinter in corn residue. In addition, many diseases prefer a cool and wet environment to survive and infect the plant. Using a premium seed treatment can protect seedlings from root and shoot infections. Foliar fungicides are even more important in continuous corn due to the more conducive environment for disease. Prolonging plant and stalk health is critical for late season standability.

In continuous corn, corn rootworm (CRW) population can become elevated. Using a soil applied insecticide or transgenic hybrid with two below ground modes of action against CRW can help protect the roots against feeding. Foliar insecticide applications properly timed to control female CRW beetles have also been found to help reduce future year CRW populations.



Graph 1. Effect of crop rotation on corn yield averaged across 41 site-years between 2005–2011.

GOLDEN HARVEST CROP ROTATION TRIALS

Golden Harvest conducted crop rotation studies across the Midwest from 2005–2011 for a total of 41 site-years. On average, corn grown in a rotation with soybean yielded 19 bu/A greater than corn grown continuously (Graph 1).

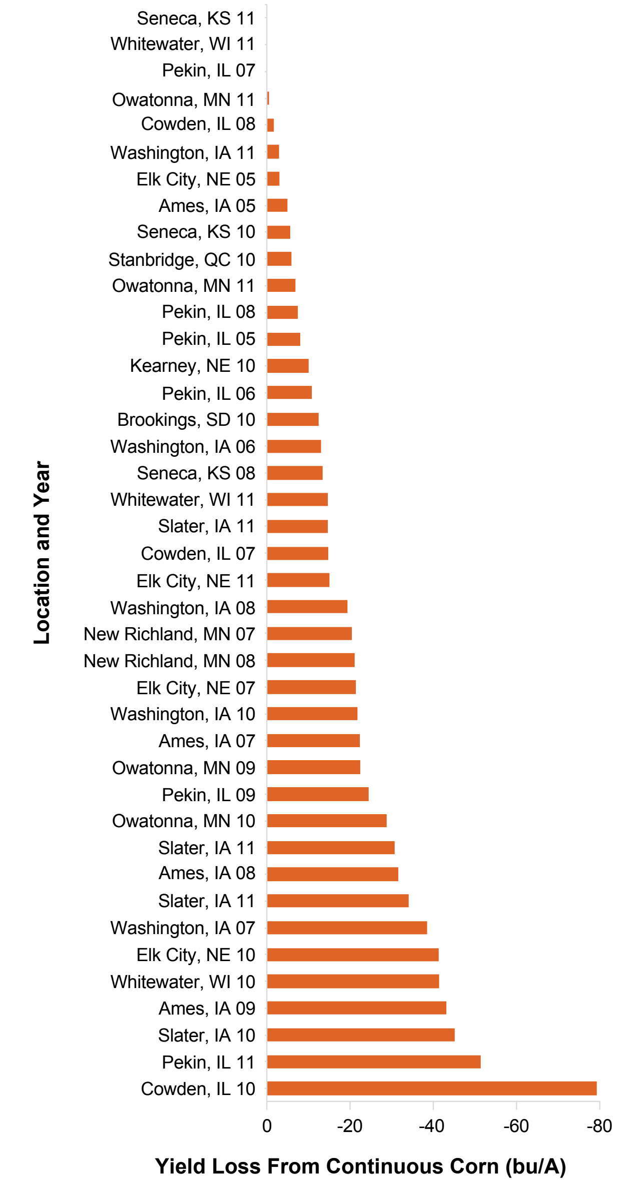
The magnitude of yield penalty varied between sites. The effect of crop rotation was drastically different from year to year even at the same location suggesting that growing conditions play a large role in the severity of yield loss. For example, corn grown continuously at Elk City, NE experienced a loss of 3 bu/A in 2005, 21 bu/A in 2007, 42 bu/A in 2010, and 14 bu/A in 2011 compared to rotated corn (Graph 2). Adequate precipitation and mild temperatures mitigate the detrimental effect continuous corn can have on yield.

Consider placing continuous corn rotations in more productive fields to help reduce yield penalty. Previous rotation trials have seen an overall lower percent yield loss at locations with higher overall yield potential (Graph 3). Pre-existing environmental stress which creates lower yield environments likely exacerbates the negative responses of continuous corn itself, causing larger penalties.

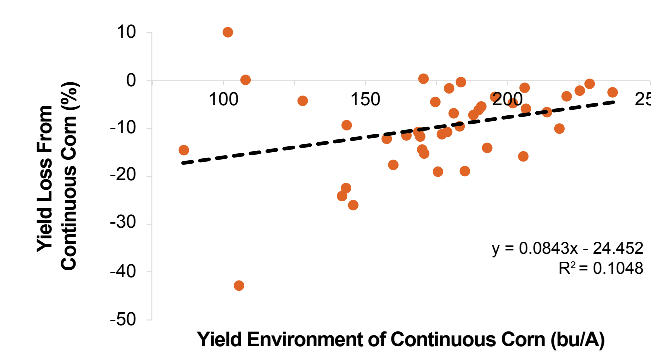
Hybrids differ in their suitability for continuous corn. When selecting hybrids, choose locally-adapted hybrids with desired traits, relative maturity and proven yield. Focus on hybrids with solid agronomics such as strong disease package, excellent seedling vigor and good root and stalk strength.

OVERCOMING THE CONTINUOUS CORN YIELD PENALTY

Despite the challenges when growing continuous corn compared to rotated corn, high yields are still achievable with proper management. Placing a strong agronomic hybrid in a high yielding environment while focusing on residue management, fertility and pest control is key to overcoming the continuous corn yield penalty.



Graph 2. Effect of crop rotation on corn yield at 41 sites between 2005 and 2011.



Graph 3. Influence of yield environment on continuous corn yield penalty at 41 sites between 2005 and 2011.

DON'T LET VOLUNTEER CORN CATCH YOU OFF GUARD

INSIGHTS

- Volunteer corn has been shown to reduce yields by up to 20% in corn and up to 56% in soybeans if left untreated.
- Minimizing harvest losses, stalk lodging and opportunities for germination are effective measures to proactively manage a potential volunteer corn escape the following season.
- Each management strategy for volunteer corn must be tailored to the specific crop being planted next, with respect to the traits incorporated into it.

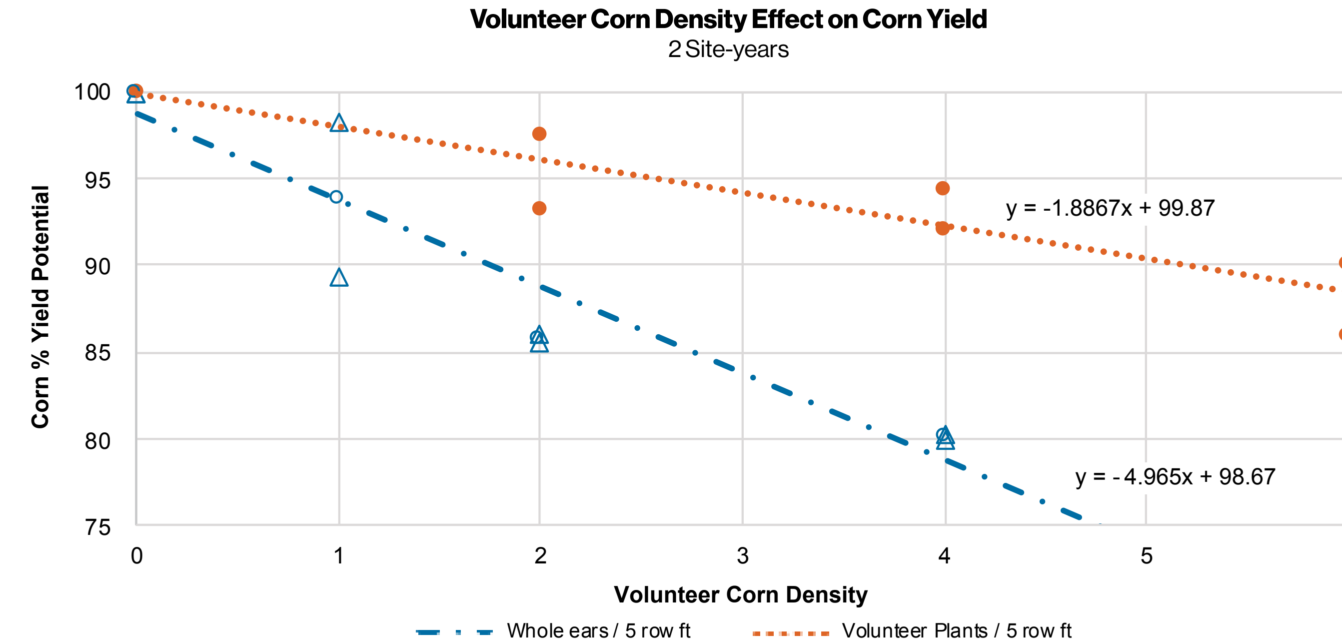
Many areas experiencing dry conditions in 2023 will be at a higher risk of needing to manage volunteer corn in 2024. Drought can produce smaller ears that are hard to harvest and have lower test weight corn from premature death that can blow out the back of the combine. Volunteer corn is a competitive weed and has been shown to reduce yields by up to 20% in corn and up to 56% in soybeans if left untreated. Management of volunteer corn plants in crop production has traditionally involved a combination of cultural and mechanical practices. Minimizing harvest losses, stalk lodging and opportunities for germination are effective measures to proactively manage a potential volunteer corn escape the following season. Each management strategy for volunteer corn must be tailored to the specific crop being planted next, with respect to the traits incorporated into it. Like any other weed, volunteer corn starts competing with crops at early growth stages, so it is imperative to control volunteers early in the season to maintain corn and soybean yield potential.

The Golden Harvest Agronomy In Action research team conducted trials to understand the effect of volunteer corn on both corn and soybean yields. Trials were conducted in Iowa, Illinois and Nebraska using volunteer corn arranged in consistent patterns and various densities. Conventional corn, not having any herbicide tolerance, was harvested the previous fall for use as volunteer corn. The corn hybrids used in the trials were herbicide-tolerant to both glyphosate and glufosinate. Comparisons were made showing the effectiveness on volunteer corn between the two non-selective herbicides. Multiple herbicide application timings were used to evaluate the importance of application timing on volunteer corn.

Figure 1. Four whole ears of volunteer corn per 5 feet.

EFFECT OF VOLUNTEER CORN ON CORN AND SOYBEAN YIELDS

- Volunteers reduced yield by up to 20% (corn) and 56% (soybean)[1] (Graphs 1 and 2).
- Individual plants cause less yield loss than whole ears dropped on ground.
- Yield loss increases as density of volunteers increases.



Graph 1.

- Volunteer corn managed at a 6-inch height or earlier may not impact yield negatively in corn or soybeans.
- Delaying management until 12-inch volunteer height may result in yields similar to when volunteers were left uncontrolled.

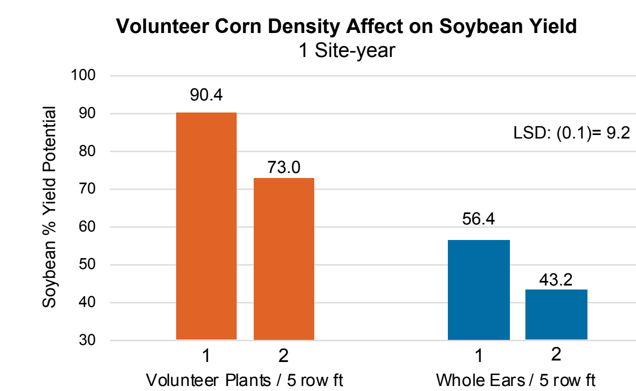
MANAGEMENT

Herbicide options:

- If volunteer corn is derived from a hybrid that only had glyphosate herbicide tolerance, glufosinate-based herbicides could be used in combination with Duracade® or Viptera® trait stacked corn hybrids, which are tolerant to glufosinate, to effectively control small volunteer corn plants.
- Volunteer corn in soybeans can be managed using graminicides herbicide options such as Fusilade® DX.

Options to minimize future volunteer risk:

- Use Viptera corn hybrids to manage insect damage that could contribute to ear drop from insect feeding in the ear shank.
- Use Duracade hybrids alone or in combination with Force® insecticide to prevent root lodging from corn rootworm root damage.
- Schedule field harvest based on scouting for fields at an elevated risk of lodging and ear drop.
- Properly adjust combine to minimize harvest losses.
- Complete fall tillage early to promote volunteer growth before a killing freeze.
- Consider no-till to minimize seed-to-soil contact and reduce volunteer germination.
- Graze cattle in fields with lodging and ear drop to minimize germination of volunteers the following year.



Graph 2.

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.

Positioning corn hybrids on the appropriate fields and with the right management practices is critically important for maximizing yield potential. Golden Harvest is committed to providing information on how hybrids respond to different management systems and inform growers which hybrids are best for their environment.

In 2023, Golden Harvest implemented genetic x environment x management (G x E x M) on-farm replicated strip trials at six locations to better understand how hybrids respond to enhanced management at a local level (Figure 1).

Trials consisted of 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.

G X E X M TRIAL RESULTS

Yield response to the enhanced management system ranged from 5–17 bu/A, depending on location (Graph 1). Clinton, IL, Malta, IL and Saint Johns, MI were the most responsive locations yielding 15–17 bu/A greater with enhanced management compared to standard management. The enhanced programs were not as intensive at Charles City, IA, Saint Ansgar, IA and Sumner, IA which responded by 5–7 bu/A. The environment, hybrid and base management program all play roles in the magnitude of yield benefit from management.

On average across all locations, there was a 11 bu/A yield improvement with enhanced management suggesting there is yield potential to be gained on these farms through better crop management. In these trials, there were

Figure 1. Locations for on-farm G x E x M trials in 2023.

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.

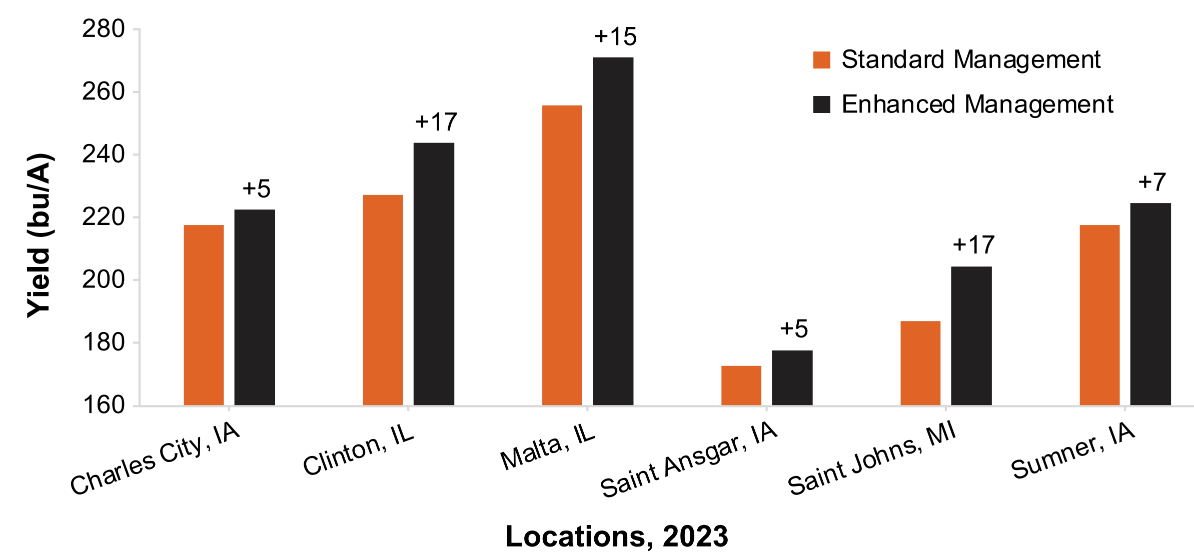
HYBRID RESPONSE TO MANAGEMENT

Hybrids responded differently to enhanced management (Graph 2). At the two locations that included G97B68 brand, it was the most responsive hybrid to enhanced management yielding 11 bu/A greater at Saint Ansgar and 27 bu/A greater at Saint Johns than the standard program. G03B19 brand was at five locations and tended to have an average response to management compared to all the other hybrids at each location (Figure 3). In contrast, G01B61 brand was a solid yielding hybrid but was one of the least responsive with intensive management increasing yield by 1 bu/A at Saint Ansgar, 5 bu/A at Malta and 9 bu/A at Saint Johns.

At Clinton, G14B32 brand was the lowest yielding hybrid under standard management but experienced a 35 bu/A response to the enhanced program. In comparison to

Location	Standard	Enhanced
Charles City, IA	• Broadcast MAP @ 11 N, 52 P_2O_5 lbs/A + Potash @ 120 lbs K_2O/acre + Gypsum @ 17 lbs S/acre • Preplant broadcast 32% UAN @ 160 lbs N/acre + ATS @ 5 N, 12 S lbs/A	• Surface dribble 32% UAN @ 9 gal/A + ATS @ 1 gal/A + 9% Zn @ 0.5 gal/A
Clinton, IL and Malta, IL	• Preplant broadcast 32% UAN @ 200 lbs N/acre	• In-furrow 6-24-6-.25 Zn @ 5 gal/A • Surface dribble 32% UAN @ 17 gal/A + ATS @ 5 gal/A • 2x2x2 NACHURS Triple Option® @ 15 gal/A • Sidedress 32% UAN @ 17 gal/A • R1 foliar Miravis® Neo fungicide @ 13.7 oz/A
Saint Ansgar, IA	• Strip-till MAP @ 11 N, 52 P_2O_5 lbs/A + Potash @ 90 lbs K_2O/acre + Gypsum @ 9 lbs S/acre • Surface dribble 32% UAN @ 35 lbs N/acre + ATS @ 3 N, 6 S lbs/A • V5 sidedress 32% UAN @ 106 lbs N/acre + ATS @ 4 N, 9 S lbs/A	• In-furrow 6-24-6 @ 4 gal/A + KTS @ 1 gal/A + 9% Zn @ 1 pt/A + Syntose® FA @ 1 pt/are + Xylem Plus @ 1 qt/A • R1 foliar Miravis Neo fungicide @ 13.7 oz/A + Grizzly® Too @ 1.6 oz/A + 10% Boron @ 0.5 pt/A
Saint Johns, MI	• Broadcast MAP @ 11 N, 52 P2O5 lbs/A + Potash @ 150 lbs K_2O/acre • FurrowJet Pro-Germination @ 6 gal/A + Sure-K @ 9 gal/A • Planter 1x3x2 28% UAN @ 45 lbs N/acre + eNhance @ 20 oz/A + accesS @ 3 gal/A • V6 sidedress 28% UAN @ 164 lbs N/acre + eNhance @ 0.6 gal/A	• FurrowJet Micro 500 @ 3 qt/A + Manganese @ 1 qt/A + Humusolver 12% @ 1 qt/A + eNhance @ 3 qt/A + Nresponse @ 2 gal/A • Planter 1x3x2 Humusolver 12% @ 1 qt/A + 10-34-0 @ 10 gal/A + Boron @ 1 qt/A + LiberateCa™ + 1 qt/A • V6 sidedress 28% UAN @ 12 gal/A + eNhance @ 16 oz/A + Humusolver 12% @ 4.4 gal/A + accesS @ 4 gal/A + Kalibrate™ @ 4 gal/A + Boron @ 0.5 qt/A + LiberateCa @ 0.5 qt/A • V6 foliar Trivapro® fungicide @ 13.7 oz/A + C-Tech @ 1 qt/A + Sugar @ 0.5 qt/A • VT sidedress 28% UAN @ 23 gal/A + eNhance @ 31 oz/A + Humusolver 12% @ 2 gal/A + accesS @ 3 gal/A + Kalibrate @ 1.5 gal/A + Boron @ 0.5 qt/A + LiberateCa @ 0.5 qt/A • R3 foliar Miravis Neo fungicide @ 13.7 oz/A
Sumner, IA	• Fall anhydrous ammonia @ 164 lbs N/acre • Broadcast Triple Superphosphate @ 45 P_2O_5 lbs/A + Potash @ 180 lbs K_2O/acre • Preplant Broadcast 28% UAN @ 45 lbs N/acre + ATS @ 7 N, 15 S lbs/A	• In-furrow InVigoron MAX (10-18-4) @ 2 gal/A • R1 foliar Miravis Neo fungicide @ 13.7 oz/A

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



Graph 1. Average hybrid yield response to enhanced management at six locations in 2023.

Figure 2. G97B68 brand grown with enhanced management on left and standard management on right at Saint Ansgar, IA in 2023.

Figure 3. G03B19 brand grown with standard management on left and enhanced management on right at Saint Johns, MI in 2023.

Malta, G14B32 brand was the highest yielding hybrid with an average response to management compared to the other hybrids. Clinton experienced stressful growing conditions for much of the growing season. It was dry from planting until early July. Crop growth was stunted, and nutrient availability was likely limited. Placing fertilizer near the crop row with the planter provided available nutrients to the plant in the enhanced system. Growing conditions at Malta were ideal for much of the growing season. When grown in a favorable environment with intensive management, G14B32 brand yielded 309 bu/A. Even under standard management G14B32 brand yielded 296 bu/A. This data illustrates that in unique environments with nutrient, water, and heat stress, G14B32 brand may respond more to intensive management. However, with adequate growing conditions and solid crop management, the top-end yield potential of G14B32 brand is unmatched.

SUMMARY

Genetic x environment x management trials aim to study how hybrids respond to intensive management in specific local environments. The environment significantly influences yield potential, and by understanding the interaction between hybrid genetics and crop management practices, it becomes possible to optimize product placement and maximize yield potential.

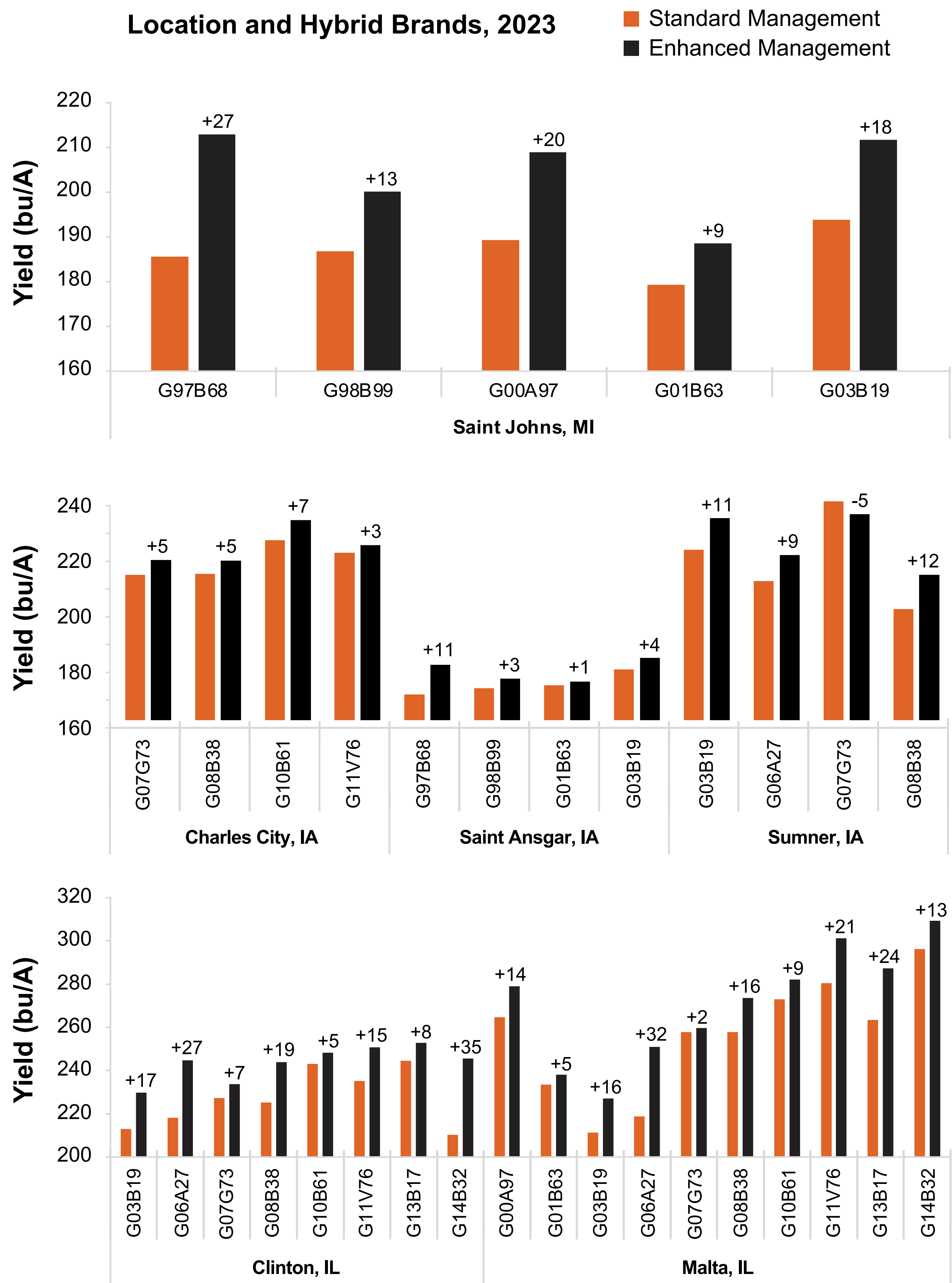
The key takeaways from these trials include:

1. There is yield potential to be gained with more intensive crop management during preplant, at-planting, vegetative 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. Achieving high-yield corn requires a comprehensive systems approach.
4. Setting and maintaining high yield potential throughout grain fill is crucial for maximizing yield.

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.

Interested in participating in local genetic x environment x management trials? Please reach out to your local Golden Harvest Agronomist or Sales Representative.



Graph 2. Hybrid yield response to enhanced management at six locations in 2023.

FACTORS BEHIND FLUCTUATING CORN YIELDS: UNDERSTANDING THE VARIABILITY

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.

Extreme weather conditions across the Midwest such as intense heat, drought and other environmental stresses can often lead to highly variable crop yields. Many factors impact potential yield loss and should be considered when planning for the next crop season.

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 you help better understand how precipitation, temperature and soil parameters interact and result in high yield variability.

Temperature		Grain Ear Weight	Kernel Size	Grain Fill Duration
Day (°F)	Night (°F)	(g)	(mg)	(days - silk to black layer)
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]

TEMPERATURE VARIABILITY

Corn is well-adapted to warmer days to maximize growth and cooler nights to 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 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 up to 50% yield loss, whereas stress prior to or after pollination only resulted in 20–25% yield loss.[2]

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

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 avoid being 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.

CORN MANAGEMENT
MAIN MENU

MAIN MENU

HARVEST DATE MANAGEMENT AND PHANTOM YIELD LOSS IN CORN

INSIGHTS

- Grain yield loss with delayed harvest is often speculated to be caused by respiration within kernels after maturing.
- Yields declined at two of three trial sites with delayed harvest, but kernel weight did not decline.
- Harvest should happen when appropriate grain moisture is reached, and decisions should be weighed against economics of drying corn.

Scan to watch video:
Corn Harvest Timing and Demystifying Phantom Yield Loss

INTRODUCTION

There are a lot of things to consider when trying to decide how early to start corn harvest. Delaying harvest and taking advantage of field drying can reduce grain drying costs. However, while grain is field drying, plant health and stalk quality simultaneously begin to deteriorate, increasing potential for harvest losses.

DOES CORN LOSE DRY MATTER WHEN FIELD DRYING?

The notion that field-drying corn will often put fields at a higher risk of yield loss from dropped ears, stalk lodging, mechanical harvest losses or increased disease and insect damage is widely agreed upon. Loss due to a delayed harvest is also believed by many to still occur in the absence of any of the previously mentioned methods, but rather through a loss in kernel dry matter after reaching physiological maturity, often coined as "phantom yield loss". It is believed that during the in-field drydown process, although kernels have reached physiological maturity and can no longer take up any additional sugars, they continue to undergo respiration which would reduce kernel dry matter. Respiration is a process that all living organisms undergo in which they take in oxygen and in turn release heat and carbon dioxide. The loss in weight is a result of the carbon released within carbon dioxide. Although seeds are considered a living organism which does continue to respire, respiration dramatically slows down after kernels reach 30% moisture[1] and is reduced even more in dry, cooler conditions. Previous studies measuring dry matter loss from 28% moisture grain samples over time, when stored at 50–65°F temperatures, took 50–55 days to lose 1% dry matter. Although fall daily high temperatures can reach much greater than 65°F, the minimum night temperature brings the 24-hour average much closer to 65°F. In the same study, it took ten days of constant 80°F temperature to observe a 1% dry matter loss, illustrating that respiration loss does increase with rising temperatures. These prior studies would suggest that dry matter loss from a few warm fall days may not be enough to economically offset drying costs associated with harvesting wet grain.

Harvest timing trials have also been conducted with the objective to quantify yield loss and better determine the actual cause of loss. Five of six trials conducted at universities reported either no yield reduction or no grain dry matter loss (Table 1), although numerous unpublished trials and observations in large-scale field comparisons have repeatedly observed similar yield loss

UNIVERSITY HARVEST DATE TRIAL FINDINGS

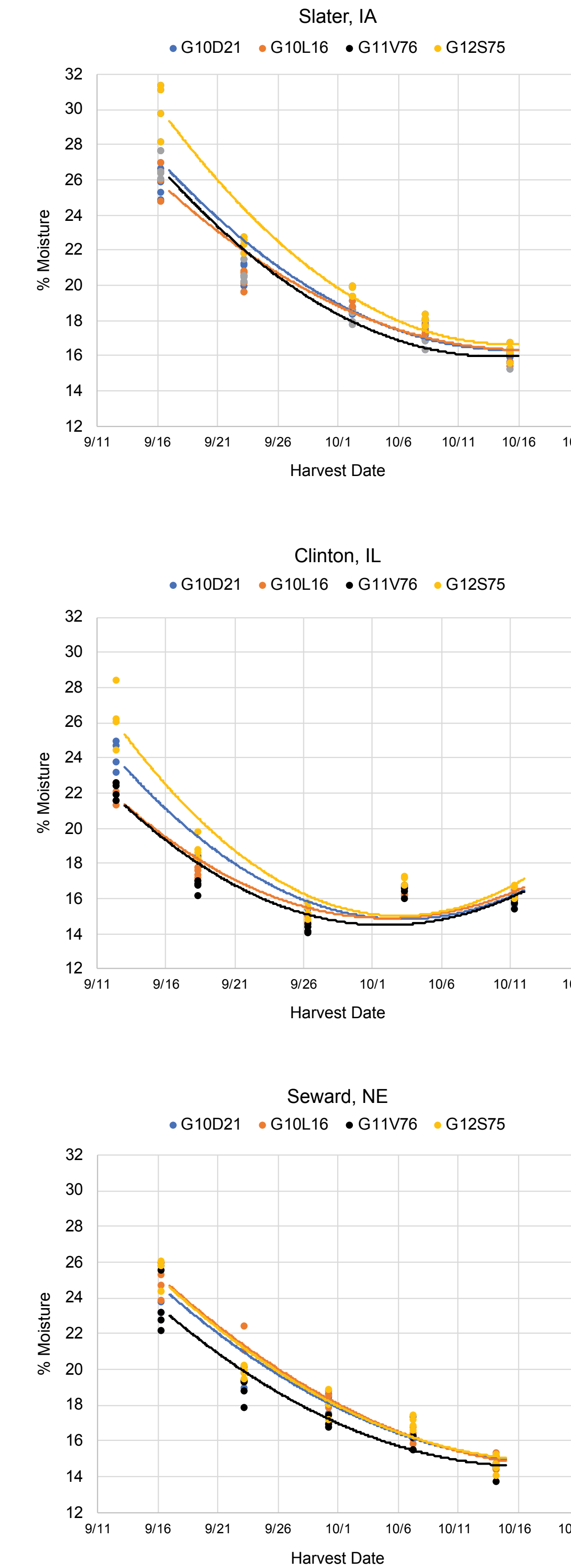
Year	Researcher	Finding
1976	Iowa State University[1]	No yield reduction
1984	University of Illinois[2]	No dry matter reduction
1991–94	Purdue University[3]	0.9% dry weight loss per point decrease in grain moisture
1995–97	University of Nebraska[4]	No dry matter reduction
2002–04	Ohio State University[5]	No dry matter reduction
2016–17	Iowa State University[6]	No dry matter reduction

Table 1.

as reported by Purdue University 1991–94 trials. On-farm comparisons finding yield losses ranging from 0.5 to 5 bushels for each percent drop in moisture are commonly observed by many in the industry. There are often little to no observable harvest losses reported in these same fields, further suggesting potential kernel dry matter loss. However, there can be less obvious reasons causing yield differences. Yield monitors are known to have higher error rates when harvesting high-moisture corn, which can be worsened if not re-calibrating in-season as moisture begins to drop. In addition to potential yield monitor error, field losses may be present more than often realized. Two single kernels per square foot hidden under residue is equivalent to one bushel per acre loss (Figure 1). Header losses are found more often as grain moisture drops below 20%.

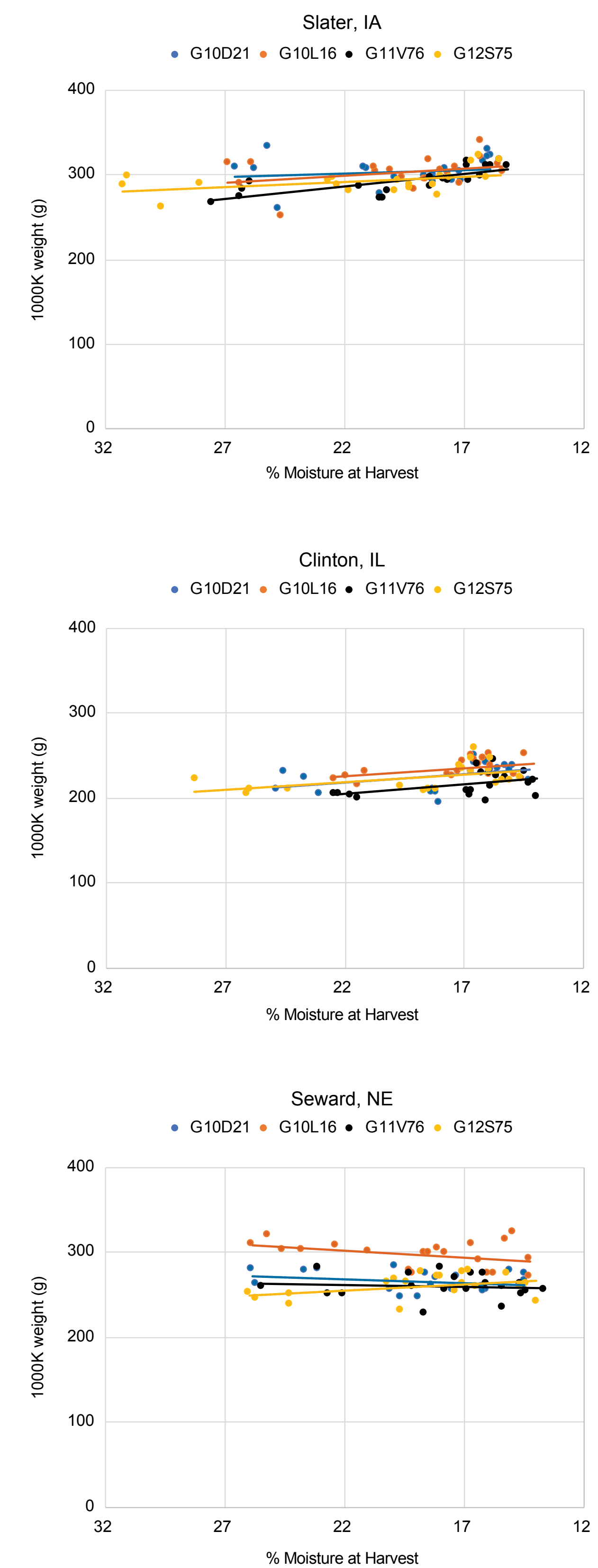
AGRONOMY IN ACTION HARVEST TIMING TRIALS

The Golden Harvest Agronomy in Action research team designed trials in 2021 to quantify yield loss associated with delayed harvest to understand if changes in kernel dry matter may be the cause of any yield reductions. Four hybrids ranging from 110- to 112-day relative maturity (RM) were planted at Seward, NE, Slater, IA, and Clinton, IL. Trials were planted in a manner that allowed for harvesting each hybrid five times over



Graph 1. Hybrid drydown rates at trial locations.

MAIN MENU



Graph 3. Kernel dry weights of individual hybrids compared to harvest moistures at trial locations.

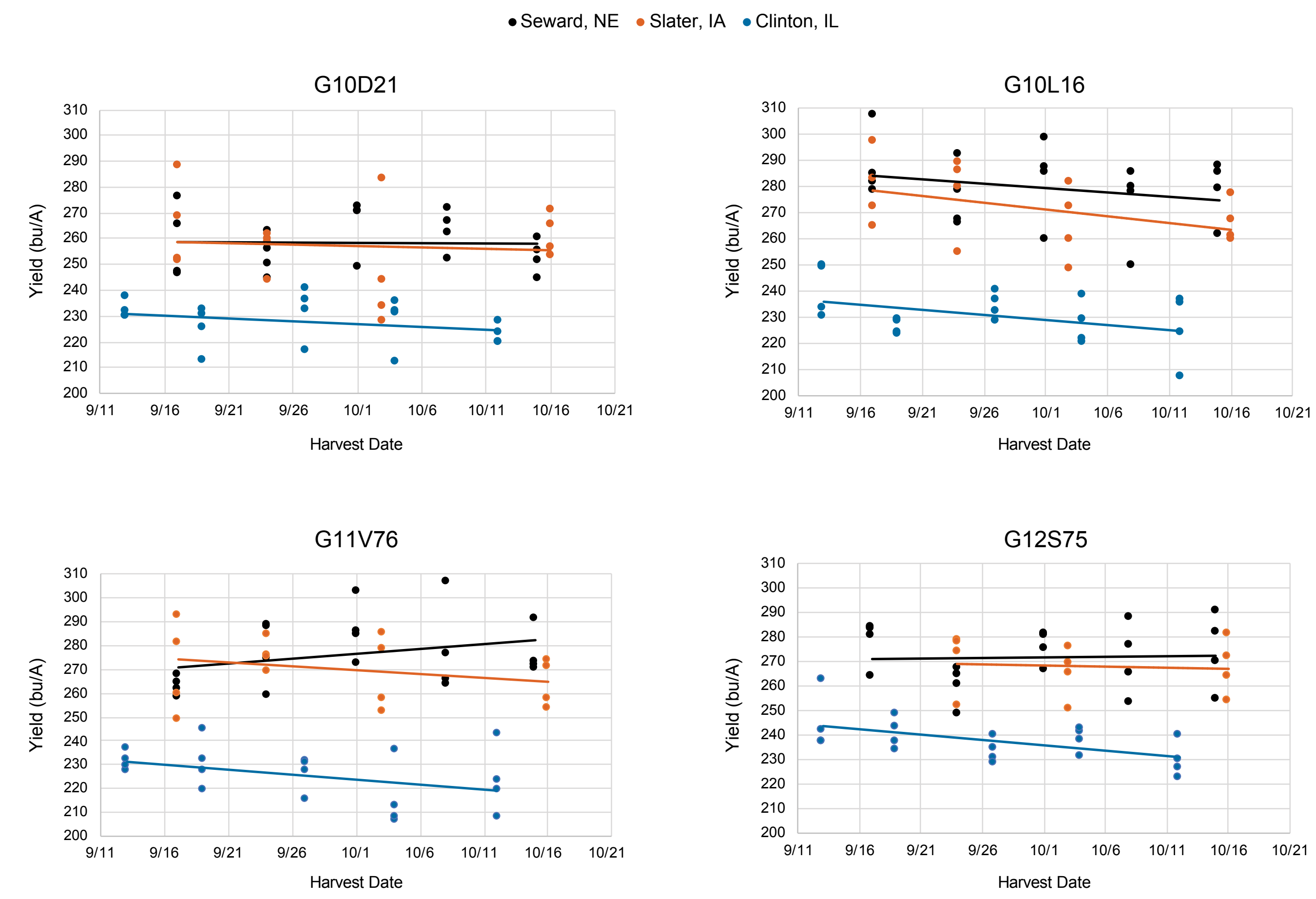
consecutive weeks with the first harvest date beginning when all hybrids reached physiological maturity. In addition to collecting weekly grain yields, grain samples were also collected to measure changes in kernel dry matter weights. Individual kernels from subsamples were counted and weighed to determine 1,000 kernel weights. Grain moisture was also collected using a DICKEY-john® GAC™ moisture tester to adjust wet kernel weights to a dry matter basis.

Weekly drops in grain moisture were similar across all trials with some variation in drydown rates among hybrids (Graph 1). Clinton, IL experienced precipitation later in the harvest season, which temporarily increased grain moisture.

Trials in Slater and Clinton lost an average of 0.3 bushels per day, or an average of ~9 bushels over 30 days, while the trial in Seward showed no significant yield loss (Graph 2). On average, trials showed a 0.6 bu/A loss for each point of moisture removed in the field. This is similar to the 0.9 bu/A per point of moisture published by Purdue.[3]

Kernel weight was not found to decrease between the first and last harvest dates in any hybrids at any of the sites (Graph 3). This suggests that although yield decreased over time, the decrease was not due to respiration and loss of kernel dry matter. No lodging or dropped ears were observed in these trials. It is most likely that drier corn experienced greater mechanical loss during harvest than higher moisture corn. While earlier harvests may capture more yield, this gain should be weighed against the costs of drying grain.

Strategies for building a harvest plan may be different for individual farmers based on total acres needed to harvest, daily per acre harvest capacity, ability to dry grain or drying charges at local elevators. Emphasis should be put on the economics of managing wetter grain and the potential for field loss associated with field drying. There are undoubtedly costs and risks associated with field drying, but kernel biomass reduction caused by respiration is not likely causing it.



Graph 2. Hybrid yield response to harvest date.

Figure 1. Surface residue covering 2 kernels per ft², equivalent to 1 bu/A.

CORN MANAGEMENT
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 can 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 does not change much with growing conditions, although the number of kernels per row (ear length) is often influenced by environmental 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

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.

Causes:

- The initial ear development is 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)

Symptoms:

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

Causes:

- Later developing silks are 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.


Unfilled Ear Tips


Incomplete Basal Fill

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 prior to fertilization.

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.

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.
- It is not well understood why only kernels within a single row or two is affected, but it is speculated silks on upper side may drape over lower silks, impeding pollination, or differential heating around ear circumference interferes with ovule fertilization.


Zipper Ears

Incomplete Kernel Set

INCOMPLETE KERNEL SET (SCATTERED / POOR KERNEL SET)

Symptoms:

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

Causes:

- Failed pollination, likely from asynchronous pollen shed, inadequate pollen supply or clipped silks (insect or mechanical damage).
- Severe drought or 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

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.
- Often the result of stress or injury to primary ear formation resulting in secondary ears from same shank.

BARBELL-EARS (PINCHED EARS)

Symptoms:

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

Causes:

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

Translucent Kernels

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.

Top: Viptera® trait stack corn hybrid ears. Bottom: Insect feeding damage caused by Western bean cutworm from a corn hybrid without Viptera protection.

GRAIN EAR FLEX TYPES AND MANAGEMENT CONSIDERATIONS

INSIGHTS

- Ear flex is how the corn plants adjust in size and number of kernels as a response to stress or management practices.
- Understanding how management such as seeding and nitrogen rate influence ear flex characteristics is critical for management.

The ability of a corn hybrid to influence the number and depth of kernels is often referred to as its capacity to "flex". Yield potential increases or decreases depending upon how hybrid flex characteristics interact with severity and timing of abiotic stress. The final number of kernels produced can be negatively influenced as early as the V5 growth stage while the potential number of kernels are being determined and remains vulnerable throughout early grain fill stages. The merit of a third flex trait (Figure 1), kernel size, is often underestimated. Kernel size and weight is highly influenced by favorable plant health and growing conditions throughout the latter half of grain fill stages (R3–R5).

Heritable traits like number of kernel rows, ovules produced per row and kernel size can influence how individual hybrids may respond differently to stress at specific growth stages. The term ear "flex" is commonly used to refer to how some hybrids with these phenotypic traits can take advantage of favorable environments. Flex characteristics can also provide insights to how some hybrids are able to minimize yield loss when under stress.

CHARACTERIZING TYPES OF HYBRID EAR FLEX

Ear flex characteristics almost always come up during hybrid selection and management discussions. Most often ear flex phenotypes are applied to seeding rate planning. As a result of this, the seed industry has commonly placed hybrids into one of the following three categories:

1. **Flex ear hybrids** that get bigger at lower populations with favorable agronomic conditions.
2. **Semi-flex ear hybrids** that maintain number of kernels and size at higher populations yet flex out at lower populations.
3. **Fixed ear hybrids** that have very small changes in ear size when planting at lower and higher populations.

Classifying hybrids into flex or fixed ear types is often done by observing ear sizes at low populations. However, most hybrids available get lumped into the semi-flex category that is not only qualified by their ability to flex at low populations, but their ability to "maintain" number and weight of kernels at higher populations or when stress occurs. Ear length is the easiest phenotype for agronomists to visually quantify, whereas the equally important but harder to quantify characteristic of kernel depth and weight is often overlooked, resulting in misclassification of hybrids. Since the ability of most hybrids to flex comes from multiple traits that influence kernel number as well as weight, ear flex scores can be more accurately determined from comparing grain yields at lower and higher densities. Planting lower densities allows plants to maximize individual plant yield potential, whereas at higher density, individual plant yield potential is limited due to neighbor competition.

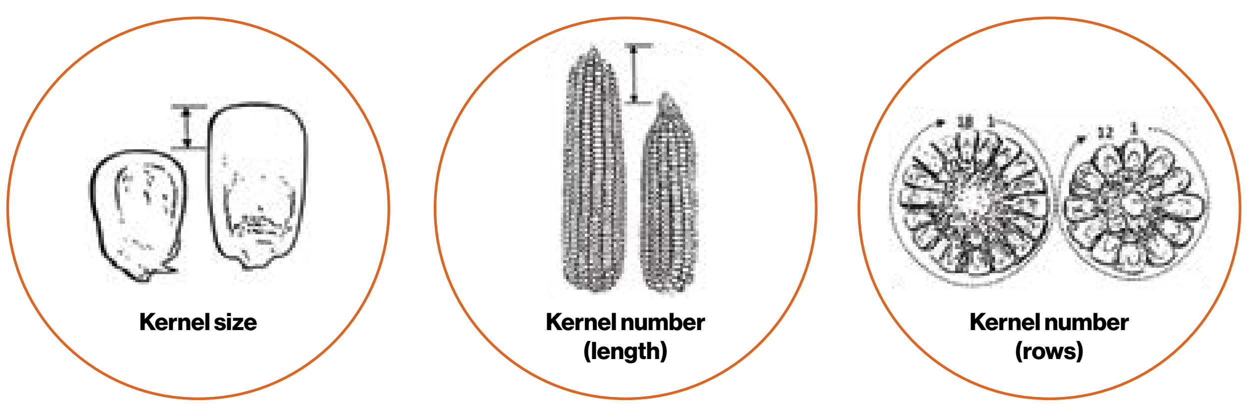


Figure 1. Examples of corn ear flex characteristics.

HYBRID FLEX TYPE APPLIES TO HYBRID MANAGEMENT

Although the descriptions are self-explanatory, it can be challenging to understand which one provides the most advantages or disadvantages with specific growing environments and agronomic management practices. Some agronomists believe that by better classifying hybrids into one or more approaches describing how they flex may help to uniquely manage and minimize potential yield/economic loss.

Understanding how and why hybrids flex differently opens the ways to take advantage of customized placement and management practices. The prevailing agronomic belief is that the following four flex traits, and their influence on physiological processes at specific crop growth stages, influences the amount of grain per plant produced.

- **Kernel row number (girth)** flex hybrids could be negatively influenced by stress that coincides with when row number is being determined prior to the V6 growth stage.
- **Early kernel per row (ear length)** flex hybrids could be negatively influenced by a stress occurring from V7–VT growth stages as the potential number of kernels is being formed prior to pollination.
- **Late kernel per row (tip back)** flex hybrids could be negatively influenced by stress occurring during pollination and grain fill stages (R1–R3) that would result in aborted kernels and tip back. Split applying nitrogen and managing foliar disease are believed to be more important with these types of hybrids.
- **Kernel weight (size or density)** flex hybrids are highly dependent on kernel weight from increased kernel depth or tightly pack starch molecules to maximize yield potential. These hybrids are more susceptible to stress such as drought or insufficient nitrogen in the last 30 days prior to blacklayer. Avoiding sandy soils without access to irrigation is an example of how to manage a hybrid like this.

In addition to these four traits, some hybrids are known to add additional grain per plant by producing a second ear at the node below where the primary ear forms. This is more frequently observed in the Western Corn Belt planted at ultra-low seeding rates that normally have low annual precipitation rates and no access to irrigation. Establishment of a second ear in these environments usually only occurs in years with above-normal precipitation combined with low seeding rates.

The reality is that most hybrids are dependent on all four of the main flex traits to some degree. Using these principles to manage specific hybrids would be more valuable if seed company corn portfolios were more dependent on truly fixed (determinate) or flex (indeterminate) ear types of hybrids that were unable to respond to stand loss or environmental stresses.

In relation to management choices, plant density, nitrogen rate and hybrid selection are three of the easiest changes to make. Determining the best nitrogen rate is complicated by environmental interactions that can reduce or increase plant available nitrogen in various years. Previous research has predominately deemphasized the need for hybrid specific nitrogen recommendations.[1,2] However, there are trials reporting differential hybrid response to nitrogen availability.[3,4] Others have observed hybrids responding differently to nitrogen rates in combination with incremental seeding rates[5,6] although reports of fixed ear type hybrids not needing incremental nitrogen as seeding rates increased to an optimal level have also been reported.[7] It is more likely that ear flex types have more of an influence on optimum seeding rate than on optimum nitrogen rates. Planting hybrids with flex ear characteristics can help reduce potential yield loss when the environment or pests reduce plant populations lower than the desired target.

CORN MANAGEMENT

MAIN MENU

CAPTURING DRYLAND CORN YIELD POTENTIAL WITH HYBRID FLEX

INSIGHTS

- Hybrids differ in their ability to efficiently recover yield potential when planted at low seeding rates.
- All Golden Harvest® hybrids tested in the trial exhibited some degree of ear flex at low seeding rates (17,000 seeds/acre).
- Hybrids varied in how they used kernel number or kernel weight to contribute to overall yield potential flex.

INTRODUCTION

Hybrid selection is the most important management decision farmers face each year. After yield potential, there are a plethora of factors that are weighed when making those selections. Ear flex potential is one characteristic that is, at minimum, reviewed if not selected for. Most associate the value of ear flex with an opportunity to reduce seed costs through plant population reductions.

Hybrid flex can also provide value in water-limited geographies where normal precipitation totals will not support higher seeding rates. These environments rarely experience yield responses to seeding rates greater than 20,000–24,000 seeds per acre. The goal in these environments is to plant the lowest possible seeding rate needed in a normal year. However, this defensive approach limits yield potential in years when timely rainfall events occur. Placement of a hybrid that not only provides yield stability in the dry years but also has enough ear flex to capture upside yield potential in wet years at lower seeding rates is useful to gain additional ROI potential (Figure 1).

TRIAL DETAILS

Agronomy in Action research trials were established at three locations in the western Corn Belt (Waterloo, NE, York, NE and Clay Center, KS) in 2023 with the goal of characterizing the ability of a hybrid to recover yield at low populations when water is not a limiting factor. All three sites were irrigated to emulate non-limiting environments. Golden Harvest hybrids ranging from 97- to 117-day maturity were tested. These hybrids had ear flex ratings ranging from semi-determinant to flex, with the majority (9 of 12) in the semi-flex category (Table 1). Each hybrid was planted at 17,000 and 29,000 seeds/A in four replications at each site.

Figure 1. Decreasing plant population (left to right) can affect ear flex through total kernel number and/or kernel weight.

Hybrid Brand	Ear Flex Rating	Seeding Rate 17k	Seeding Rate 29k	Yield Change
		bu/A		
G97B68	SF	169.1	205.1	36.1*
G03B19	SF	186.9	212.8	26.6*
G06B57	SD	197.9	209.3	11.4*
G09B15	SF	195.1	226.1	31.9*
G09Y24	SF	198.2	222.9	24.8*
G10L16	SF	210.5	237.7	22.9*
G13N18	F	197.3	231.1	34.2*
G14B65	SF	182.5	240.7	58.2*
G15J91	SF	189.9	231.8	44.6*
G16K01	F	201.7	246.9	44.9*
G16Q82	SF	185.1	230.1	44.0*
G17A81	SF	186.2	237.8	54.7*
Average		192.9	229.3	36.4*

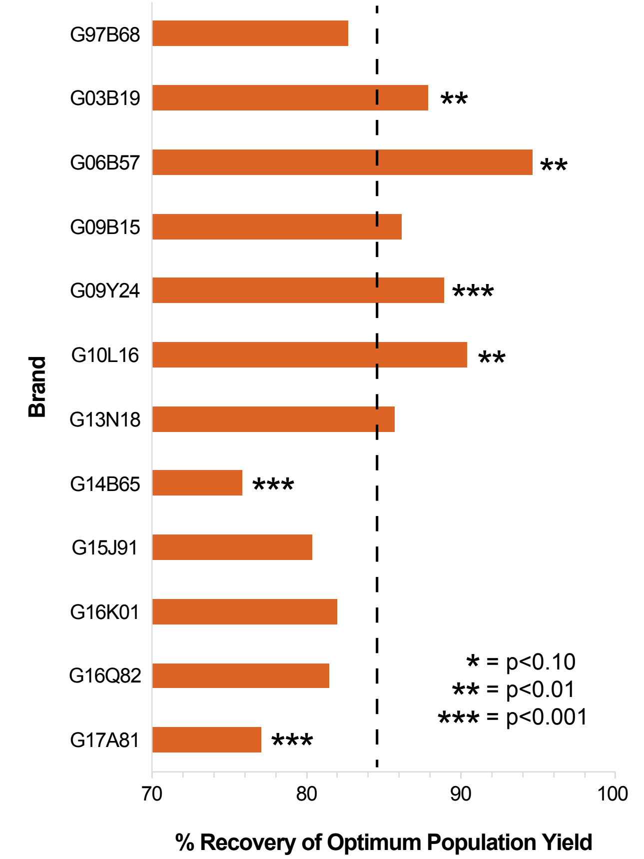
Table 1. Hybrids assessed in the trial, their respective ear flex ratings (F: flex, SD: semi-determinant, SF: semi-flex), and yield responses to population across three Agronomy in Action research trials. Asterisk indicates significant yield change.

HYBRID YIELD RECOVERY

Yield performance of individual hybrids at 17,000 and 29,000 seeding rates are listed in Table 1. Yield recovery (YR) was then calculated from these responses (Graph 1). This is a ratio that identifies the ability of a hybrid to fulfill its yield potential relative to an optimum yield environment through overall ear flex. It is calculated through the equation:

$$\text{Yield Recovery (\%)} = \frac{Yield_{17K}}{Yield_{29K}} \times 100$$

Hybrid YR ranged from 75.8 to 94.6%, with an overall average of 84.3%. Comparison of YR of each hybrid against the overall average found that four hybrids (G03B19, G06B57, G09Y24, and G10L16 brands) were statistically more efficient at recovering overall yield potential of the 29,000 seeding rate. In comparison, two hybrid brands (G14B65 and G17A81) exhibited YR ratios below the overall average.



Graph 1. Yield recovery (%) of twelve Golden Harvest hybrids in response to population reduction from 29K to 17K. Dashed vertical line represents the trial YR average. Asterisks indicate whether a hybrid's response was significantly different than the site average.

Combining YR with overall yield potential identifies candidates that theoretically most efficiently capitalize on abundant precipitation when it occurs when planted at low populations. For example, G10L16 brand exhibited significantly greater YR and 9% greater yield at the 17,000 rate when compared with the overall average (Table 1 and Graph 1), suggesting it may be a logical choice for this type of strategy. Other hybrids (G06B57, G09B15, G09Y24, G16K01 brands) produced YR and yields at the 17,000 seeding rate similar to, if not greater than, the averages, also indicating their possible suitability.

It's important to note that this data is only comprised from one year of testing, and only serves as an indicator of hybrid flex responses under optimal weather conditions. This trial does not provide insights into how hybrids with a high yield recovery rate in non-limiting water environments might perform under drought or heat stress conditions. It does provide good insight as to how a hybrid you may currently be planting in a water-limited environment may respond in years with above normal precipitation. Additional testing will be required to verify these responses and build sound recommendations.

FACTORS THAT CONTRIBUTED TO EAR FLEX

Most associate ear flex with ear girth and length. However, there are multiple components that factor into ear flex potential: kernel number (total rows + length) and kernel weight (density + depth). To gain a better understanding of which of these factors primarily contributed to overall ear flex in relation to plant population, all hybrids at low and high seeding rates at Waterloo, NE were subsampled and yield components (rows/ear, kernel length, total kernels/ear and kernel weight) were measured. On average, kernel number and weight each increased 10.0 and 8.7% when seeding rate was reduced, while kernel row number remained constant (average of 15.8 rows for both seeding rates) (Table 2). When evaluating individual hybrids, only G16Q82 brand increased its number of rows when reducing seeding rate to 17,000 (16.9 vs 15.8 at 29,000). The overall lack of change to kernel row number was surprising since it is one of the initial yield components determined by the plant prior to the V6 growth stage. One possible explanation could be that the 29,000 seeding rate was not high enough to create adequate interplant competition to cause plants to reduce kernel rows.

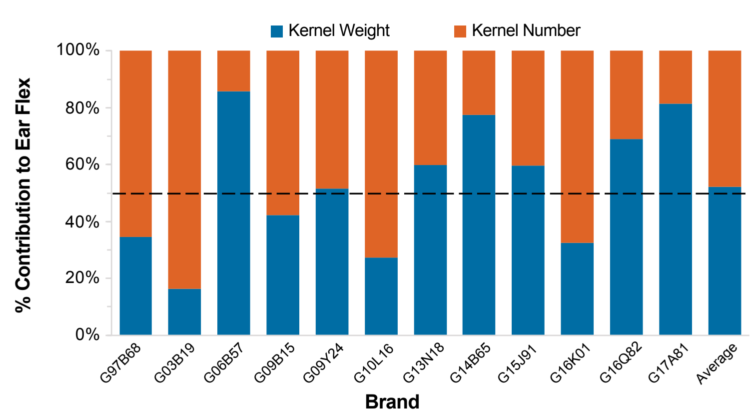
CORN MANAGEMENT
MAIN MENU

Average ear weight increased by 19.5% with lower seeding rates resulting from both kernel number and weight changes (Table 2). However, the individual component contribution to overall ear flex varied by hybrid. Averaged across all hybrids, kernel number and weight contributed relatively similar amounts to the overall flex (52 and 48%, respectively; Graph 2). However, six hybrid brands (G06B57, G13N18, G14B65, G15J91, G16Q82, and G17A81) gained ≥ 60% of total ear flex from increased kernel number. In comparison, the remaining hybrid brands (G97B68, G03B19, G09B15, G10L16, and G16K01) gained ≥ 58% of its ear flex from increased kernel weight. Removing G09B15 brand from the group increased the proportion to ≥ 65%. Only G09Y24 brand exhibited a 50:50 ratio of contribution between kernel number and weight.

These results indicate that hybrid genetics play an important role in determining the contribution of specific yield components on overall flex. This is further demonstrated in Figure 2, where two 116-day hybrids, G16K01 and G16Q82 brands, exhibited vastly different yield component contribution ratios. Ear flex of G16K01 brand was largely driven by kernel weight (68%) whereas G16Q82 brand was influenced more by kernel number (68%). Relationships between the ear flex yield components and several other characteristics (yield at 17,000 seeding rate, % yield recovery, relative maturity, flex rating) were also investigated, and no significant patterns were detected. It is probable that seasonal weather influences the genetic effect on some, if not all, of these ear flex yield components. Therefore, quantifying that interaction would require multiple years of the trial.

Hybrid Brand	Seeding Rate	Ear Rows	Ear Length	Kernel Number per Ear	Kernel Weight	Ear Weight
			kernels		mg/kernel	g/ear
G97B68	17K	15.9 a	40.6 a	647 a	356 a	230 a
	29K	16.4 a	36.6 b	601 b	312 b	187 b
G03B19	17K	17.0 a	38.4 a	653 a	357 a	233 a
	29K	16.9 a	38.0 a	642 a	334 b	215 b
G06B57	17K	14.9 a	40.1 a	596 a	337 a	201 a
	29K	14.8 a	35.4 b	524 b	329 a	173 b
G09B15	17K	15.2 a	44.9 a	684 a	353 a	241 a
	29K	14.9 a	41.3 b	613 b	311 b	191 b
G09Y24	17K	16.6 a	42.8 a	712 a	333 a	237 a
	29K	16.2 a	40.0 b	646 b	305 b	196 b
G10L16	17K	15.5 a	43.0 a	670 a	382 a	256 a
	29K	15.3 a	40.1 b	614 b	313 b	192 b
G13N18	17K	14.6 a	47.6 a	693 a	376 a	260 a
	29K	15.0 a	42.7 b	640 b	361 a	233 b
G14B65	17K	16.5 a	42.5 a	701 a	328 a	230 a
	29K	16.2 a	39.6 b	639 b	320 a	205 b
G15J91	17K	16.0 a	46.1 a	737 a	348 a	280 a
	29K	16.5 a	39.6 b	653 b	323 b	243 b
G16K01	17K	14.7 a	48.2 a	706 a	397 a	253 a
	29K	14.8 a	45.8 a	670 b	361 b	192 b
G16Q82	17K	16.9 a	48.0 a	812 a	311 a	260 a
	29K	15.8 b	42.3 b	667 b	287 b	218 b
G17A81	17K	15.7 a	52.3 a	819 a	318 a	271 a
	29K	15.8 a	45.0 b	707 b	308 a	230 b
Average	17K	15.8	44.6	705	351	247
	29K	15.8	40.8	638	323	206

Table 2. Response of several ear flex yield components of twelve Golden Harvest hybrids to reducing seeding rate from 29K to 17K at Waterloo, NE, 2023. Different letters indicate significant reductions (P≤0.10).

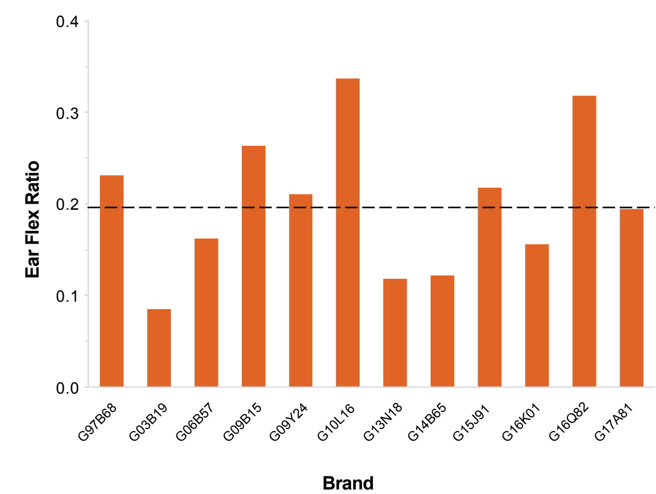


Graph 2. Contribution of yield components (kernel number and kernel weight) to overall ear flex of twelve Golden Harvest hybrids. Dashed line indicates where contributions of each component would be equal.

DETERMINING OVERALL FLEX ABILITY OF A HYBRID

One potential way of using the per plant ear weight yields obtained through the ear component analysis is to calculate an ear flex ratio (EFR) for each hybrid (Graph 3). The EFR is the individual ear weight gain from reduced seeding rates divided by the high seeding rate ear weight. This ratio indicates the amount of flex each hybrid demonstrated when planted at low populations compared to when planted within its optimum dryland population range. This ratio does not suggest a hybrid's overall suitability or placement indicators, as neither drought tolerance nor any other agronomic characteristics are factored into it. One general takeaway from this single location analysis is that all hybrids show some degree of ear flex when seeding rate is reduced from 29,000 to 17,000. For reference, a hybrid with a fully determinate ear would have an EFR of zero. Also, one important consideration is that these ratios do not perfectly align with current Golden Harvest published ear flex ratings driven largely by phenotyping. This is likely because current commercial flex ratings are based on observations across a wide spectrum of environments and populations. The EFRs in Graph 3 are from a single location and based on quantitative rather than qualitative data. Overall, the Golden Harvest corn portfolio exhibits solid ear flex potential at low seeding rates, as indicated by an average EFR of 0.196 (dashed line in Graph 3). Four hybrid brands (G97B68, G09B15, G10L16, and G16Q82) did exhibit EFRs that were 18% greater than the overall average. Additional years and locations of testing are required to verify these responses. In the future EFRs could help with identifying hybrid suitability in environments requiring low population and when key hybrid characteristics (i.e., drought tolerance) are simultaneously considered.

Figure 2. Ear comparisons of two hybrids in 2023 at 29,000 and 17,000 seeding rates where kernel number (G16Q82 brand) and kernel weight (G16K01 brand) were the primary contributor to overall ear flex.



Graph 3. Ear flex ratios for twelve Golden Harvest hybrids. Dashed horizontal line indicates ratio averages across all hybrids.

SUMMARY

The combination of understanding how hybrids flex at low populations paired with their ability to recover overall yield potential can help with hybrid selection, especially when trying to identify candidates that can primarily provide yield stability under normal weather conditions yet offer yield upside when conditions are favorable.

Results from the trial also indicated that the individual contributions of grain yield components (kernel number and kernel weight) are greatly influenced by genetics. Despite this, all Golden Harvest hybrids evaluated in the trial showed some degree of flex potential at low populations, meaning that selecting for ear flex and genetic diversity can be simultaneously achieved if desired.

CORN MANAGEMENT
MAIN MENU

POTENTIAL IMPACT OF WILDFIRE SMOKE ACROSS MIDWESTERN U.S. CORN AND SOYBEANS

INSIGHTS

- Many states across the Midwest experienced days of poor air quality caused by wildfire smoke in 2023.
- Studies show that prolonged extensive shading or light reduction is required to see higher levels of yield loss and it is unlikely that wildfire smoke haze caused excessive yield loss.

The Midwestern US experienced air quality warnings and hazy days as smoke from wildfires moved over the region. This raised the question of the potential impact of smoke on growing crops. Available solar radiation from sunlight (in addition to temperature and precipitation) plays a strong role in crop growth and development.

POTENTIAL IMPACT OF SMOKE ON CROPS

Sunlight is an essential component in photosynthesis that results in production of carbohydrates used for plant development and grain production. Reductions of plant available light at key growth stages can have negative impacts on yield potential and possibly put plants at higher risk for late season stalk lodging. Corn utilizes the C4 carbon fixation pathway which has a higher light saturation point than soybeans (C3 pathway), making it more susceptible to solar radiation or photosynthetically active radiation (PAR) reductions.

Map showing Air Quality Index caused by wildfire smoke and other factors like Ozone and PM (PM 2.5 and PM10). June 27, 2023; EPA AirNow - https://gispub.epa.gov/airnow

Flowering and grain fill growth stages are expected to be more negatively impacted by reduced sunlight than vegetative stages. Yield response to solar radiation is dependent on the 1) crop stage when light is deficient, 2) length of time solar radiation is reduced, and 3) severity of solar reduction. Low solar radiation has the biggest effect on corn yield potential during silking and grain fill periods.

INFLUENCE OF CROP STAGE AND SHADING INTENSITY

- Shading corn to 50% light intensity reduced corn yield by:
  - 12–20% when shaded during silking.
  - 19–21% when shaded during grain fill.[1,2]
- Less severe shading (85% light intensity) resulted in no yield loss in the same trials.
- Shading during silking often results in ear tip-back or fewer kernels per row whereas shading during grain fill results in decreased kernel weight from shallower kernels.

Smoke haze over corn in Ohio, June 28, 2023. Image source: W. Looker.

These studies show that dramatic shading or light reduction is required to see higher levels of yield loss potential. While there may be some yield loss in areas from reduced solar radiation caused by smoke, it is likely small and insignificant. Other factors such as temperature, precipitation, nutrients, etc. are also critical during silking and grain fill and will play a role in yield potential.

July flowering and August grain fill periods are the most critical times to evaluate for sunlight deficiencies as they are both periods that can highly influence yield and stalk strength. If planting was delayed into late May or early June, it may be more applicable to consider August and September solar radiation impact on corn since flowering and grain fill dates are later than normal.

OTHER CONSIDERATIONS

Increased Ozone Levels: Wildfires produce large quantities of pollutants such as nitrogen oxides and organic carbons which can react with sunlight to make ozone (O_3).

Ozone is a damaging air pollutant that may be harmful to plant growth. Elevated ozone pollution, if present near where plants are growing, has the potential to damage plant tissue during respiration causing plant stress.

Increased Light Diffusion: Smoke creates diffuse light which could beneficially lower leaf surface temperatures. Less direct light could reduce the amount of transpiration needed to cool leaves and be a benefit in drought/water stress conditions. Diffuse sunlight could potentially help improve photosynthetic efficiency since it has been found to be optimized at 50–67% of full sunlight intensity in some cases.[3]

Lack of precipitation in an area (and associated cloud cover) can create more days with adequate solar radiation, but can also reduce the solar radiation demands of the plant (due to reduced water uptake). The presence of smoke in drier regions may not always result in solar radiation deficiencies, even though less radiation was accumulated for the season.

HYBRID TOLERANCE AND RESCUE NITROGEN APPLICATIONS IN WATER-LOGGED SOILS

INSIGHTS

- Early-Season water-logging reduced yields by as much as 24%.
- Applying nitrogen (N) following saturated conditions recovered 55% of lost yield potential.
- Hybrids varied greatly in their tolerance to waterlogged soils and sidedress N applications.

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

In 2023, Golden Harvest Agronomy in Action Research expanded on a trial first conducted in 2022, designed to address three questions:

1. What impact does saturated soil have on crop growth and yield?
2. If early-season ponding water creates N deficiency, how much yield can 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?

Surface drip irrigation at Slater, IA or sprinkler tape irrigation at Clinton, IL and Waterloo, NE was used to create zones of artificially saturated soil conditions (Figure 1).

Figure 1. Excessive water applied with sprinkler tape irrigation at Clinton, IL (left) and surface drip irrigation at Slater, IA (right) in 2023.

Figure 2. Yellowing and stunted plants in the excessive irrigation blocks at Slater, IA in 2023.

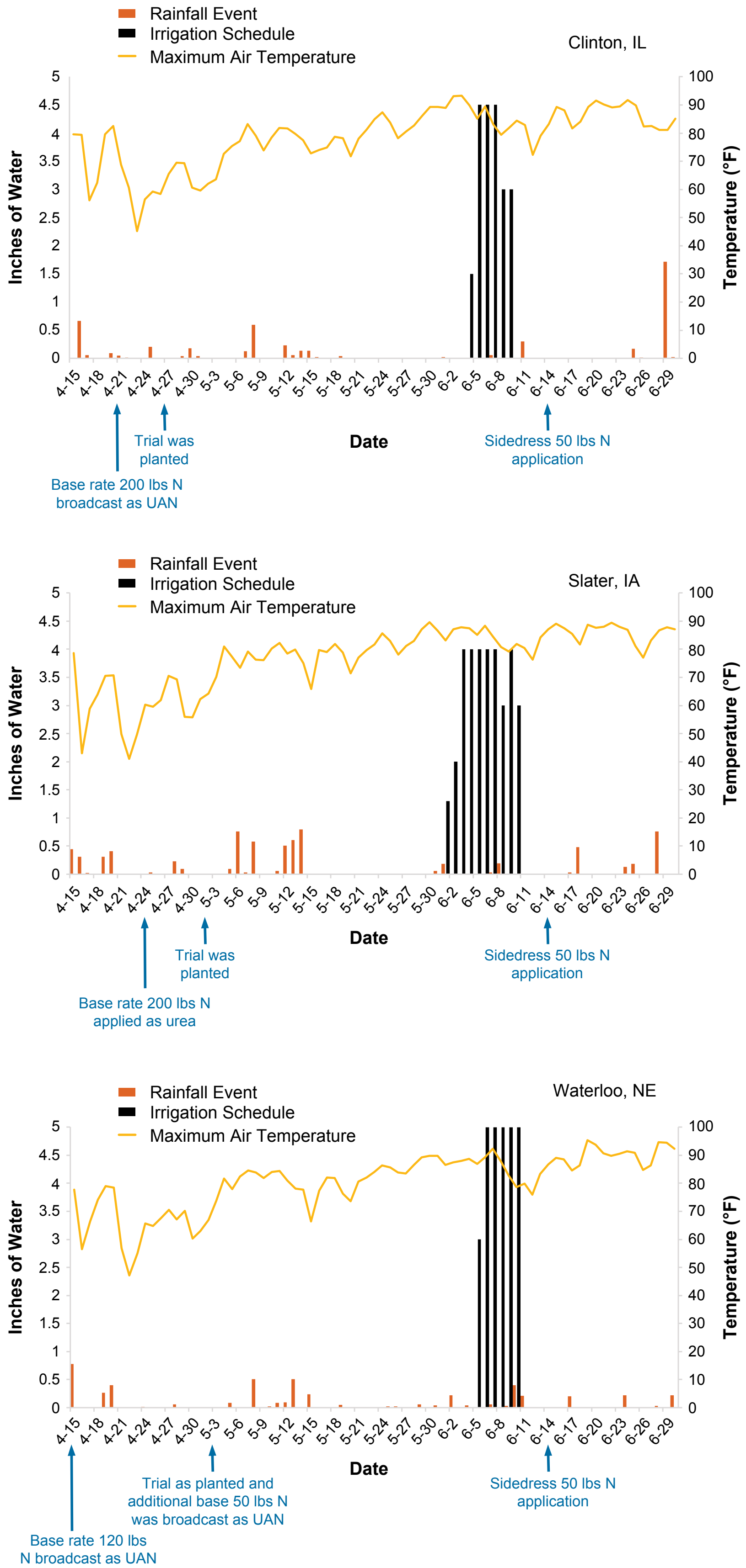
Treatments included two water regimes, two nitrogen programs and ten Golden Harvest® corn hybrids. The water regimes were either blocks watered repeatedly for 6–10 days to create artificial soil saturation or blocks that were rainfed. When the ground was dry enough to drive across after irrigation, half 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.

WEATHER PATTERNS

All three locations experienced between 3.5 inches to 5.5 inches less precipitation during April and May than the 30-year average. In addition, all locations received little rainfall during the two weeks prior to irrigation. Due to the dry conditions, filling the soil profile with water and maintaining saturation was challenging. Only at Slater, IA, using surface drip irrigation, was the desired effect of creating conditions conducive to denitrification along with yellow and stunted plants achieved (Figure 2). The surface drip irrigation applied a constant low volume supply of water (0.5 inch/hour) keeping the soil waterlogged. In contrast, at Clinton, IL and Waterloo, NE, the sprinkler tape output was 1.5–2 inches/hour, and the system had to be ran in intervals to avoid surface water runoff. The hot and dry conditions during irrigation made it difficult to maintain soil saturation using this irrigation method.

SOIL TEST RESULTS

Soil samples were taken from the rainfed and excessive irrigation blocks when ground was fit to walk on after irrigation. Although no yellowing or stunted plants were observed in the irrigated blocks at Clinton or Waterloo, the excessive irrigation did result in a reduction in soil nitrate levels (54–83%) likely from nitrate leaching (Table 1). Lower soil nitrate levels in the excessive irrigation blocks at Slater were likely from N loss through a combination of leaching and denitrification. Soil sulfur (S) and sodium (Na) levels increased in the irrigated blocks from 10 to 32 S ppm and 11 to 65 Na ppm, indicating the irrigation water contained both elements (Table 1).



Graph 1. Inches of water from rain and irrigation and the maximum air temperature from mid-April through end of June at Clinton IL, Slater, IA and Waterloo, NE in 2023.

Nutrient	Water Regime	Location		
		Clinton, IL	Slater, IA	Waterloo, NE
NO_3^- (ppm)	Rainfed	37	35	46
	Irrigated	17	9	8
S (ppm)	Rainfed	7	10	-
	Irrigated	7	32	-
Na (ppm)	Rainfed	15	11	-
	Irrigated	20	65	-

Table 1. Soil NO_3^-, S, and Na levels post irrigation at Clinton, IL, Slater, IA and Waterloo, NE in 2023.

EFFECT OF EXCESSIVE IRRIGATION AND SIDEDRESS NITROGEN

On average, excessive irrigation tended to increase yield by 6 bu/A at Clinton, IL and significantly increased yield by 35 bu/A at Waterloo, NE (Graph 2). The combination of starting the irrigation schedule with a dry soil profile, sprinkler tape application system and extended dry weather after irrigation, all contributed to why the blocks receiving excessive irrigation yielded more than rainfed blocks. Filling the soil profile with extra water provided more value than the detrimental effects of excessive moisture, such as N loss and/or temporary low soil oxygen levels. At Slater, IA, utilizing surface drip tape to maintain soil saturation reduced yields by 88 bu/A (Graph 2). N loss through denitrification and leaching along with low soil oxygen levels stunting root and plant growth all were contributing factors in reducing yield.

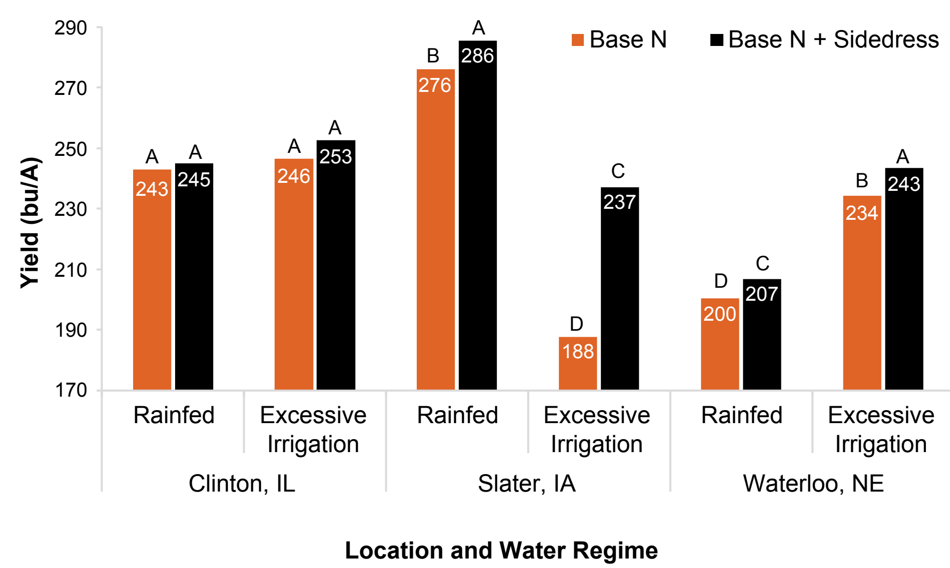
Like results from the study conducted in 2022, the 50 lbs of N/acre sidedressed post-irrigation provided a greater yield response in the excessive irrigation blocks compared to the rainfed blocks at all three locations. Sidedress N significantly increased yield by 7 bu/A at Waterloo, NE and 10 bu/A at Slater, IA within the rainfed blocks. In comparison, in the excessive irrigation blocks, sidedress N significantly increased yield by 9 and 49 bu/A at Waterloo and Slater, respectively. Sidedress N at Slater mimicked a rescue N application after a week of heavy rain events which was successful at mitigating a portion of the lost yield potential. However, sidedressing N was not enough to fully recover all yield lost due to the excessive moisture. It is suspected that the N response at Clinton was lower because of a lack of measurable precipitation until ten days after surface application resulting in N volatilization.

HYBRID RESPONSE TO NITROGEN SIDEDRESS

When averaged across water regime and all three locations, there was a significant difference on how hybrids responded to the additional 50 lbs of N/acre sidedress. All hybrids had a positive yield response ranging from 9 to 21 bu/A (Table 2). G12S75, G14B32, and G15J91 brands were the three most responsive hybrids to sidedress N while G13B17 brand was the least responsive hybrid.

HYBRID RESPONSE TO SATURATED SOILS

Like many other management and environmental factors, hybrids varied in their tolerance to an extended period of saturated soils at Slater, IA. The yield potential was statistically decreased for all hybrids in the excessive irrigated block ranging from -48 to -85 bu/A (Table 3).



Graph 2. Effect of water regime and nitrogen program on yield averaged across ten Golden Harvest hybrids.

G08B38, G12S75, G06A27, and G06B57 brands were statistically more yield tolerant to waterlogged soils than G09B15, G10B61 and G15J91 brands. Responsiveness of G06A27, G12S75 and G15J91 brands was similar to their response in 2022.

Hybrid Brand	Base N	Base N + Sidedress (+50 lbs N/acre)	Δ
	bu/A		
G06A27	218	230	+12
G06B57	219	231	+13
G08B38	222	235	+13
G09B15	231	244	+13
G10B61	234	248	+14
G11V76	232	245	+13
G12S75	235	256	+21
G13B17	237	246	+9
G14B32	243	259	+16
G15J91	243	258	+15

LSD (0.10) Hybrid x N Program = 6

Table 2. Effect of sidedress N on yield for ten Golden Harvest hybrids averaged across water regime and three locations.

Hybrid Brand	Rainfed	Excessive Irrigation	Δ
	bu/A		
G06A27	269	209	-60 AB
G06B57	265	205	-60 AB
G08B38	264	216	-48 A
G09B15	285	200	-85 C
G10B61	288	206	-82 C
G11V76	281	208	-73 BC
G12S75	286	232	-53 A
G13B17	275	204	-71 BC
G14B32	297	223	-74 BC
G15J91	299	221	-78 C

LSD (0.10) Hybrid x Water Regime = 17

Table 3. Effect of excessive irrigation on yield for ten Golden Harvest hybrids averaged across N program at Slater, IA in 2023.

There can be many genotypic and phenotypic hybrid characteristics influencing why some hybrids tolerate saturated soils better than others. Compared to all the other hybrids, G13B17 brand experienced the smallest yield increase with the sidedress N application, however, it was one of the more negatively affected hybrids from the excessive irrigation. This is an indication that N stress was not the main factor for the yield reduction with excessive irrigation but rather related to another factor such as reduced root growth from low soil oxygen levels or potentially elevated disease pressure. In comparison, G12S75 brand was one of the more tolerant hybrids to waterlogged soils but had the highest yield response to additional N sidedressed. It is speculated that G12S75 brand is genetically more tolerant to saturated soils and can maintain root growth under low soil oxygen levels increasing the ability to utilize the sidedress N.

SUMMARY

Results from this study demonstrate that yield decreases from waterlogged soils can be mitigated but not eliminated with rescue N applications. With heavy rain and/or irrigation events, N loss through leaching and/or denitrification is a concern and nitrogen management becomes even more important under these conditions.

Although all hybrids were negatively affected by growing in waterlogged soils, the degree of impact was different between hybrids. Similarly, all hybrids showed a different level of response to sidedress N. This information can be used to place specific hybrids on fields known to have drainage issues or areas of a field with a history of ponding. In addition, after a heavy rain event, rescue N applications should be targeted to hybrids that are less tolerant to N stress.

At locations where maintaining complete soil saturation and creating an environment conducive to denitrification was not achieved, the importance of soil water profile was demonstrated. Filling the soil water profile was more advantageous than the detrimental effects of over-watering.

Understanding the dynamic between environment and hybrid selection can help mitigate yield losses from potential weather risks.

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

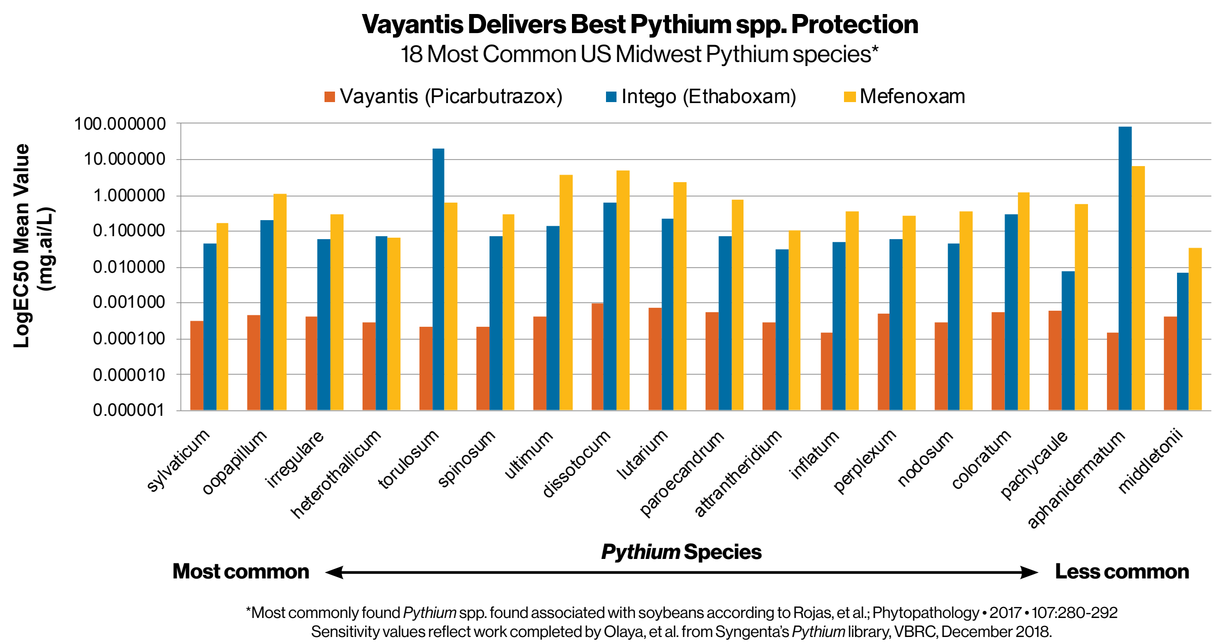
INSIGHTS

- 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 three 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 isolates 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® fungicide seed treatment, 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 mean EC 50 shown represents the effective concentration (EC) at which fungal growth is inhibited by 50%. Lower values observed

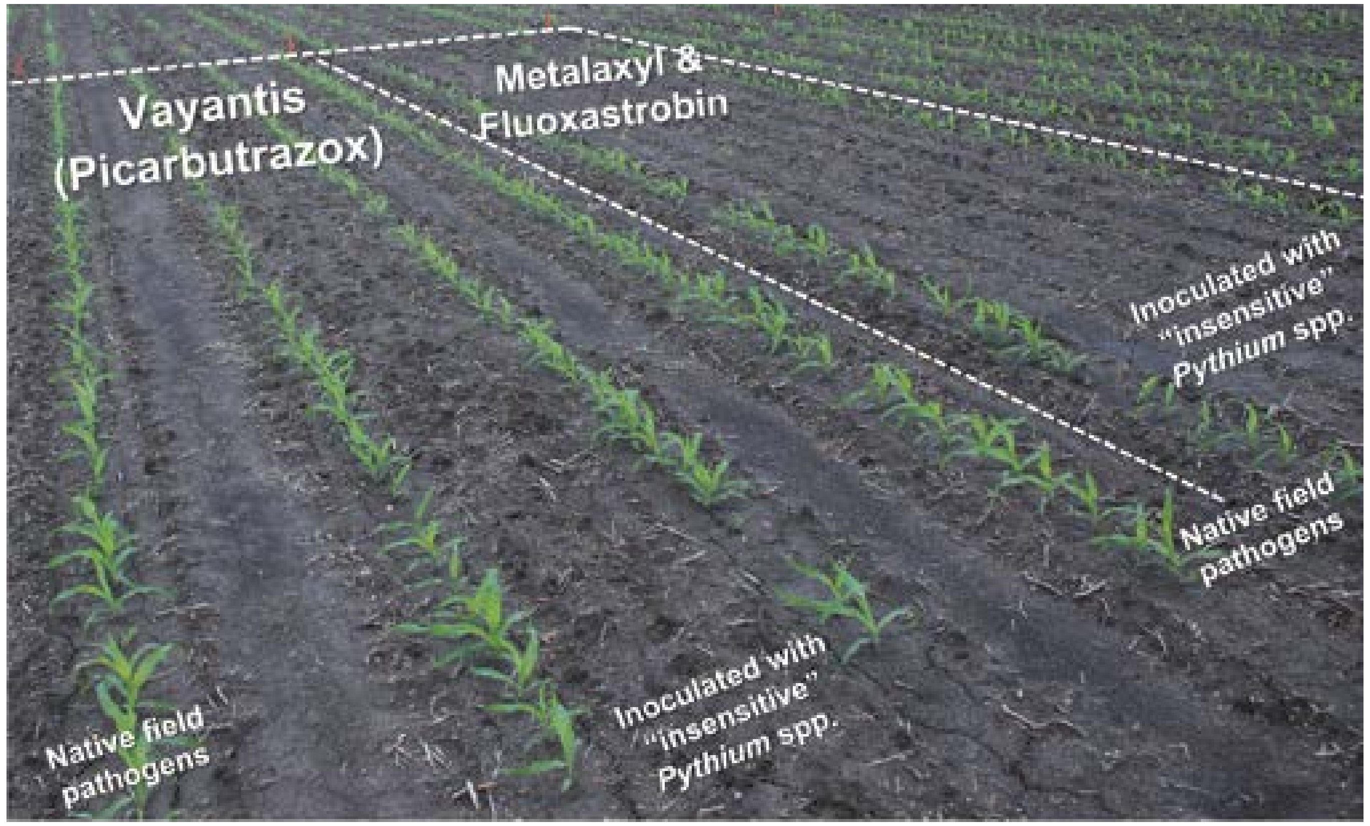


Figure 1. Emergence differences resulting from seed treatment and presence of "insensitive" *Pythium* spp.

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

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.

It is likely that without the use of additional new fungicide modes of action, stand establishment could become more challenging in fields over time.

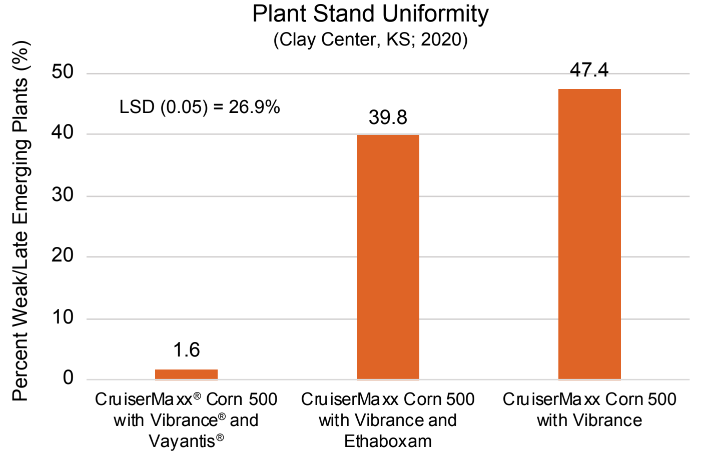
VAYANTIS FIELD TRIAL LEARNINGS

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.

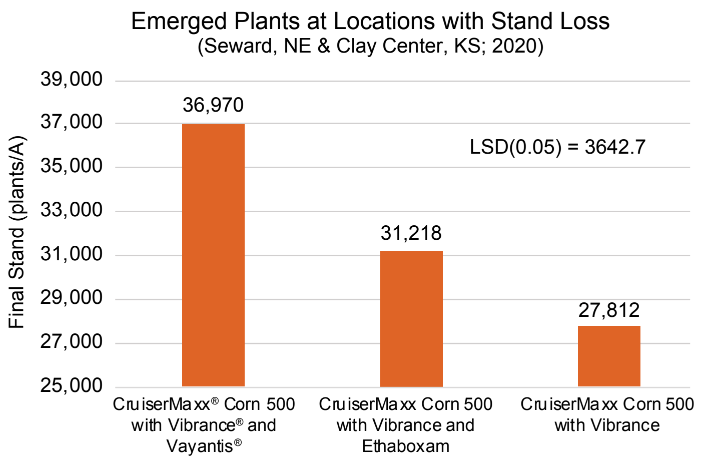
Research trials have repeatedly demonstrated that uniformity of seed emergence and plant growth is almost as equally important as achieving target final population. One Golden Harvest Agronomy In Action research seed treatment trial at Clay Center, Kansas, encountered stressful emergence conditions that 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 16% increase in yield potential in this trial (Graph 4).

SUMMARY

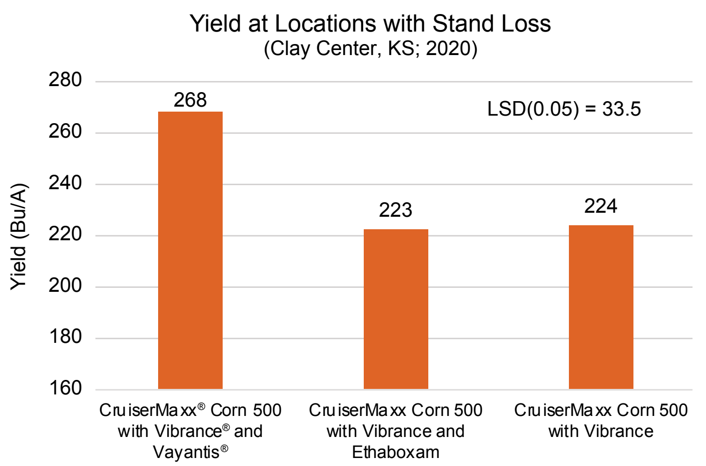
Pythium is one of the leading causes of yield loss in corn. It is commonly the first pathogen seeds encounter each spring and is frequently thought of as the most significant corn seed/seedling disease. *Pythium* commonly causes reduced plant stands, weaker, stunted plants and, ultimately, reduced yield 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

*CruiserMaxx Corn 500 is an on-seed application of Cruiser 5FS insecticide delivered at the 0.50 mg a.i./seed rate and Maxim Quattro fungicide.

BACTERIAL LEAF STREAK OF CORN

INSIGHTS

- It is important to properly identify bacterial leaf streak (BLS) since managing with fungicides is not effective.
- BLS management should start with hybrid selection (resistance), crop rotation and residue management.

Bacterial leaf streak of corn (BLS) was first documented in the U.S. in 2014, with rapid expansion since formal identification in 2016. The disease has been reported in Colorado, Illinois, Iowa, Kansas, Minnesota, Nebraska, Oklahoma, South Dakota, Texas and Wisconsin. The causal agent of this disease is *Xanthomonas vasicola* pv. *vasculorum*. This bacterial infection has been observed on field corn along with sweet corn, popcorn and seed corn.

SYMPTOMS

- Interveinal, narrow leaf lesions with wavy margins that can range in size from small flecks to very long lesions.
- BLS lesions appear yellow, tan, brown or orange in color.
- Lesions appear water-soaked and very yellow in color, often having a yellow halo when backlit by the sun (Figure 1).
- Lesions may appear anywhere on the leaf, eventually growing together to form large, necrotic areas (extreme cases).
- Symptoms often start on the lower leaves and spread upward via rain splash but have also been observed to begin development in the mid- to upper canopy after heavy rain events or after tassel emergence.

SIMILAR DISEASES

Symptoms of BLS can be confused with gray leaf spot (GLS) caused by a fungal pathogen (Figure 2). However, GLS tends to have straight, blocky lesion margins in contrast to the wavy or jagged lesion margins caused by BLS. Proper identification is important with BLS as it is not a fungus that is effectively controlled with a fungicide like many other common corn foliar diseases.

Figure 2. Left: BLS with wavy margins. Right: GLS with rectangular lesions that move down leaf veins.

CONDITIONS FOR BLS

Researchers believe that this bacterium overwinters in infected crop residue and can enter through leaf stomata openings or damaged plant tissue. Infection is more likely where inoculum is present and susceptible hybrids are grown.

BLS development favors high relative humidity and leaf wetness and is most often observed in continuous corn fields with minimal tillage. It thrives in wet conditions created from overhead irrigation or with extended rainfall periods but can also be observed in drier conditions and management practices. This disease is likely spread by residue movement via equipment, stalk feeding and wind dispersal.

Proper identification is important with BLS as it is not a fungus that is effectively controlled with a fungicide like many other common corn foliar diseases.

Figure 1. Bacterial leaf streak lesions on corn leaves. The yellow halo or illuminated effect shows in the center of the image where backlit by the sun.

MANAGEMENT

- Selecting corn hybrids with moderate to high tolerance is the best option for management, since fungicide applications are ineffective for bacterial diseases such as BLS.
  - Golden Harvest Seed Advisors can provide recommendations for locally adapted hybrids with good BLS tolerance.
- Crop rotation to a non-host crop and control of volunteer corn plants may also help reduce the bacterial pathogen in the residue.
- Weed management is important since weeds can be a host for BLS.
- Tillage may be somewhat effective; however, the soil management strategy of the field should play a role in the management decision.
- Harvesting severely infected fields last and cleaning equipment to make sure infested residue isn't spread to other fields may slow pathogen distribution.

MAIN MENU

CORN FUNGICIDE TIMING CONSIDERATIONS

INSIGHTS

- Applying Miravis® Neo fungicide provided economically advantageous yield responses at several sites despite low disease pressure and abnormally dry conditions.
- R1 fungicide applications provided the most consistent response in low disease environments.
- Conditions more conducive to early disease development will likely result in more response from multiple applications.

INTRODUCTION

Foliar fungicide applications can be an effective way to protect and improve corn yield potential. Yield increases can be the result of protection from diseases or plant health benefits that help withstand stress. The most successful disease management programs require proactive fungicide applications at first sign of or just before symptoms develop. In addition, diseases such as tar spot can develop almost anytime throughout the corn reproductive stages. Due to this, early application timings may not have enough residual to provide protection all the way to corn maturity. The ability of some diseases to rapidly develop at various times has increased interest in better understanding when and what value can be generated with multiple fungicide applications in comparison to a single timing.

Figure 1. Drone used for late-season fungicide applications.

FUNGICIDE APPLICATION TIMING TRIALS

Fungicide trials were established across the Cornbelt by the Agronomy in Action Research Team in hopes of comparing single and multiple fungicide applications under natural disease complexes. This trial compared the following fungicide programs:

1. Xyway® LFR® fungicide (15.2 oz/A) applied at planting in a 2×2 placement
2. Miravis Neo fungicide (13.7 oz/A) at R1 timing
3. Miravis Neo fungicide (13.7 oz/A) at V12 timing and R1
4. Xyway LFR fungicide (15.2 oz/A) applied at planting followed by Miravis Neo fungicide (13.7 oz/A) at R1
5. Xyway LFR fungicide (15.2 oz/A) applied at planting followed by Miravis Neo fungicide (13.7 oz/A) at V12 and R1 timings
6. No fungicide, check comparison.

At planting applications were applied with a 2×2 placement attachment on research planters as specified with fungicide labels. Mid-season V12 applications were applied to specified plots using a calibrated hand boom. Late-season R1 foliar applications were made using a drone equipped with a boomless controlled droplet atomizer system to creates more consistent droplet sizes than flat fan nozzles (Figure 1). Overall disease pressure was low across trial sites with minimal symptoms appearing near corn physiological maturity.

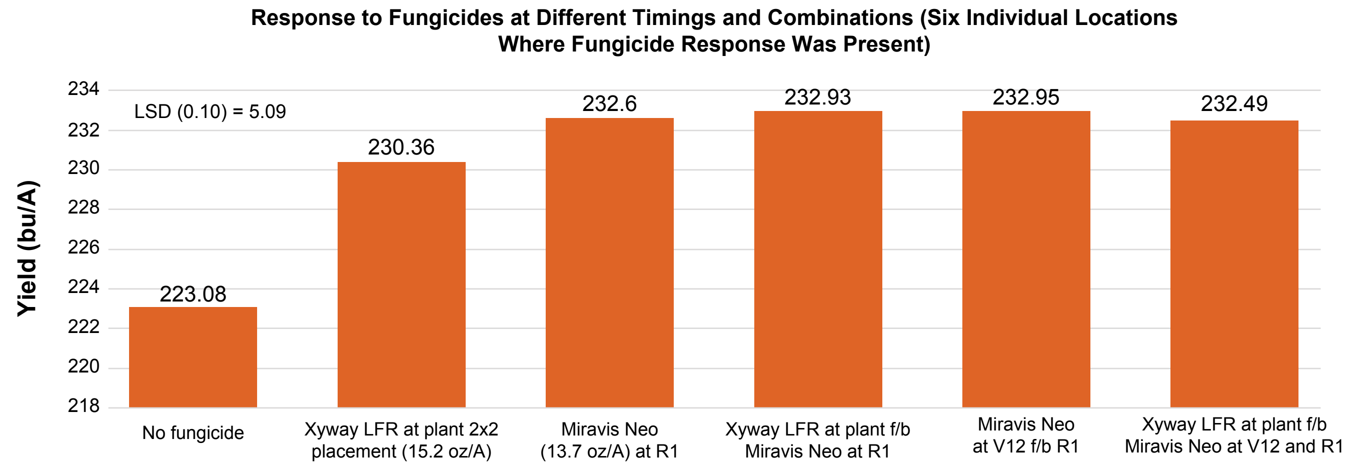
TRIAL RESULTS

Results from this trial showed an average yield increase of 10.6 bu/A with a single-pass fungicide application at the R1 growth stage in nine of ten trials (Table 1). Responses ranged from 0 to 19.2 bu/A depending on trial site, although only two of the nine trials were statistically significant. Minimal disease symptoms were observed at locations throughout the season, indicating that positive yield trends were more likely result of increased plant health. Six of the nine sites had a statistical increase in yield from one or more of the individual fungicide treatments. These more responsive sites were averaged together and analyzed for differences among individual timings (Graph 1). There was no yield advantage of additional applications beyond the single R1 timing when averaged across responsive locations, likely due to low disease presence. Xyway LFR fungicide alone did improve yield over the no fungicide check but yielded less than any Miravis Neo fungicide treatment. It is also unclear from this trial how much protection Xyway LFR fungicide would provide under late season disease progression if present.

Lower disease pressure and drier than normal conditions across all sites likely contributed to the lack of differences between fungicide treatments. There may be situations where a second fungicide application during grain fill may be warranted due to significant late-season pressure. In these situations, relative risk of late disease development based on presence of conducive conditions for disease development in a specific area should be considered before applying. Applying fungicide products that contain multiple active ingredients, like Miravis Neo fungicide and Trivapro® fungicide, can offer a better chance of disease control compared to single active ingredient fungicides.

Location	Untreated Check Yield	Response to Miravis Neo at R1
	bu/A	
Waterloo, NE	213.8	+ 19.2
Blue Earth, MN (2)	204.2	+ 18.2
Grundy Center, IA	257.3	+ 14.9
Malta, IL	246.2	+ 10.2
Bridgewater, SD	172.1	+ 9.9
Slater, IA (1)	253.8	+ 7.2
Janesville, WI	206.5	+ 6.3
Blue Earth, MN (1)	211.6	+ 4.9
Slater, IA (2)	272.0	+ 4.7
Clinton, IL	244.8	No Response
Average		**+ 10.6**

Table 1. Response of corn yield to Miravis Neo application at the R1 growth stage at ten Agronomy in Action trials.



Graph 1. Response to fungicides at different timings and combinations at six locations where fungicide response was observed.

MAIN MENU

THE BASICS ABOUT DRONES FOR FUNGICIDE APPLICATION

INSIGHTS

- Drone spraying can be a valuable option in areas where ground or aerial application is either cumbersome or not feasible.
- Agronomy in Action Research team found no difference in corn yield response between drone and ground fungicide application.
- There are several variables (e.g., cost, FAA requirements, etc.) that must be considered when evaluating whether to invest in a drone sprayer.

INTRODUCTION

Adoption of drones in agriculture continues to rise. Initially, most utilization was for field scouting. However, usage for pesticide application continues to rise. Multiple years of Agronomy in Action Research trials have demonstrated the value of R1 fungicide application in corn, even when disease pressure is low. Initially, nearly all applications were made using large scale aerial or high clearance sprayer equipment. However, as drone-specific spraying technologies continue to develop, and affordability improves, grower interest in purchasing and operating drones for pesticide application is growing. As adoption continues, there are still many questions about the effectiveness of spray applications as compared to traditional methods. This article discusses the basics of fungicide application by drones and how it compares to its traditional ground-based counterpart.

SPRAY DRONE BASICS

Exact spray width and capacity of spray drones varies by manufacturer, though spray patterns up to 35 feet and 10-gallon tank capacities are common. Initial spray drones were equipped with booms (Figure 1). However, this design will likely decrease in popularity going forward due to less consistent spray coverage and drift potential.[1] New spray drones are now generally equipped with a boomless controlled droplet atomizer system (Figure 2), where spray droplets are produced by the rotational speed of a cup.[2] This creates more consistent droplet sizes compared to a range of droplet sizes that are produced by fan spray tips.

Figure 1. Example of a boomed spray drone equipped with flat fan nozzles.

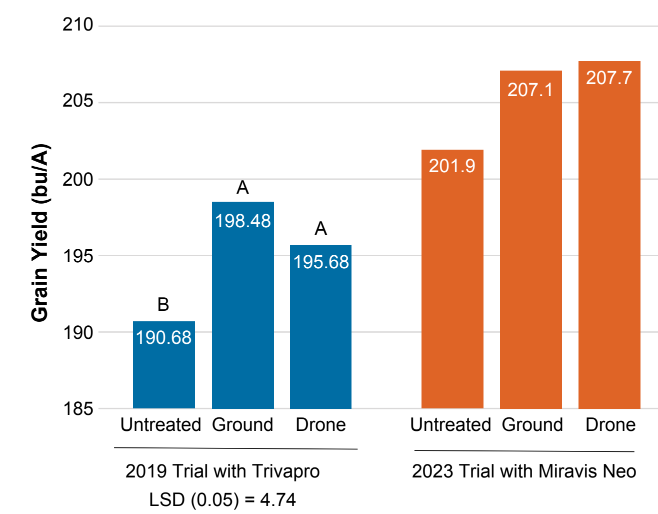
Figure 2. Example of a boomless spray drone.

A key difference between drone and traditional sprayers is spray volume. Most pesticides labeled for aerial application require rates of at least 2.0 gal/A, meaning maximum coverage area for a 10-gal spray drone tank would be five acres. Although the carrier volume is significantly less than other traditional methods, academic research has found that it produced more consistent vertical coverage within the canopy.[3] Additional academic research has also shown that fungicide application by a drone was effective against foliar diseases. In Kentucky, Trivapro® fungicide (13.7 oz/A rate) reduced grey leaf spot severity at three sites and increased grain yield by 4.4% (9.1 bu/A).[4]

TRIALS COMPARING APPLICATION METHODS

Agronomy in Action Research trials were conducted at Slater, IA in 2019 and Waterloo, NE in 2023 to assess the effectiveness of spray drone fungicide application on corn grain yield (Figure 3), and how it compared to ground application. Fungicide (Trivapro in 2019; Miravis® Neo in 2023) was applied at R1 to multiple Golden Harvest® corn hybrids (36 in 2019 and two in 2023). The drone application consisted of a carrier rate of ≤3 gal/A (3 in 2019, 2 in 2023) applied approximately 10 feet above the crop canopy. Ground application consisted of a rate of 20 and 15 gal/A in 2019 and 2023, respectively.

Yield increases of 5.0 and 5.8 bu/A were observed in 2019 and 2023, respectively when fungicide was applied with a spray drone compared to the untreated control



Graph 1. Response of corn yield to fungicide application method at Slater, IA in 2019 (left) and Waterloo, NE in 2023 (right).

(Graph 1). No significant foliar diseases were present in the untreated checks at or after the time of application, suggesting the yield response was likely driven more from plant health benefits of azoxystrobin + SOLATENOL® fungicides within Trivapro and azoxystrobin + ADEPIDYN® fungicides within Miravis Neo. Although ground applications were 2.8 bu/A greater than drone applications in 2019, differences were not statistically significant. Ground and drone application method yields were similar in 2023, indicating both application methods were equally effective delivering active ingredients with systemic activity. Improvements in nozzles utilizing droplet atomization systems in 2023 likely improved drone performance over flat fan nozzles used in 2019. Research under high disease pressure is needed to assess how non-systemic contact fungicides perform when applied with drone sprayers.

Figure 3. Drone fungicide application over corn.

WHERE DO SPRAY DRONES FIT?

Drone sprayers are not meant to replace traditional ground or aerial options, although there are situations where they may have a better fit:

1. Field conditions do not allow for ground equipment traffic.
2. Small or irregularly shaped fields.
3. Uneven terrain (e.g., terraces, draws).
4. Areas or gaps missed by traditional application.
5. Fields where off-target movement poses a risk (e.g., near residential areas or vineyards).

Drone spraying also creates an opportunity for site-specific pest management. For example, if field scouting identifies pockets within a field where insect or disease pressure has reached an economic threshold, drone spraying could be utilized to target application only in those areas, thus reducing overall cost (when compared to a blanket application across the entire field).

IMPORTANT CONSIDERATIONS

Besides equipment cost, there are several other factors to consider when evaluating drone spraying:

1. **Application efficiency:** Because of the limited swath path and tank capacity, application efficiency is limited (<50 A/hour). In addition, battery life is relatively short (typically under 15 minutes, depending on weather conditions), also requiring frequent changes and charging.
2. **Regulations:** Drones used for non-recreational use require FAA Part 107 (Certified Remote Pilot) and 137 (Dispensing Chemicals and Agricultural Products with UAS) certifications. The drone plus cargo cannot exceed 55 lbs (unless an exception is granted).
3. **Pesticide applicator licensing:** State or local certification for aerial application of pesticides may be required.
4. **Product label:** Most labels currently do not provide restrictions with drone application because they are generally captured within aerial application restrictions at the time this article was written.
5. **Insurability:** Most general farm policies do not cover drones, so a separate policy may be necessary.

SUMMARY

Fungicide application with drones has a fit in areas where traditional application via ground or aerial application is not feasible or is cumbersome. It can also potentially reduce input costs in fields where only targeted fungicide application is needed. There are significant factors that must be weighed when assessing the decision to adopt this application method. However, the capabilities would complement any disease management program.

PREPARE FOR EXTENDED DIAPAUSE NORTHERN CORN ROOTWORM IN ROTATED CORN FIELDS

INSIGHTS

- Northern corn rootworm (NCRW) is a significant pest in the Corn Belt and has adapted to crop rotation in areas by a mechanism known as extended diapause.
- The NCRW populations exhibiting extended diapause can survive two or more years as eggs in the soil until corn returns to the crop field.
- An integrated management approach should be leveraged for this adapted corn pest.

Corn rootworm has been a perennial problem for most corn-growing regions since the 1940s. The pest has thrived in Midwestern areas where corn acres are dense. Repeatedly planting corn over consecutive years is advantageous to Corn rootworm survival since eggs laid by adult beetles in the summer will not hatch until being exposed to a period of cold temperatures throughout the winter. This period of overwintering referred to as "diapause" normally only occurs the first year before hatching begins the following spring. Presence of a host crop like corn to feed on the following spring is therefore critical to larva (Figure 1) survival the following season. The unique biology of this pest has historically allowed crop rotation to be a highly effective management practice up until more recent years.

Figure 1. CRW larva.

Figure 2. NCRW beetle adult.

CORN ROOTWORMS EVOLVE TO OVERCOME ROTATION

There are four species of corn rootworms present in North America, but Western corn rootworm (WCRW) and Northern corn rootworm (NCRW) are the most economically important. Adult NCRW are uniquely identified by the solid green color of the elytra wing cover (Figure 2) and are recently getting more attention due to

This adaptation of lengthening the overwintering dormancy period to span two or more winters allows the rootworm population to survive crop rotation or harsh environmental conditions.

how their lifecycle has evolved. NCRW has genetically adapted to corn-soybean crop rotations by extending its diapause period, where the eggs remain dormant in the soil for multiple years before hatching. Delaying egg hatch for multiple seasons gives NCRW more opportunities to reestablish itself in a year following soybeans. This phenomenon has yet to be observed in the WCRW species and adds complexity to decision making processes when crop rotation has been serving as the primary management practice. Extended diapause NCRW populations were first observed in the mid-1980s and have fluctuated in presence over the years. In 2023, Golden Harvest agronomists started seeing larger numbers of NCRW beetles and root damage from larvae in rotated corn fields, indicating extended diapause was likely present. Distribution of 2023 observations largely aligned with historically reported geographies where extended diapause was known to exist, although it was also found in a few counties outside the normal range (Figure 3). Observations from 2023 are a good indicator that NCRW may reappear in the same fields in the 2025 season, even if soybeans are planted in 2024.

UNDERSTANDING EXTENDED DIAPAUSE

Understanding NCRW extended diapause is crucial for effectively managing the pest. All corn rootworm eggs need to diapause over the winter before being able to hatch in the spring. Repeated use of crop rotation has imposed a selection pressure for NCRW individuals with a longer diapause duration that gives the best chance for survival. This adaptation of lengthening the overwintering dormancy period to span two (up to four) winters allows the rootworm population to survive crop rotation or harsh environmental conditions.

Research shows that the extended diapause trait is not ubiquitous across all NCRW populations, meaning that not all eggs will delay hatching for multiple seasons.[1] It can be common for 50–60% of the eggs to hatch the first year, while the remainder hatch in following years.[3,4]

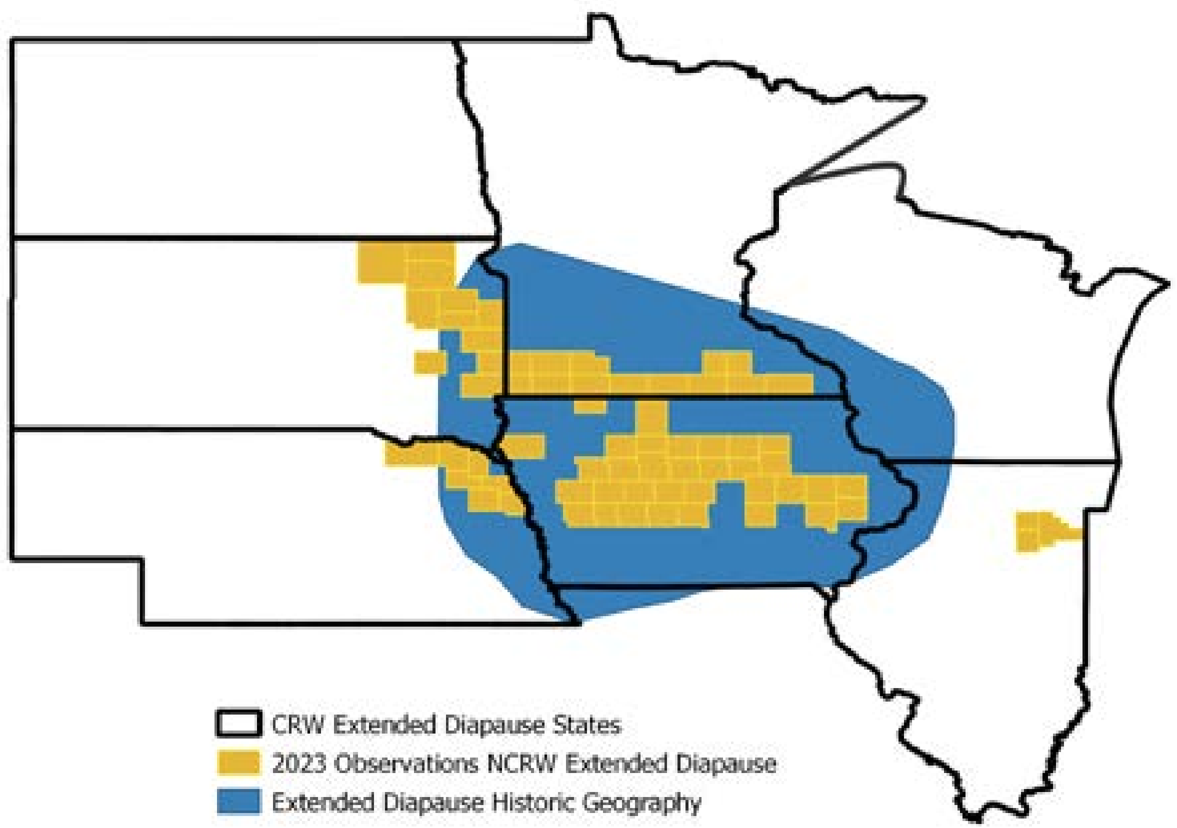


Figure 3. Geography of historically observed extended diapause in NCRW and the counties where NCRW extended diapause was observed by Golden Harvest Agronomists in 2023.

SCOUTING TO DETERMINE RISK

Regular monitoring or scouting of corn fields for root injury and adult beetles can help evaluate the severity of infestation and future risk. Scouting can involve techniques such as pre-season DNA soil sampling analysis, in-season adult sticky traps and late-season root evaluations. Corn Rootworm populations can be highly sporadic from field to field and within fields. Scout enough areas to fully represent whole fields.

Adult beetle traps can be a good indicator of future NCRW populations but can have challenges when estimating two or more years in advance. Traditionally yellow sticky trap thresholds of two or more corn rootworm beetles/trap/day have suggested that alternative management may be needed the following year if planting corn, regardless of species.[2] Since NCRW beetles can migrate short distances from neighboring fields, it cannot be assumed that beetles observed in rotated corn fields are always a result of extended diapause. There is not a lot of data available to correlate sticky trap captures with NCRW extended diapause risk or injury, but researchers in Minnesota have been using four or more NCRW per plant as a threshold for determining risk of extended diapause in corn-soybean rotations. The higher threshold levels account for an additional year of egg mortality and consider that only a portion of the population will have delayed hatch.[1] Digging roots and noting larvae feeding in rotated corn fields is a better indicator of extended diapause when assessing risk of future problems. It may still be possible to have root damage in rotated fields that was not due to extended diapause if volunteer corn was present and attracted beetles into soybean fields the prior year.

Multiple management practices exist for protecting against NCRW species with extended diapause:

1. Longer Crop Rotation Durations: Short term rotations involving corn every other year may no longer be effective, but diversifying rotations with a third-year non-host crop or multiple years of alfalfa can still be effective where possible.

2. Corn Rootworm Traits: Dual mode of action corn rootworm traits like Duracade® and Agrisure® Total trait stacks can be highly effective. Be mindful that repeated use of the same trait could select for resistant rootworm populations. Rotating management options and modes of action can help minimize this.

3. Soil-Applied Insecticide: Multiple options now exist for applying soil-applied insecticides such as Force® through planters.

4. Foliar Insecticides: Well-timed foliar insecticide applications can effectively reduce the number of gravid females prior to laying eggs. Multiple applications may be needed to effectively control beetles that have emerged at different timings.

MANAGEMENT STRATEGIES

It is important to note that the management of NCRW extended diapause requires a comprehensive and adaptive approach. Individual management practices such as short-term crop rotations may no longer provide adequate protection if NCRW extended diapause is present in an individual field. Regular monitoring and understanding of local population dynamics is critical to developing long term economical solutions.

CORN PEST MANAGEMENT
MAIN MENU

MANAGING FOR BETTER NITROGEN USE EFFICIENCY

INSIGHTS

- Keeping adequate nitrogen (N) available to the crop all season long involves a systemic 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

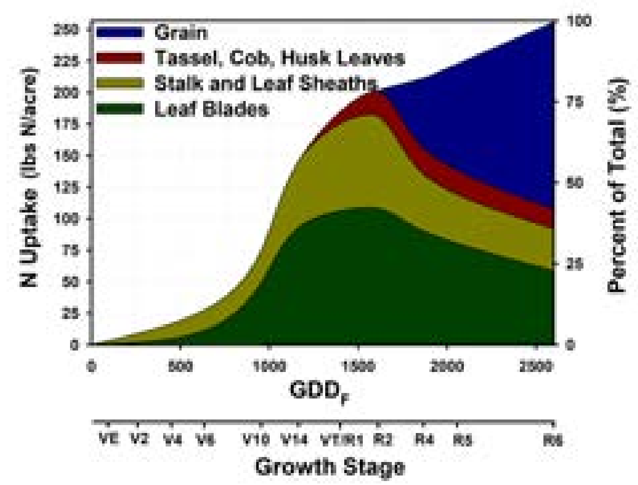


Figure 1. Seasonal N uptake in corn. Peak N uptake occurs between the V8 and VT/R1 growth stages (Bender et al., 2013).

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 straight 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, 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 (NO_3-) 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 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

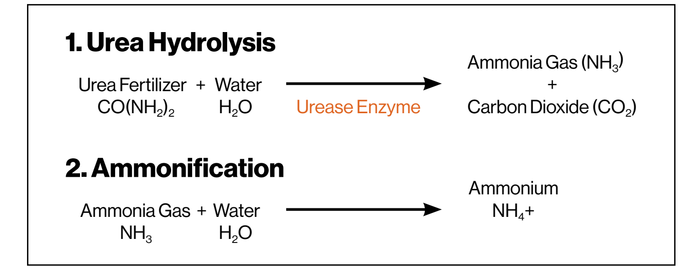


Figure 2. Chemical process of urea hydrolysis. Urease inhibitors slow the activity of the urease enzyme.

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+) naturally 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 where the nitrification process takes place. 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).

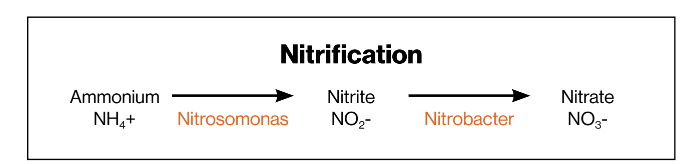


Figure 3. Chemical process of nitrification. Nitrification inhibitors reduce bacteria populations and/or block enzyme binding sites for the reaction to take place.

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.

NUTRIENT MANAGEMENT
MAIN MENU

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.

PLANTER APPLIED NITROGEN PLACEMENT IMPACT ON CORN YIELD

INSIGHTS

- Volatilization risk increases when surface dribbling nitrogen, although subsurface banding and dribbling yielded similarly in these trials.
- Dual banding nitrogen did increase yield in these trials as compared to single banding.
- Planter applied N can reduce risk of nutrient loss, but applications could be impacted by weather.

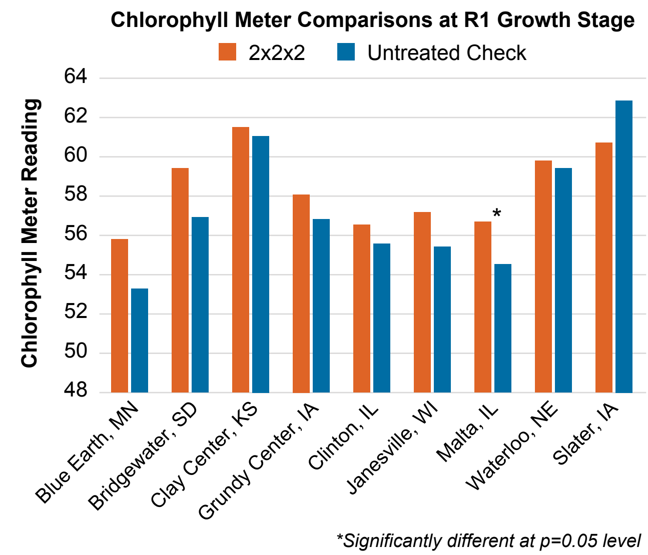
Figure 1. Planter surface dribbling nitrogen in a dual band, on either side of the seed furrow.

INTRODUCTION

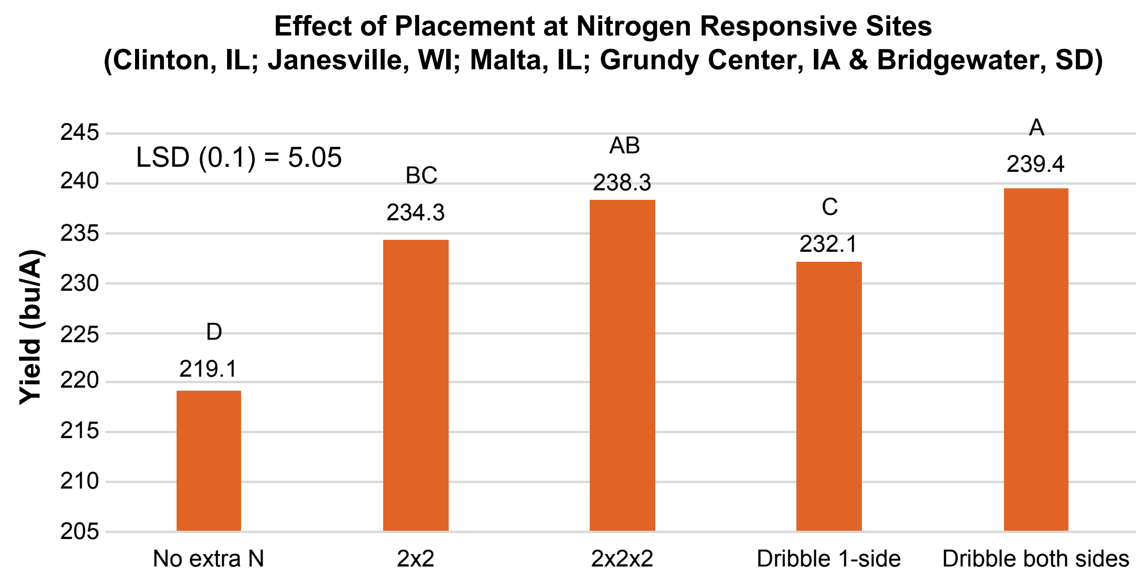
Nitrogen (N) is an essential nutrient in corn production. Corn needs a high amount of nitrogen to support plant growth and development. Nitrogen is a component of amino acids and enzymes that support a variety of plant essential functions. Insufficient nitrogen can severely impact crop yields. A well-designed nitrogen plan will supply enough nitrogen to support crop growth demand without applying excess that could potentially be lost. Splitting application timings can help ensure enough nitrogen is available at times of rapid crop growth and help prevent excess nitrogen from being lost to leaching. One way to accomplish this is by applying a portion of the total nitrogen with the planter.

AT PLANTING NITROGEN PLACEMENT TRIAL

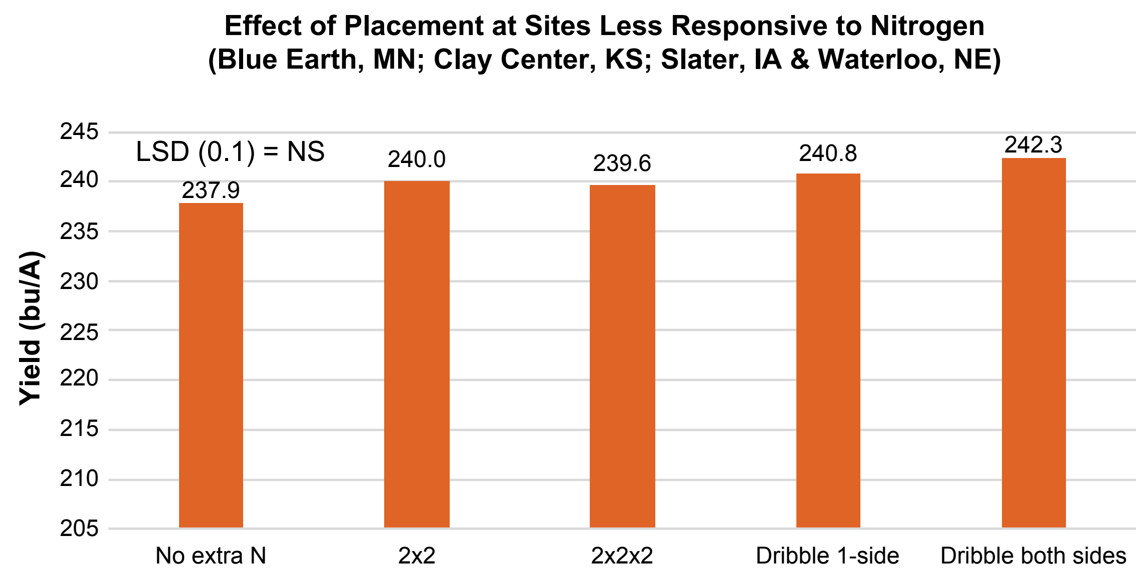
Agronomy in Action Research trials were established at nine Midwest locations to determine if at-planting nitrogen applications increase yield potential, and if so, does the response vary based on placement. Fifty pounds of N per acre as urea ammonium nitrate (UAN) nitrogen was applied



Graph 1. Chlorophyll measurements for 2×2×2 and no nitrogen treatments across all locations.



Graph 2. Yield effect of placement at nitrogen responsive sites.



Graph 3. Yield effect of placement at sites less responsive to nitrogen.

two inches to one or both sides of the seed furrow as a surface dribbled (Figure 1) or sub-surface band (1–2-inch depth) application with the planter. Individual treatments of incremental nitrogen applications were compared against the base pre-plant nitrogen rates applied across the entire trial, which varied by local farmer.

Leaf chlorophyl measurements were taken at R1 from the ear leaf of the dual-banded subsurface treatment and check plots to identify trial locations that were deficient in nitrogen. Chlorophyll measurements were taken using an atLEAF® CHL PLUS chlorophyll meter which allows noninvasive quantification of plant chlorophyll content.

TRIAL RESULTS

Chlorophyll readings were higher in plots receiving incremental nitrogen than plots with base nitrogen rate at eight of nine trial locations, indicating most of the locations had the potential to respond to nitrogen. Of the eight sites, chlorophyll readings were significantly higher than check plots at the Malta, IL location, indicating it had the highest likelihood of increased yield with incremental nitrogen (Graph 1). Yield data from individual locations was used to identify sites more responsive to nitrogen to understand if N placement differences exist. Statistical yield increases from one or more nitrogen treatments was observed at Clinton, IL, Malta, IL, Janesville, WI, Grundy Center, IA and Bridgewater, SD. Results were averaged across these locations to look for differences amongst treatments (Graph 2). When averaging across N responsive sites, significant yield increases were observed with all nitrogen treatments compared to the no extra nitrogen treatment. In general, dual banded nitrogen applications increased yields more than single banded applications but the response was more significant (7.3 bu/A) within surface dribbled treatments. When averaged across locations that did not have a significant response to incremental nitrogen, N placement had no effect on yield (Graph 3).

SUMMARY AND CONCLUSION

Banding fertilizer has been found to greatly increase the amount of nitrogen taken up by the plant in comparison to broadcast applications.[1] Surface applied nitrogen fertilizer is much more dependent on rainfall to move it into the rooting zone and more vulnerable to volatilization than soil incorporated nitrogen. Due to this, previous trials have found that nitrogen uptake is greater with subsurface banding than when dribbling on the surface.[1] Cooler temperatures and timely rainfall which incorporated surface dribbled nitrogen into the soil at these locations resulted in minimal volatilization even though surface dribbling would normally have a higher risk of loss. Previous research has not shown significant differences in plant nitrogen uptake when applying as a single or dual band on both sides of the row.[1] Yield advantages from dual banding in our trial was likely not related to volatilization since dual banded surface dribble and subsurface banded nitrogen treatments responded similar. Potentially, the response to dual banding was a result of how nitrogen dispersed more evenly throughout the soil rooting zone resulting in more efficient uptake. Additional trials would need to be done to know how repeatable this dual banding response is.

Nitrogen applied at planting requires additional planter setups and can slow down planting to refill tanks. Nitrogen placement is important as high salt concentration in proximity of the seed may affect germination. Moving the applied band of nitrogen two or more inches away from the furrow can resolve this issue. Soil type should also be taken into consideration as nitrogen can more easily move into proximity of the seed in sandy soils. Shifting nitrogen applications away from fall or spring preplant timings to planting and in-season sidedress timings can reduce some of the risk of loss of N to the environment, but weather conditions can limit in season applications. Wet weather could delay applications beyond optimal timing or prevent application entirely in severe instances. Risks of in-season application should be weighed against the total number of acres to cover to determine feasibility of split nitrogen application programs.

Figure 2. Planter attachment showing the 2×2×2 (dual banded, soil incorporated) nitrogen application method.

NUTRIENT MANAGEMENT
MAIN MENU

CAUSES OF PURPLE CORN OBSERVATIONS IN THE SPRING

INSIGHTS

- There are a few situations that can cause leaf purpling such as hybrid genetics or nutrient deficiency.
- Yield loss due to leaf purpling is mostly dependent upon the cause behind the symptoms which can be compounded with other environmental factors.

Purpling of corn leaves is generally a result of the inability of a corn plant to take up adequate quantities of phosphorous **OR** due to the presence of unique gene(s) in specific hybrids that trigger production of reddish-purple anthocyanin pigments in young corn plant tissue (Figure 1). Optimal daily growing conditions normally result in production of high concentrations of sugar photosynthates within leaves. Typically, sugars would be metabolized overnight and redistributed to other parts of the developing roots and stems. Cool night temperatures or other biotic/abiotic stressors that inhibit root development can concentrate sugar levels in leaves. It is believed that since anthocyanin occurs in the form of a sugar, concentrations of other sugars can further promote anthocyanin production and cause excessive purpling.

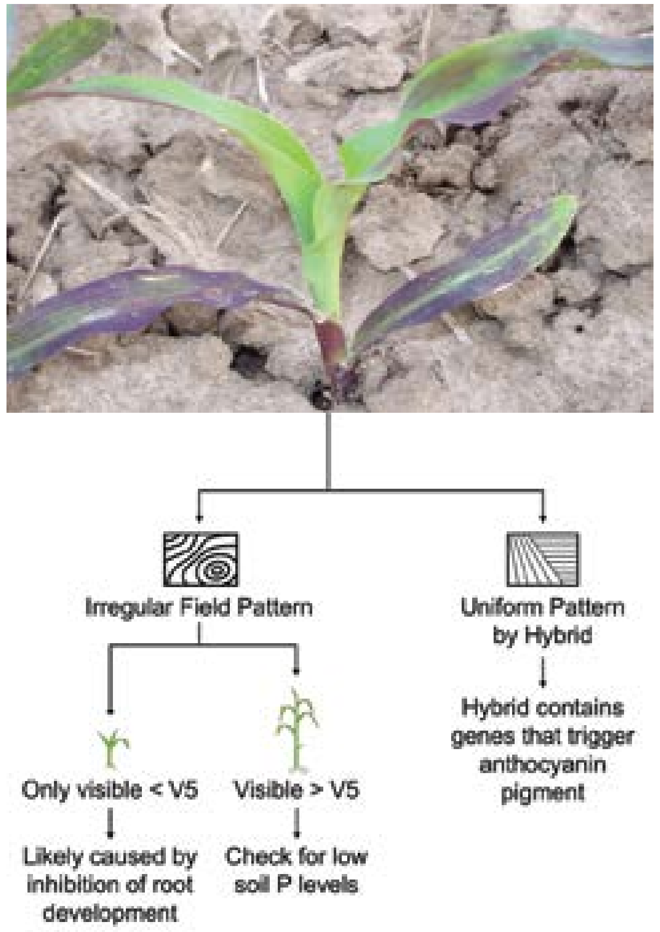


Figure 1.

HYBRID SPECIFIC RESPONSE

Most corn hybrids contain one or more genes responsible for anthocyanin pigment production which causes purpling of leaf tissue (Figure 2). Hybrids containing multiple cold-sensitive anthocyanin genes can be more prone to leaf purpling when soil and air temperatures are low during early vegetative stages.[1] Hybrids containing multiple genes responsible for purpling can also be more visible than other hybrids growing under the same field conditions. As affected corn plants begin to transition from small seminal/radicle root systems to larger and rapid-growing nodal root systems, they are better able to reallocate sugars from leaf tissue to roots and begin to green up. Purpling caused by pigment-producing genes usually occurs uniformly across fields and only in specific hybrids, making it easy to distinguish from other causes.

ROOT INHIBITION AND PHOSPHOROUS AVAILABILITY INFLUENCE ON LEAF PURPLING

Although some hybrids are more prone than others to leaf purpling at early growth stages, it can be a common symptom in any hybrid when the plants are unable to take up enough phosphorous (P). Although purpling of leaves is a symptom of low soil phosphorous levels, it can also be an indication that the plant is having difficulty extracting nutrients from soil with sufficient P levels due to other reasons. Purpling of leaves when soil phosphorous levels are sufficient is usually the result of one or more factors that slowed or stopped root development. There are a variety of environmental, management and pest related reasons that can impede root growth in the early vegetative stages, resulting in leaf purpling. Applying additional phosphorous to purple corn when soil test values are adequate will not likely result in additional yield.

LEAF PURPLING INFLUENCE ON YIELD POTENTIAL

Yield loss due to leaf purpling is mostly dependent upon the driving cause behind the symptoms. Stress such as cool temperatures or wet soil conditions that result in slowed root development may be temporary, and as conditions improve, plants grow out of symptoms with little to no yield penalty. More persistent stress from things like compaction or herbicide injury may persist longer into the growing season and have potentially larger impacts on yield potential, depending on the original cause. Purpling caused by insufficient soil P levels can result in significant yield penalties and should be addressed with future nutrient management plans. Hybrids that are more prone to purpling will usually grow out of symptoms quickly as temperatures warm and nodal root systems begin to develop with little to no influence on yield potential.

Causes for slowed root development that can result in leaf purpling:

- Soil pH influence on phosphorous availability
- Cool soil and air temperatures
- Soil compaction
- Planter sidewall compaction
- Shallow planting depth
- Starter fertilizer salt burn (high rates/low OM)
- High ammonia concentrations from spring anhydrous applications
- Wet, saturated soils
- Seedling diseases
- Insect root feeding
- Overapplication of herbicide (overlaps)

Figure 2. "Purple corn syndrome" from the accumulation of anthocyanin in the leaves.

NUTRIENT MANAGEMENT
MAIN MENU

MAIN MENU

CORN STARTER AND PHOSPHORUS ENHANCING PRODUCT

INSIGHTS

- Phosphorus (P) is an essential nutrient important for many plant functions but can be tied up in the soil.
- Starter fertilizer responses were observed at five of eight trial sites in 2023.
- AVAIL® T5 further increased yield at 3 of the 8 trial sites, and only when added to lower rates of 10-34-0.
- Use of phosphorus enhancing products like AVAIL T5 has the potential to increase P uptake in some soils, possibly leading to yield increases.

INTRODUCTION

Phosphorus is essential for plant growth and development. Adequate phosphorus levels aid in many different functions in the plant, from root development, photosynthesis and reproductive processes. Much of the phosphorus in the soil solution is unavailable for plant uptake due to being bonded to positively charged soil ions. Due to this, soil applications of manure or fertilizers containing phosphorus may not be immediately available for the same reasons.

Because phosphorus is an essential plant nutrient that is relatively tied up in the soil solution, there is interest in practices to make it more available. AVAIL T5 is a phosphorus enhancing product that reacts with positively charged soil nutrients like calcium, aluminum and magnesium to prevent phosphorus from becoming tied up. AVAIL T5 is added to fertilizer to sequester surrounding antagonistic metals in the soil, therefore increasing phosphate solubility and making it more available to the plant. Previous research has found that AVAIL T5 has potential to increase yield with lower amounts of phosphorus fertilizer in certain soil conditions, possibly allowing reduced fertilizer rates.[1] Since phosphorus availability in the soil is also negatively influenced by high or low soil pH levels, it is possible that AVAIL T5 may provide more value under these conditions. With more available phosphorus in the soil solution there's a better chance for root interception and plant uptake.

2023 AGRONOMY IN ACTION TRIAL

The Agronomy in Action Research team evaluated the effect of two rates of phosphorus fertilizer in combination with AVAIL T5 phosphorus enhancer. The two rates of starter fertilizer were used to ensure that AVAIL T5 responses were not masked by the availability of phosphorous at the higher rate. The trial compared an untreated check to 2.5 gal/A (GPA) and 5 gal/A rates of 10-34-0 (ammonium polyphosphate) fertilizer applied in-furrow at planting, both with and without AVAIL T5. Early maturity locations planted G06A27-D brand and later maturity locations planted G15J91-V brand corn hybrids. Trials were harvested with a research combine, taking yield and moisture measurements at harvest.

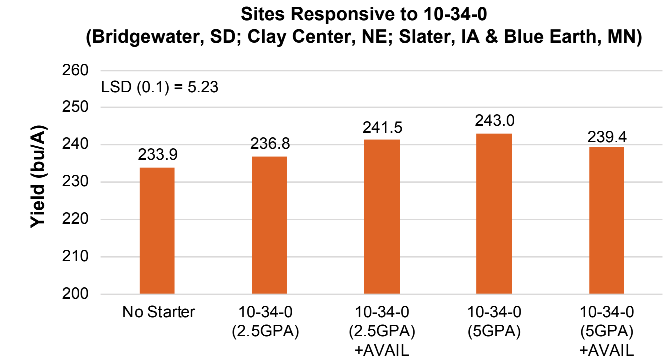
TRIAL RESULTS

Of the eight trial locations, five had a positive yield response to 10-34-0 starter fertilizer applications at planting. Four of the five responsive sites responded to both 2.5 and 5 GPA rates (Graph 3). The fifth location, Waterloo, NE, only responded to the 5 GPA rate. There was no yield response to starter fertilizer at either rate or AVAIL T5 with

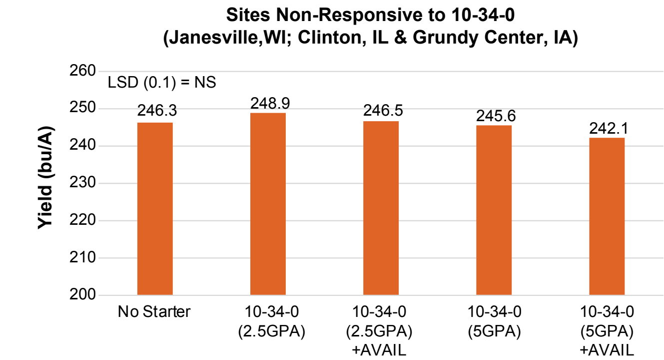
Location	pH	P (ppm)	P Rate
Blue Earth, MN	5.4	25	H
Bridgewater, SD	5.5	44	VH
Grundy Center, IA	6.7	57	VH
Janesville, WI	5.4	53	VH
Clay Center, KS	6.3	39	VH
Clinton, IL	6.2	33	VH
Malta, IL	6.4	92	VH
Slater, IA	5.3	41	VH
Waterloo, NE	6	31	VH

Table 1. Phosphorous trial site pH and phosphorous levels.
H = High, VH = Very High

MAIN MENU



Graph 1. Yield response to 10-34-0 and AVAIL T5 additive averaged across responsive sites.



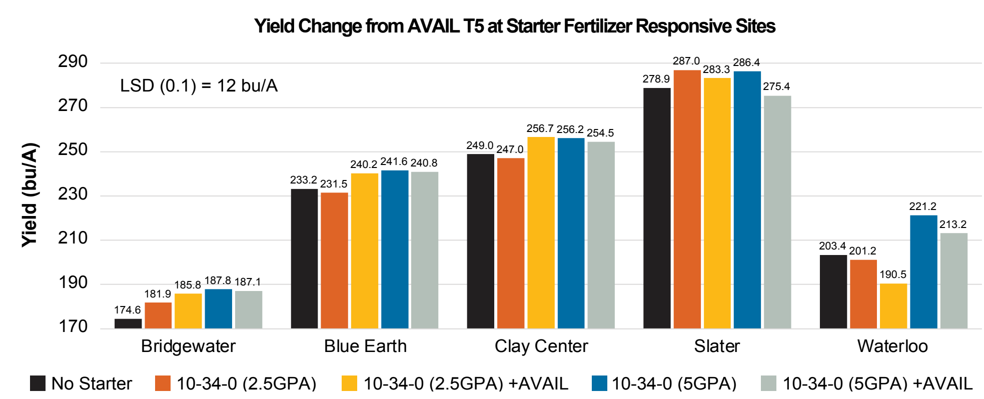
Graph 2. Yield response to 10-34-0 and AVAIL additive averaged across NON-responsive sites

the three remaining locations (Graph 2). University trials have also found varied responses to starter fertilizer, often contributing it to differences in tillage, pH, soil texture, soil drainage and soil P and potassium (K) levels.[2,3,4] Soil test phosphorus results at the 2023 trial sites ranged from high to very high at all locations (Table 1), likely limiting potential for response to applied phosphorus or AVAIL T5. Previous trials have shown yield responses from starter fertilizer to decline with increasing soil test P and K levels, yet yield increases still occurred in trials with soils having high P and K levels.[5]

When averaging across the four sites responsive to both starter fertilizer rates, adding AVAIL T5 to the low rate (2.5 gpa) increased yields. At the same sites, there was no response to AVAIL T5 when added to the 5 GPA starter fertilizer rate. AVAIL T5 also did not further increase yield when added to either starter rate at the Waterloo, NE site even though increasing starter fertilzer rate to 5 GPA did increase yield.. This suggests that the 5 GPA starter rate provided enough plant available P on its own, eliminating the need for AVAIL T5. When looking within the five individual starter fertilizer responsive sites, only three had yield increases resulting from adding AVAIL T5 (Graph 3). Yield responses resulting from adding AVAIL T5 at those three sites (Bridgewater, SD; Blue Earth, MN; and Clay Center, NE), which all had high or very high soil P levels, may have been attributed to two of three sites having lower soil pH values (<5.5) that reduced P solubility (Table 1). Findings from this study agree with previously published research that AVAIL T5 can increase yield potential in some conditions, but not predictably and not consistently[1]. Before broadly adopting fertilizer additives into an operation, growers should conduct side-by-side comparisons with their current practices to determine the suitability of any product.

PHOSPHORUS MANAGEMENT

Like other nutrients, phosphorus availability is affected by soil acidity, so monitor soil pH levels and apply lime accordingly. Phosphorus placement is another consideration, and using directed placement of starter fertilizers can sometimes aid in root interception of phosphorus in the soil. Care should be taken to limit phosphorus applications and keep soil test levels out of the excessively high category. There is concern of losing phosphorus from fields too, and care should be taken to not apply manure or fertilizer to frozen ground. Heavy rain can result in large losses of phosphorus from soil and sediment runoff.



Graph 3. Yield contributions of 10-34-0 starter fertilizer and AVAIL T5 phosphorus enhancer at sites with a starter response, 2023.

DROUGHT-INDUCED POTASSIUM DEFICIENCY IN SOYBEANS AND CORN

INSIGHTS

- Drought and dry soil conditions influence multiple processes in crops, specifically potassium uptake from the soil.
- Potassium deficiency may impact corn or soybean yield potential depending on the growth stage when nutrient uptake is decreased.

Yellowing of leaves could occur in fields for many reasons such as disease presence, low fertility or management factors. Even after identifying that symptoms are fertility related it can still be challenging to determine the specific cause. For example potassium (K) deficiency symptoms can occur in fields with sufficient nutrient levels for a variety of reasons ranging from drought to compacted soils.

Potassium (K) deficiency symptoms can occur in fields with sufficient nutrient levels for a variety of reasons ranging from drought to compacted soils.

Potassium deficiency is more commonly seen at early, rapid growth stages, and less often in late reproductive stages. Potassium is very mobile within the plant and is readily remobilized from roots and stems just before seed fill is initiated. It is an important nutrient for photosynthesis, enzymatic reactions, starch synthesis, nitrogen fixation and energy metabolism in plants. Plants take up large quantities of K during their life cycle and K deficiency may limit plant growth, ultimately impacting yield potential.

Figure 1. Yellowing symptoms in corn from K deficiency.

Figure 2. Yellowing symptoms in soybeans impacted from K deficiency.

POTASSIUM DEFICIENCY SYMPTOMS

Corn:

- Yellowing or browning starting at leaf tip, then along leaf margins, followed by necrosis and dieback (Figure 1).
- Usually appears in older leaves first. Generally, from a distance, leaves appear light green.
- Common during rapid growth periods when plant demand goes up, V6–V8 growth stages.[1]

Soybeans:

- Yellowing along leaf margins is visible in middle and upper leaves later in season and on lower leaves early in season, and the impacted leaves may fall off (Figure 3).
- Leaf margins may become brown or necrotic with prolonged deficiency (Figure 4).
- K deficiency may advance soybean maturation, along with other nutrient deficiencies and excessively wet or dry soil.[2]

FACTORS IMPACTING K DEFICIENCY

- Drought: Potassium is made available in the soil solution making availability dependent on soil moisture. In drought conditions, the diffusion of K to the roots is slowed, so soils with marginal K levels will likely show even more symptoms with low soil moisture.
- Inadequate K levels: Soils can become depleted of K.
- Stunted root system: An active root system is required to take up K, so factors like temperature, compaction, seed furrow side-wall compaction, dry soils, shallow planting depth or pathogen/insect pest injury may stunt a root system.
- Growth stage: Soybeans demand a high amount of K during the R1–R5 growth stages where 75% of the total K uptake occurs.[3]

MANAGEMENT

- Test soil and leaf samples for K in normal and affected areas to help determine K levels.
- If soil K levels are adequate, precipitation will likely increase availability to the plants.
- Apply K fertilizer as recommended before the next crop. Fertilizer programs will vary because the amount of K supplied by the soil varies from large differences in soil parent materials.[4]
- Prevent soil compaction or limitations to root development and activity.
- There are no economically effective rescue treatments. In-season rescue fertilizers are only recommended if not enough K was applied in early fertilizer applications. Generally, precipitation will improve potassium availability.

Figure 3. Yellowing around soybean leaf margins.

Figure 4. Advanced K deficiency symptoms.

CHARACTERIZING HYBRIDS FOR RESPONSE TO INCREMENTAL ZONE-PLACED FERTILIZER

INSIGHTS

- Banding nutrients closer to rows can minimize risk of loss and increase nutrient availability.
- Hybrids can respond differently to precision fertilizer placement.
- Golden Harvest is committed to providing information on best placement and management of hybrids based on field research.

Hybrids can respond differently to management practices such as seeding rate, fertility, sidedress nitrogen and foliar-applied fungicide. Understanding how hybrids respond to these management practices can help farmers not only select the right hybrids for their farm, but also aid in management decisions throughout the growing season. Golden Harvest is committed to providing information on how hybrids respond to different management systems.

HYBRID RESPONSE TO FERTILITY TRIAL

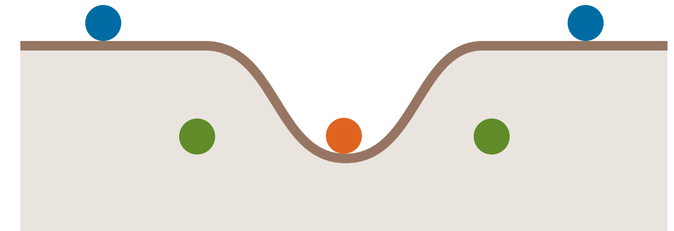
The Golden Harvest Agronomy in Action Research Team conducted trials to characterize hybrids for their response to enhanced fertility practices utilizing precision fertilizer placement.

A total of 36 Golden Harvest® corn hybrids ranging in relative maturity (RM) between 80 and 118 days were evaluated across ten locations throughout the Midwest. At a given location there were 14 to 18 hybrids planted depending on the RM range for the location.

Each hybrid was tested under two fertility programs: base versus incremental zone-placed fertilizer programs. The base program was the grower's normal fertility program at each location. In most cases it was broadcast phosphorus (P) and potassium (K) in the fall followed by a single or split application of nitrogen (N) in the spring. Some locations received manure as the bulk fertility needs. The incremental zone-placed fertilizer program included additional precision placed fertility added to the base program.

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

Precision fertilizer placement was completed using a research planter that can apply 1) seed-safe fertilizer in-furrow with the seed 2) higher rates of fertilizer in a 2x2x2 placement 3) dribble sulfur and nitrogen next to the row on the soil surface behind the planter (Figure 1). AVAIL® T5 was added to the 2x2x2 fertilizer and iNvigorate® was added in-furrow to maximize nutrient use efficiency. Nutrients, rates and placement of fertilizer for zone-placement components were consistent across all locations and are outlined in Table 1.



Placement	N	P_2O_5	K_2O	S	Zn
In-furrow	3	14	3		0.15
Surface Dribble	60			15	
2x2x2	7	22	29	2	
Total via Planter	70	36	32	17	0.15

Table 1. Visual image and table showing the amount of nutrients applied with the planter and the placement of the fertilizer in relation to the seed.

Locations varied in soil fertility levels (Table 2). All locations had adequate P and K soil test levels except Slater, IA which was low in K. Sulfur (S) soil test values were very low to low and zinc (Zn) was adequate to high for all locations. The base rate of N applied was the local grower management choice which ranged between 150–200 lbs of N/A.

RESPONSE TO PRECISION FERTILIZER PLACEMENT

On average across all hybrids and locations, incremental zone-placed fertilizer increased yield by 10 bu/A over the base fertility program. The yield response was between 4 and 18 bu/A depending on the location (Graph 1). Corn grown at seven out of the ten locations had a statistically significant yield response to incremental zone-placed fertilizer. Hybrids at Slater, IA showed sulfur deficiency symptoms early and had the greatest response to the precision placed fertilizer yielding 18 bu/A more than the base program. The large response was likely driven by low soil test values for multiple nutrients including K and S. The other locations had sufficient P and K soil test values, so it is suspected that many of the responses were driven from additional N and S. Clinton, IL was planted early on April 26 into cool soils where S mineralization was likely reduced. In the base fertility plots, plants were visually yellowing near the new growth, a common symptom of early-season S deficiency (Figure 2). Whereas, in the plots with incremental zoned-placed fertility, plants were greener and taller likely from the 17 lbs of S/A applied with the planter along with additional N.

Location	Base N Rate lbs/acre	pH	Organic Matter	CEC	P†	K††	S	Zn
			%	meq/100g	ppm	ppm	ppm	ppm
Blue Earth, MN	200	5.4	4.5	33	25	188	8	1.3
Bridgewater, SD	150	5.5	3.4	22.3	44	220	-	-
Clinton, IL	120/60	6.2	3.1	16.6	33	203	5	2
Grundy Center, IA	160	6.7	4.7	21.1	57	224	5	4.2
Janesville, WI	120/60	5.4	4.2	18.1	53	333	7	4.2
Malta, IL	200	6.4	4.9	16.9	92	349	7	6.3
Rennville, MN	150	5.9	5.5	23.1	32	208	-	-
Slater, IA	200	5.3	3.8	27.2	45	137	6	1.1
Waterloo, NE	120/50	6.5	3.6	16.6	50	410	10	1.8
York, NE	175	6.2	2.8	16.6	28	304	-	-

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

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

NOT ALL HYBRIDS RESPOND THE SAME

There was a large range in hybrid response to incremental zone-placed fertilizer between the different locations. Hybrid response ranged from 0 to 17 bu/A at Janesville, WI and 2 to 37 bu/A at Slater, IA.

Every hybrid was not at an equal number of locations. In addition, some locations were overall more responsive to fertility than others meaning solely comparing the average response between hybrids is not a fair comparison in determining the responsiveness of hybrids. It is important to compare hybrids against each other within a location. The Golden Harvest Agronomy in Action Research Team evaluates hybrid response to incremental zone-placed fertility using two main criteria. First, the hybrid response at each location is compared to the average response of hybrids at that location. Second, the consistency of hybrid response across all the locations is noted. Hybrids that consistently show a response above the location average are typically characterized as more responsive hybrids. Hybrids that show an inconsistent response across locations, is typically considered a less responsive hybrid. A hybrid characterized as less responsive does not mean it will not respond to incremental zone-placed fertilizer, it simply means on average it responds less than other hybrids in the portfolio.

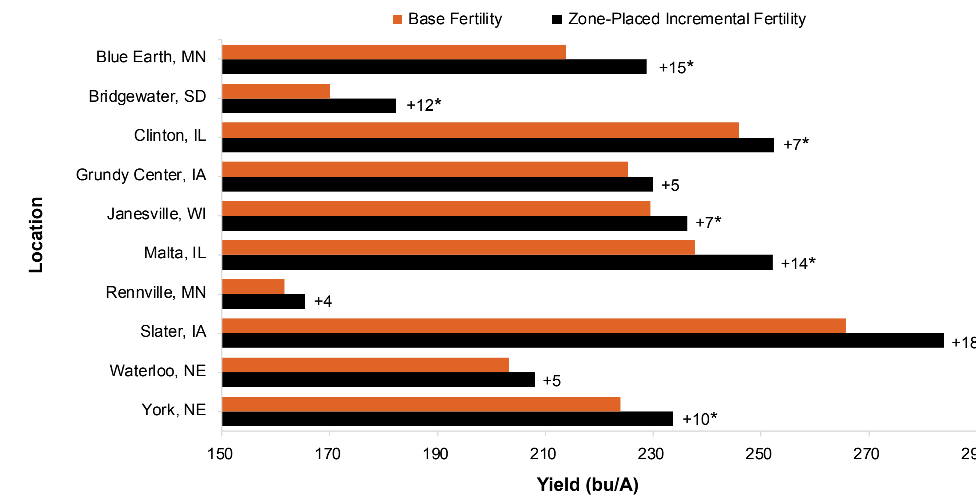
For example, Graph 2 illustrates how two short-season hybrids respond differently. G01B63 and G03B19 brands were both planted at the same five locations. G03B19 brand consistently showed a greater response across all five locations compared to the other hybrids at each location. On average, it was 8 bu/A more responsive compared to all hybrids at those locations. In comparison, G01B63 brand was more responsive than the average hybrid at three of the five locations. On average, it was 1 bu/A more responsive than all other hybrids. Graph 3 illustrates the same concept with full-season hybrids G10B61 and G11V76 brands. G03B19 and G10B61 brands are characterized as more responsive hybrids to precision fertilizer placement compared to G01B63 and G11V76 brands which are moderately responsive.

SUMMARY

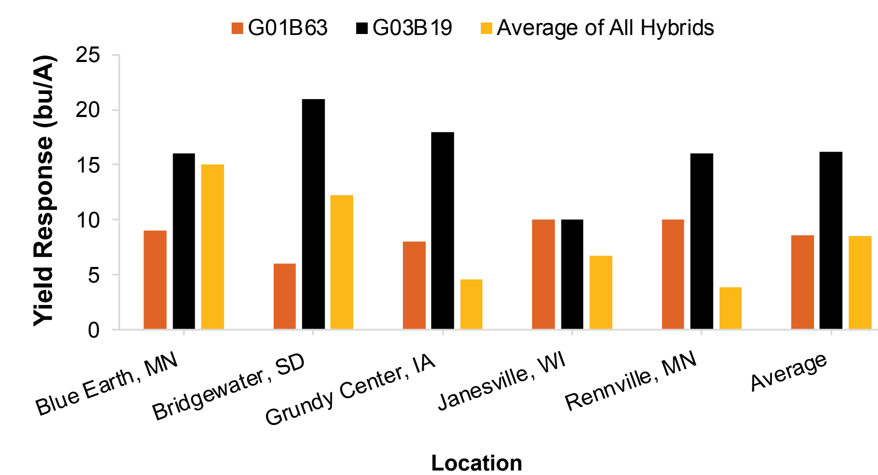
Crop nutrition is the foundation to achieving maximum genetic yield potential. Many fields have untapped yield potential through ear flex that can be uncovered utilizing precision fertilizer placement. Placing nutrients near the root zone increases nutrient availability to the plant and sets the yield trajectory for the rest of the growing season.

There can be a large range in hybrid response to incremental zone-placed fertilizer. Golden Harvest works hard to have a deep understanding of our hybrids. It is critical to know what environments a given hybrid thrives in, but also how to manage each individual hybrid. Results from these hybrid characterization research studies provides growers with knowledge to get the most out of their seed investment.

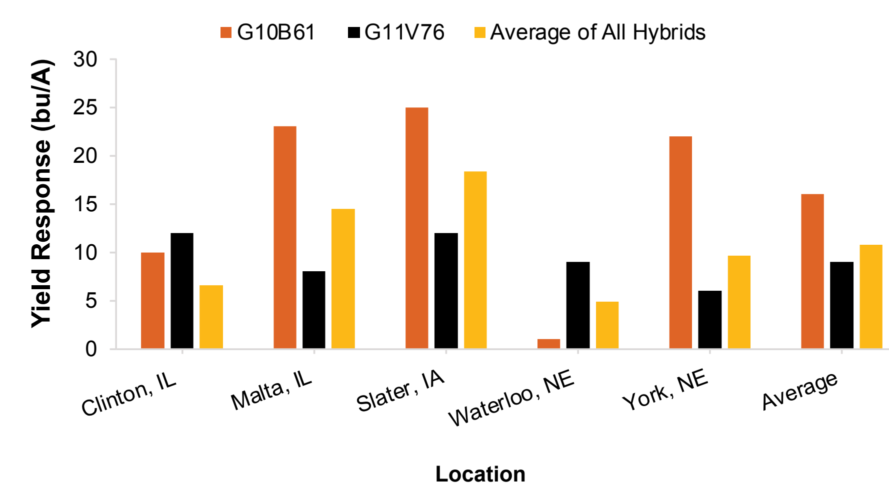
Figure 2. Corn growth response to incremental zone-placed fertilizer (right) compared to base fertility program (left) at Clinton, IL in 2023.



Graph 1. Effect of incremental zone-placed fertility on yield averaged across hybrid at ten Midwest locations in 2023. *significantly different than base fertility at α = 0.10. Averaged across hybrid.



Graph 2. Yield response of hybrids G01B63 and G03B19 brands to incremental zoned-placed fertilizer compared to the average response of all other hybrids combined at each location.



Graph 3. Yield response of hybrids G10B61 and G11V76 brands to incremental zoned-placed fertilizer compared to the average response of all other hybrids combined at each location.

SULFUR APPLICATION TIMING EFFECT ON CORN RESPONSE

INSIGHTS

- On average, sulfur (S) applications significantly increased yield regardless of application timing.
- Over two years, 5 out of 17 sites had a significant response to S fertility.
- In general, all hybrids responded similarly to S applications.
- Soil organic matter or S soil test values were not great predictors of corn response to S.

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.

2023 SULFUR ON CORN TRIALS

In 2023, sulfur Agronomy in Action trials were established at nine locations throughout the Midwest. In addition to understanding frequency of response to sulfur, the trials were designed to evaluate application timing and hybrid response differences. Two hybrids, either G06A27 and G06B57 brand or G14B32 and G15J91 brand, were planted at each location to better understand response differences among hybrids.

Sulfur treatments were applied as either at-planting or 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 of S/acre, which simultaneously provided 9 lbs of nitrogen/acre at each timing. All plots not receiving sulfur at planting were treated with 9 lbs of N/acre 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/A of total nitrogen to all treatments. Every plot received a balanced total of 59 lbs/A of nitrogen via the two timings so that nitrogen within ATS did not bias results.

Figure 1. Twenty pounds per acre of sulfur applied at planting (left) compared to none (right) at Slater, IA in 2023.

Location	Check	20 lbs S at Planting	20 lbs S at V6
	Yield (bu/A)		
Blue Earth, MN	236	241	236
Bridgewater, SD	160	174*	174*
Clay Center, KS	266	271	270
Clinton, IL	252	253	260
Grundy Center, IA	192	193	195
Janesville, WI	229	245*	242*
Malta, IL	274	275	277
Slater, IA	282	289	293*
Waterloo, NE	228	225	233
Average	236	241*	242*

* significant difference between sulfur treatment and the check at α = 0.10

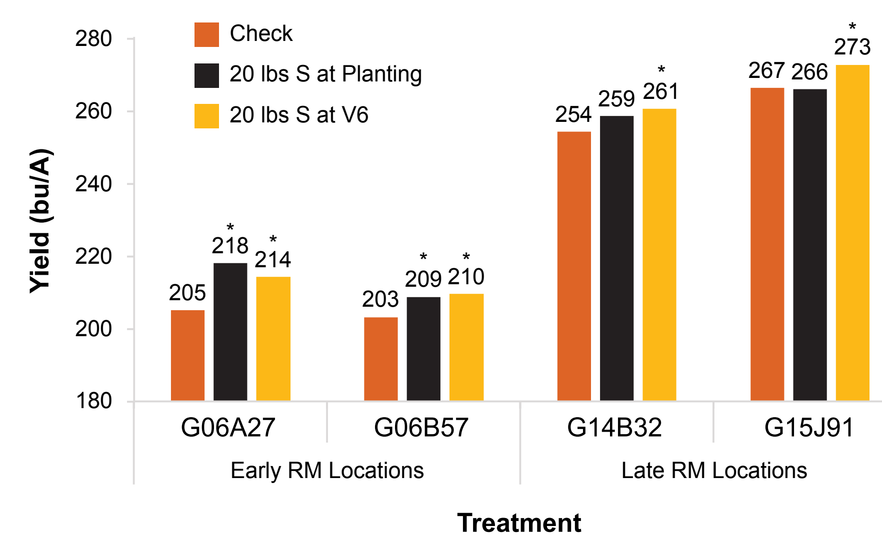
Table 1. Effect of sulfur treatment on yield at nine locations averaged across two hybrids in 2023.

Treatments were replicated six times in a split-plot design at each trial site. This trial was first conducted at eight locations in 2021 and was repeated in 2023 to better understand the environment by sulfur response interaction.

CORN YIELD RESPONSE TO SULFUR

On average, across all locations and hybrids, yield significantly increased by 6 bu/A when 20 lbs of S/acre was applied at V6 and 5 bu/A when applied at planting (Table 1). Three of the nine 2023 locations showed a significant response to sulfur fertilizer. At Bridgewater, SD, 20 lbs of S/acre increased yield by 14 bu/A regardless of application timing. At Janesville, WI there was 13 bu/A response to S applied at V6 and a 16 bu/A response when applied at planting. The V6 application of S significantly increased yield by 11 bu/A at Slater, IA.

Statistically, hybrids responded similarly to S applications. At the late relative maturity locations, G14B32 and G15J91 both significantly increased yield with S applied at V6 by 7 and 6 bu/A, respectively (Graph 1). G14B32 tended to have a greater response to S applied at planting than G15J91. At the early relative maturity locations, both hybrids significantly increased yield with both S application timings. G06A27 tended to respond better to S applied at planting while G06B57 had a similar response to both application timings (Graph 1).

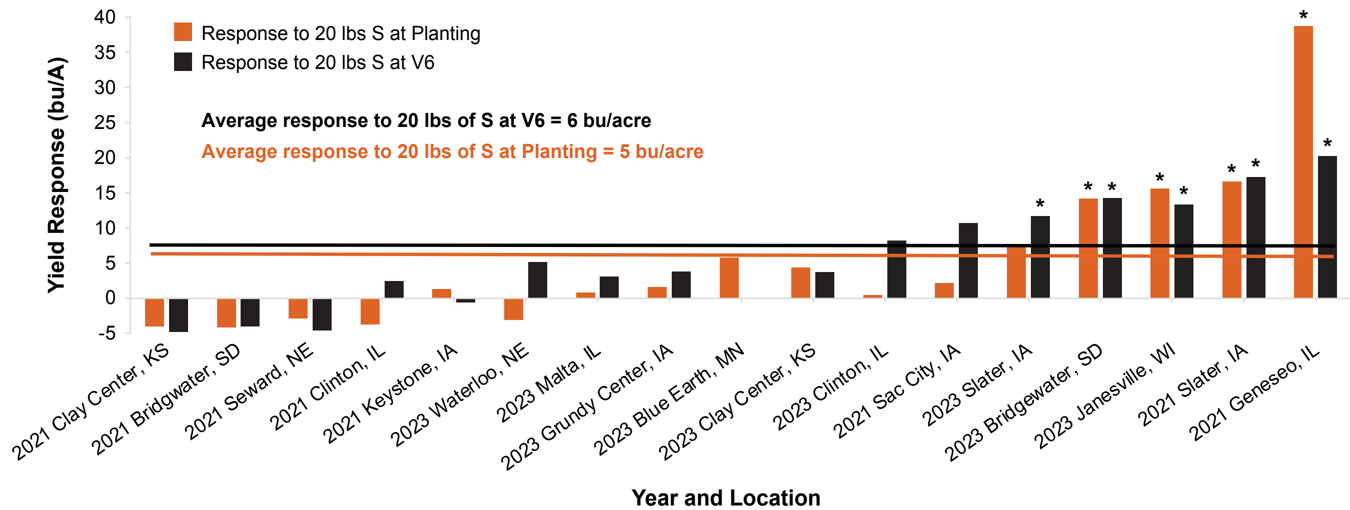


*significant difference between sulfur treatment and the check at α = 0.10

Graph 1. Effect of sulfur treatment on yield averaged across locations in 2023.

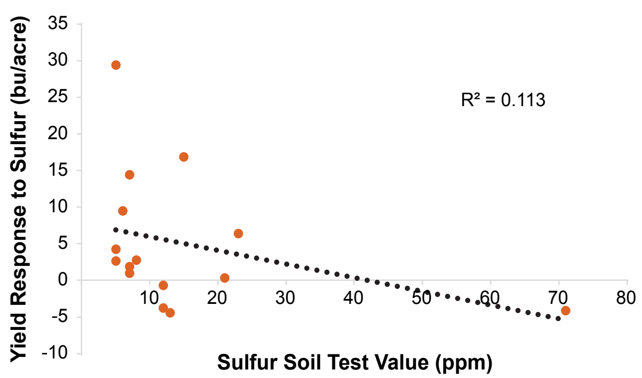
MULTI-YEAR SULFUR RESPONSE RESULTS

The yield response to S applications varied across the 17 site-years (eight in 2021 and nine in 2023). Two locations in 2021 and three locations



*significant difference between sulfur treatment and the check at α = 0.10

Graph 2. Yield response to sulfur treatment averaged across two hybrids at 17 locations in 2021 and 2023.



Graph 3. Correlation between sulfur soil test value and yield response to sulfur application.

in 2023 had a significant response to S fertilizer (Graph 2). Across both years, corn grown at Geneseo, IL in 2021 had the greatest response to S increasing yield by 39 bu/A when applied at planting and 20 bu/A when applied at V6. When averaged across location and hybrids, there was a 5 bu/A response when 20 lbs of S/acre was applied at planting and 6 bu/A response when applied at V6.

Pre-plant soil tests were taken at most locations to determine if S soil test values can be used as an indication whether a field will be responsive to S applications.

Corn yield response to sulfur fertilizer was not correlated (R^2=0.113) with pre-plant S soil test values (Graph 3). The lowest S soil test value was 5 ppm at Geneseo in 2021 as well as Grundy Center and Clinton in 2023. Those three locations showed a 29, 3 and 4 bu/A response to S fertilizer. Sac City and Slater in 2021 had S soil test values of 23 and 15 ppm but experienced a 6 and 17 bu/A response to S applications, respectively. Corn yield response was also not correlated (R^2=0.003) with soil organic matter (data not shown).

SUMMARY

Sulfur availability and plant uptake is a dynamic process that is highly dependent on environment. There is not just one factor that is responsible for the probability of corn response to sulfur fertilizer. The occurrence of sulfur deficiency in corn has increased in recent years and the detrimental effect on yields are significant. If deficiency symptoms are visual, yield potential has decreased. An in-season application of S fertilizer can stop additional yield loss, but any lost yield potential can never be recovered. These trials show that at planting applications of sulfur can also be advantageous but may be more vulnerable to leaching loss in some years. This trial did not evaluate sulfur rate response, but it is important to consider that reduced rates needed for in-furrow application may not be as responsive as surface dribbled rates used in this trial. It is important to be proactive in S fertility management to mitigate weather risks when S may not mineralize or become available during periods of cool and dry conditions. Sulfur should be considered a critical component to any fertility program to maximize yield potential.

LIQUID SULFUR FERTILIZER SOURCES CONTAINING NITROGEN OR POTASSIUM APPLIED TO SOYBEANS

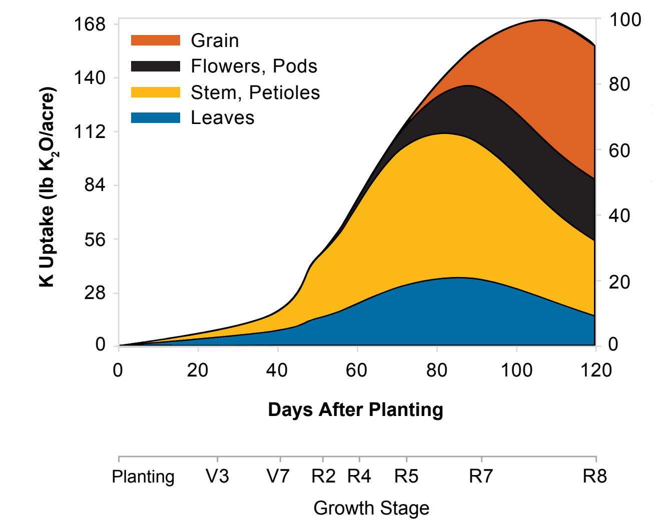
INSIGHTS

- Decreased atmospheric sulfur (S) deposition is resulting in more frequent corn and soybean sulfur deficiencies.
- Potassium (K) uptake by soybeans is 2.5 lbs of K_2O per bushel.
- In this study, soybean response to N, K or S containing liquid fertilizers was minimal suggesting those nutrients were not a yield limiting factor.

INTRODUCTION

Recently, sulfur has started to become yield limiting in many geographies, as atmospheric sulfur deposition has decreased with improved air quality standards and as crop removal rates have increased with yields. Sulfur mineralizes from organic matter in the soil into sulfate (SO_4^{2-}) which makes it more subject to leaching, similar to nitrate nitrogen. Deficiencies are often noticed in coarse, eroded or low organic matter soils that are less able to mineralize the plant-available sulfate form. Mineralization will often slow with cool soil conditions, sometimes making soils that otherwise test high in sulfur show deficiency symptoms until warming and sulfate mineralization speeds up. Due to this, soil testing procedures for sulfur are often unreliable and typically only recommended for use on sandy soils. Plant tissue samples are often needed to differentiate from other nutrient deficiencies.

Soybean demand for potassium is substantial, accumulating 2.5 lbs of K_2O/bu or roughly 175 lbs of K_2O for a 70 bu/A soybean crop (Graph 1). There is a large reserve of K in the soil, however, a relatively small amount of K is available for plant growth at any one time. Most K is tied up in the structural components of the soil and



Graph 1. Seasonal K_2O uptake in soybean. Peak K_2O uptake occurs between flowering and the end of seed filling (Bender et al., 2015).

the availability of this K is environmentally dependent. Potassium has limited mobility in the soil and is taken up by the plant through diffusion. As uptake of K occurs, the concentration in the soil solution near the root decreases. This creates a gradient for the nutrient to diffuse though the soil solution from a zone of high concentration into the depleted solution adjacent to the root. Peak K uptake occurs between flowering and the end of seed filling (Graph 1). Soil moisture, soil temperature and soil oxygen levels are all key factors that affect K uptake.

2023 SULFUR FERTILIZER TRIAL IN SOYBEANS

In 2021, S trials were conducted at nine locations across the Midwest. Ammonium thiosulfate (ATS, 12-0-26), was surface dribbled 3 inches to each side of the row during planting at 20 lbs/A of S. Non-sulfur treated plots were treated with 9 lbs/A of nitrogen (N) in the form of urea ammonium nitrate (UAN, 32-0-0) using the same application method and timing to provide an equivalent amount of nitrogen as was applied to the ATS treated plots. Sulfur applications at two of the nine locations significantly increased soybean yield by 8 and 16 bu/A.

In 2023, Golden Harvest Agronomy in Action Research expanded on the sulfur trial to answer the question: *When making a sulfur application to soybeans, is there additional yield to be gained using a sulfur source containing potassium, such as potassium thiosulfate (KTS), compared to using a sulfur source containing nitrogen, like ATS?*

Trials were established at seven locations across Illinois, Iowa, Kansas, Nebraska, South Dakota and Wisconsin. ATS or KTS was applied 2×2×2 with the planter (Figure 1). ATS was applied at 7 gal/A supplying 20 lbs of S/A and 9 lbs/A of N. KTS was applied at 9.6 gal/A supplying 20 lbs/A of S and 29 lbs/A of K. Check plots did not receive any N, K or S.

Treatments were applied to four soybean varieties at each location to measure any potential interactions. All treatments were replicated four times within each location.

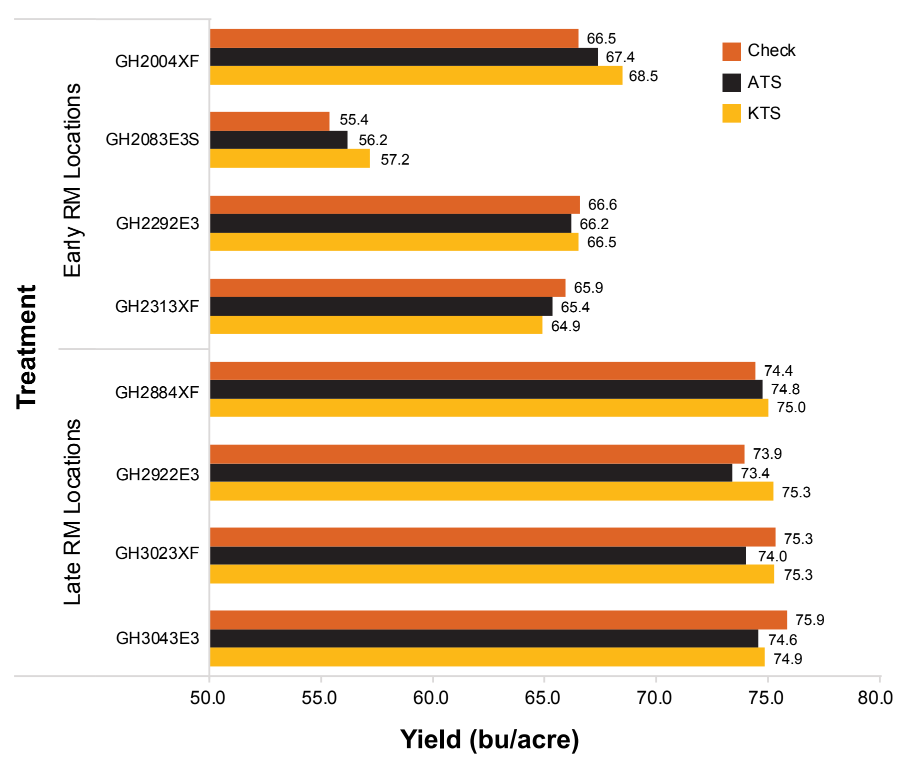
SOYBEAN RESPONSE TO ATS OR KTS FERTILIZER

There was no significant difference between ATS, KTS or the check at any of the seven locations. At Bridgewater, SD, Clinton, IL and Waterloo, NE there were small numerical yield increases. Bridgewater had a 1.4 and 1.6 bu/A response to ATS and KTS, respectively. Clinton had a 1.1 bu/A response to ATS fertilizer. Waterloo responded to the KTS by 2.4 bu/A. When averaged across all locations and varieties, soybeans yielded 70.0 bu/A treated with ATS and 70.3 bu/A treated with KTS, compared to 69.9 bu/A when no additional fertilizer was applied.

Statistically there was no interaction between fertility treatment and soybean variety meaning all varieties responded similarly to the fertility treatments (Graph 2). GH2004XF, GH2083E3S and GH2884XF brand soybeans were the only soybean varieties that tended to respond to KTS although were not statistically significant. No varieties responded to ATS (Graph 2).

SOIL TEST VALUES

Pre-plant soil tests showed adequate K levels at all locations except Clinton, IL and Slater, IA (Table 1). Both locations were the highest yielding locations ranging in yield from 79–93 bu/A meaning K demand was elevated. However, there was no yield increase when KTS was applied at either location. Sulfur soil test values were low for all sampled locations despite no response to S fertilizer. None of the locations contained a sandy soil type where most S deficiency symptoms are typically observed. Likely, there was enough S mineralized through organic matter to meet the demand of the soybean crop.



Graph 2. Effect of sulfur treatment on yield for 8 Golden Harvest soybeans averaged across early and late relatively maturity locations.

Figure 1. ATS and KTS applied with liquid fertilizer banding attachment on planter.

SUMMARY

When evaluating crop response to nutrient applications, the crop must be deficient in the applied nutrient to achieve a response. Leibig's Law of the Minimum states crop yield is limited by the lowest resource level. In this study, N, K or S was likely not the limiting factor, and adding additional fertilizer had no effect on soybean yield.

Despite no response to the S and K fertilizers in this study, both nutrients are critical for soybean production. A proactive fertility management program should be utilized to mitigate the risk when environmental conditions are not conducive to nutrient release and availability. Coarse or sandy soils are prone to S leaching and reduced mineralization often leading to deficiencies. In addition, large amounts of K are removed with the grain each year in both corn and soybeans and must be managed to maintain maximum yield potential.

Location	Soil Type	pH	Organic Matter	CEC meq/100g	K* ppm	S ppm
Bridgewater, SD	Loam	5.9	2.4	19.3	233	-
Clay Center, KS	Silt Loam	5.8	2.3	15.3	410	-
Clinton, IL	Silt Loam	6.6	3.1	15.2	149	4
Grundy Center, IA	Silty Clay Loam	5.5	3.6	18.7	213	9
Janesville, WI	Silt Loam	6.0	3.7	15.9	234	5
Slater, IA	Clay Loam	6.9	4.7	27.9	171	6
Waterloo, NE	Silty Clay Loam	6.2	3.3	16.9	395	12

*Ammonium acetate test (175–250 ppm considered adequate)

Table 1. Soil test values for six locations across the Midwest.

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

Figure 1. Iron deficiency chlorosis in soybeans.

iron concentrations, however, not all of it is readily available 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 exacerbates IDC symptoms. Although IDC symptoms are commonly

Figure 2. IDC ratings being taken in soybean research plots.

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 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]

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

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 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]


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

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 exacerbate 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.

ASSESSING THE VALUE OF SALTRO ON SOYBEAN PERFORMANCE

INSIGHTS

- The addition of Saltro® fungicide seed treatment to CruiserMaxx® APX seed treatment provided superior yield performance vs similar competitive offerings.
- Saltro was particularly valuable in high yielding, early planted fields where seedlings are exposed to greater stress.
- High SDS or SCN pressure was not required to realize the value of adding Saltro.

SUDDEN DEATH SYNDROME OVERVIEW

Sudden death syndrome is a primary soybean yield-limiting disease that infects plants early but typically delays symptomology until after flowering. It is caused by a soilborne fungus, *Fusarium virguliforme*, that overwinters in the soil and can remain viable for several years. Its symptomology is easily recognizable. As toxins produced by the fungus are translocated to the leaves, chlorosis (yellowing) and eventual necrosis (browning and death) of the area between the leaf veins occurs (Figure 1). Plants are often easy to pull out of the ground, as root decay also occurs. A bluish growth at the base of the plant also indicates the fungus is present and active.

There are no in-season management options to SDS once visual symptoms are present because fungal infection occurred when plants were in the seedling stage. The pathogen prefers cool, wet spring soil conditions for infection of soybean roots. Unfortunately, cool soils often coincide with early planting dates utilized to maximize yield by increasing plant nodes and potential pod development.

SDS can also be indirectly managed with good soybean cyst nematode (SCN) protection. SCN weakens plants and creates entry points on roots for pathogens to enter the plant.[1] Most Golden Harvest® varieties utilize the PI88788 or Peking genes as a source of SCN resistance although either trait can still be potentially overwhelmed in fields with high SCN pressure.[2] Adding Saltro to CruiserMaxx APX can provide additional protection against SDS and SCN. The unpredictability of SDS occurrence and field to field variability of SCN can make it challenging to determine when to invest in additional seed treatments to manage them. Therefore, trials were set up in 2023 to better understand if there is value in utilizing Saltro across all soybean acres, or if it should solely be utilized in fields with high SDS and/or SCN risk.


Figure 1. Interveinal chlorosis and necrosis associated with sudden death syndrome.

TRIAL DETAILS

Conducting trials targeted at SCN or soilborne diseases can be very challenging, as SCN populations and pathogens can spatially differ across short distances creating "hot" spots. To address this, trials were designed in a checkerboard pattern, and treatments were compared to the average of neighboring check plots. In the example shown in Figure 2, a particular treatment, denoted Trt1, was

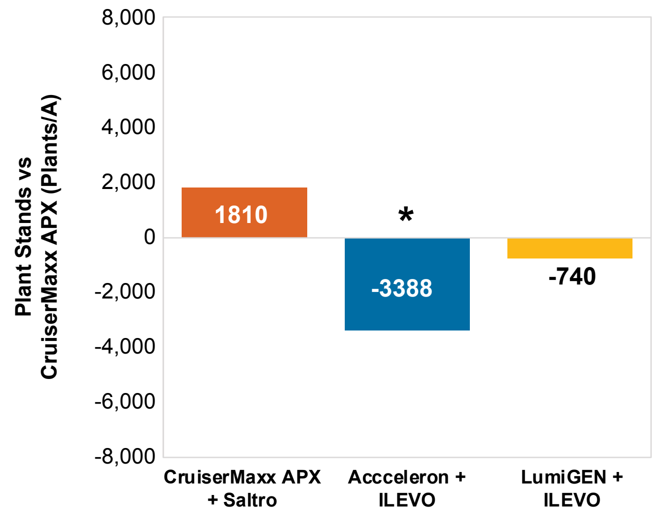
Check	Check	Check	Check	Check
Check	Trt1	Check	Trt3	Check
Check	Check	Trt2	Check	Check
Check	Check	Check	Check	Check

Figure 2. Trial plot treatment setup, 2023.

Site	Planting Date	Golden Harvest Variety Brand	SCN Count eggs/100 cc soil	CruiserMaxx APX Yield bu/A
Blue Earth, MN	5/23	GH1993XF	100	63.3
Bridgewater, SD	5/17	GH1993XF	ND†	60.1
Clay Center, KS	5/19	GH3023XF	ND	71.1
Clinton, IL 1	4/15	GH2922E3	ND	91.9
Clinton, IL 2	4/15	GH2463E3S	160	72.9
Grundy Center, IA	5/20	GH2463E3S	100	58.4
Janesville, WI	5/6	GH1993XF	480	75.1
Slater, IA 1	4/13	GH3023XF	850	86.1
Slater, IA 2	4/13	GH3023XF	1300	80.4
Waterloo, NE	5/11	GH2922E3	1653	63.0

Table 1. Planting information, SCN populations, and base yield of the CruiserMaxx APX treatment at ten Agronomy in Action sites, 2023.

†ND: Not Detectable



Graph 1. Response of plant stands of three seed treatments vs CruiserMaxx APX across seven Agronomy in Action sites, 2023.

* indicates a significant response vs CruiserMaxx APX (α=0.10).

compared to the average of the four check treatments surrounding it (highlighted in red). This method increases the probability that both comparisons are exposed to similar SCN and/or SDS disease pressure.

Ten trials were conducted at eight Agronomy in Action sites to assess the value of adding Saltro to a base seed treatment package of CruiserMaxx APX. Additional competitive seed treatments [Acceleron® + ILEVO® (Metalaxyl, Floxastrobin, Prothioconazole, Imidacloprid + Fluopyram) and LumiGEN® + ILEVO (Oxathiapiprolin, Metalaxyl, Penflufen, Prothioconazole, Cyantraniliprole, Imidacloprid, *Bacillus amyloliquefaciens* strain MBI 600, *Bacillus pumilus* strain BU F-33 + Fluopyram)] were also compared to CruiserMaxx APX. All seed treatments were applied to the same untreated variety selected for each site to further minimize potential variability (Table 1).

Sites used in the trial represented a wide range of yield environments, planting dates and SCN pressure (Table 1). All sites except Slater, IA 1, Slater, IA 2 and Waterloo, NE exhibited low SCN populations, whereas the three mentioned sites were classified as medium pressure.

SOYBEAN STANDS

Soybean stands were counted at the V3 growth stage for all sites except Clinton, IL and Janesville, WI. Adding Saltro to CruiserMaxx APX seed treatment did not statistically increase plant stands but did numerical increase them by 1,810 plants (Graph 1). Saltro (Pydiflumetoten) fungicidal activity is primarily focused on fusarium-based diseases known to reduce plant stands, therefore significant stand increases were not expected due to preexisting protection offered by CruiserMaxx APX. However, the Acceleron + ILEVO treatment which utilizes different fungicide and insecticide active ingredients had, on average, 3,388 fewer plants than CruiserMaxx APX (statistically significant at α =0.10). Plant stands of LumiGEN + ILEVO were similar to CruiserMaxx APX (740 less). Differences in final stands could be attributable to the differences in base fungicide activity across the three treatments. It is also possible that any stand reductions with ILEVO treatments may be due to phytotoxic effects on seedlings often observed with its active ingredient (Fluopyram), particularly under cool soil conditions (Figure 3). In comparison, Saltro did not produce any phytotoxic effects on seedlings, as indicated by the positive stand response and visual observations.

Figure 3. Burnt cotyledons caused by a phytotoxic response to ILEVO (Fluopyram) at Clinton, IL, 2023.

Field conditions were not very conducive for substantial seedling disease development at most sites. Although several trials were planted into cool soils in mid-April (Clinton, IL, Slater, IA), moisture prior to and after planting was generally well below average, which likely limited pathogen activity. Despite these unfavorable conditions for seedling diseases, CruiserMaxx APX still demonstrated an advantage to protect plant stands compared to other base seed treatments.

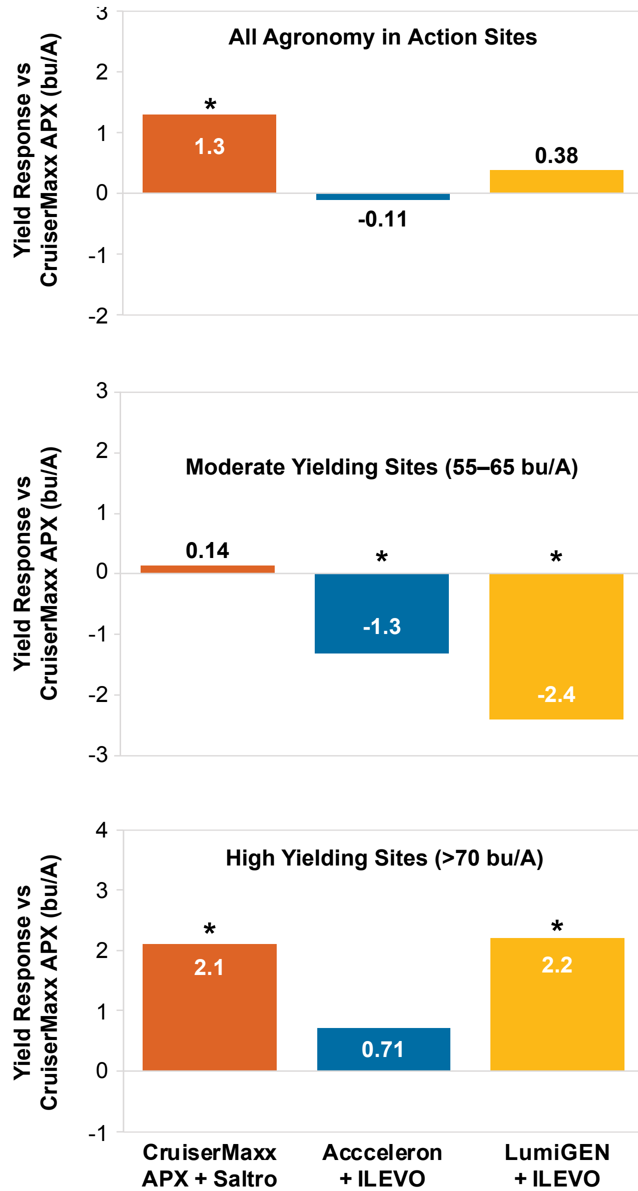
YIELD RESPONSE

Overall, the addition of Saltro increased yield by 1.3 bu/A across all sites when combined with CruiserMaxx APX (Graph 2). In comparison, no significant increases over CruiserMaxx APX were observed with Acceleron + ILEVO or LumiGEN + ILEVO. Segmenting sites into moderate-yielding (55-65 bu/A) and high-yielding (>70 bu/A) categories further showed the value of CruiserMaxx APX and Saltro. At moderate-yielding sites (Blue Earth, MN, Bridgewater, SD, Grundy Center, IA, and Waterloo, NE), Saltro addition did not enhance yield over the CruiserMaxx APX base (Graph 2). In addition to the lower yield potential, these sites were planted in mid- to late-May into warmer soils where SDS pressure was low. Despite this low disease pressure, visual SDS suppression by Saltro was still observed. Acceleron + ILEVO and LumiGEN + ILEVO yield 1.3 and 2.4 bu/A less than adjacent CruiserMaxx APX checks at these locations respectively.

The value of additional seed treatments with activity against SDS and SCN to CruiserMaxx APX was predominately observed at the high-yielding sites. These sites had earlier planting dates that generally created more stressful early growing conditions. Adding Saltro to CruiserMaxx APX increased yield by 2.1 bu/A. Overall SDS pressure was still relatively low at these sites, suggesting that Saltro still delivers value in high-yield scenarios, even when SDS or SCN pressure is low.

SUMMARY

A CruiserMaxx APX + Saltro seed treatment offers broad-acre protection against seedling diseases as well as SDS and provides an additional layer of defense against SCN when paired with PI 88788 or Peking genetic seed resistance. This trial also found that adding Saltro can still improve ROI potential, even in environments where SDS and/or SCN pressure is low, especially in intensively managed, early planted fields.



Graph 2. Response of yield of three seed treatments vs CruiserMaxx APX across all Agronomy in Action sites, moderate-yielding sites and high-yielding sites.

* indicates a significant response vs CruiserMaxx APX (α=0.10).

SOYBEAN PEST MANAGEMENT
MAIN MENU

MAIN MENU

VALUE OF ALTERNATING SCN SOURCES OF RESISTANCE

INSIGHTS

- Sustainable management of SCN requires the use of multiple tools.
- Alternating soybean sources of resistance to SCN is an important tool for season-long protection.

Soybean cyst nematode (SCN) is the most damaging soybean pathogen in North America (Figure 1). Under severe SCN pressure with no cyst protection farmers can experience up to 50% yield loss, and even fields with no visual symptoms can see up to a 10% yield loss.[1]

Once SCN is introduced into a field, it can never be eradicated. Because of that, it is a pest that must be managed; otherwise, it will eventually become a significant problem. Losses associated with SCN in any given year will be directly dependent on environmental factors, such as drought or other natural events. However, through planning and use of SCN management strategies, such as resistant soybean varieties, the impact of these SCN-related losses can be reduced.

PROTECTING YOUR YIELD POTENTIAL

While using seed treatment products can provide a second mode of action to deliver SCN suppression for your soybeans, genetic resistance to SCN is the most reliable measure against this pathogen, as it provides a longer window of protection.

For more than 20 years, greater than 95% of all SCN-resistant soybean varieties have utilized genes from the PI 88788 breeding lines as the primary source of resistance.[1] With the continued use of PI 88788, even in a rotation with a non-host crop, an SCN "race shift" can be experienced and increased cyst reproduction rates can be seen on varieties using this source of resistance. The term "race shift" is terminology used to differentiate and describe SCN populations based on their ability to reproduce on a specified set of soybean genetic cultivars or "indicator lines".

Figure 1. Soybean cyst nematode and eggs.

What this means is that PI 88788 historically reduced the number of eggs produced by SCN to less than 10% of what was produced on susceptible varieties. In recent years it is not uncommon to see reproduction rates significantly higher than 10% on PI88788 sources of resistance, potentially resulting in higher yield losses.[1] That doesn't mean that PI 88788 is not a valuable tool to manage SCN. When rotated with other sources of resistance such as Peking, it can offer more years of protection.

Newer resistant varieties of soybeans have recently been adapted for areas of the U.S. More genetic resistance options for growers means more options for SCN management.

WHAT DOES "RACE SHIFT" LOOK LIKE?

Where PI 88788 effectiveness at managing SCN populations has been reduced, varieties with an alternative source of resistance like Peking can be a great tool to help reduce SCN populations and potential yield loss. Pictured is an example of a specific field where race shift has reduced the effectiveness of PI88788 varieties (Figure 2). The two Peking varieties show minimal impact, but the PI 88788 varieties exhibit severe stunting. Additionally, even in the absence of visual symptoms yield loss may still be occurring.[2]

MAIN MENU

Figure 2. Soybean trial evaluating soybean genetic resistance to SCN.

In 2018 yield trials within the same field where race shifts occurred, Peking varieties yielded 10–20 bushels more than PI 88788 varieties (Syngenta R&D 2018). Although uncommon to see such extreme visual symptoms and yield loss as in this field, it may foreshadow what could be an everyday occurrence if diversified management practices are not implemented more broadly.

The Peking source of SCN resistance has a different mechanism for SCN resistance than PI88788. Thus, rotation of SCN sources of resistance (PI88788 and Peking) is strongly encouraged to slow the development of SCN resistance and limit SCN reproduction and economic injury levels. Additionally, limiting SCN reproduction will reduce root damage caused by nematodes that can open the door for late-season diseases like Sudden Death Syndrome (SDS) and Brown Stem Rot (BSR) which can further reduce yield. Overall, it is important to:

1. Test fields to know your SCN numbers
2. Rotate varieties with alternate sources of resistance
3. Rotate to non-host crops
4. Consider using nematode protectant seed treatments

UNDERSTANDING SOYBEAN VARIETAL RESPONSES TO FUNGICIDE-INSECTICIDE AND ENHANCED FERTILITY

INSIGHTS

- Fungicide-insecticide application increased soybean yield by 2.4 bu/A across all sites under low disease pressure.
- Enhanced fertility did not significantly increase yield across these trials.
- Soybean varieties differed in their response to fungicide-insecticide application in 2023 at some locations but not consistently across years.

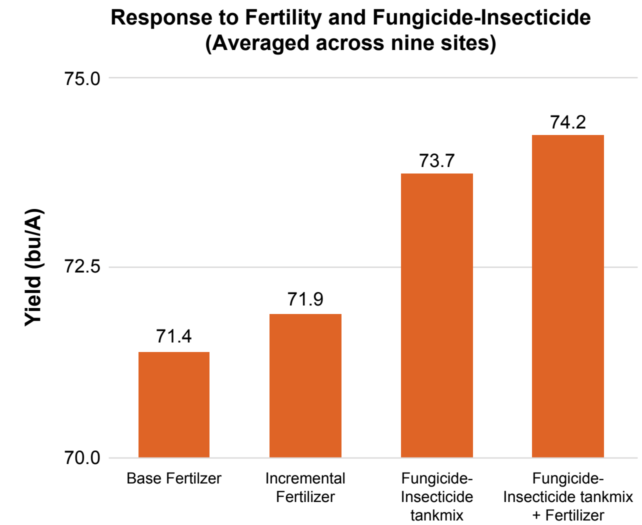
INTRODUCTION

Corn hybrids are known to respond differently to fungicide and fertility management, but less is known about individual soybean variety response differences.[1] Previous Agronomy in Action soybean management research trials in 2021 and 2022 have shown a positive response in soybean yield to fungicide application yet response to fertilizer was lower. Soybean management trials in 2022 showed similar responses to fungicide or fertility treatments across ten varieties evaluated. Trials were repeated in 2023 to further test varietal yield response to a fungicide-insecticide combination and enhanced fertility.

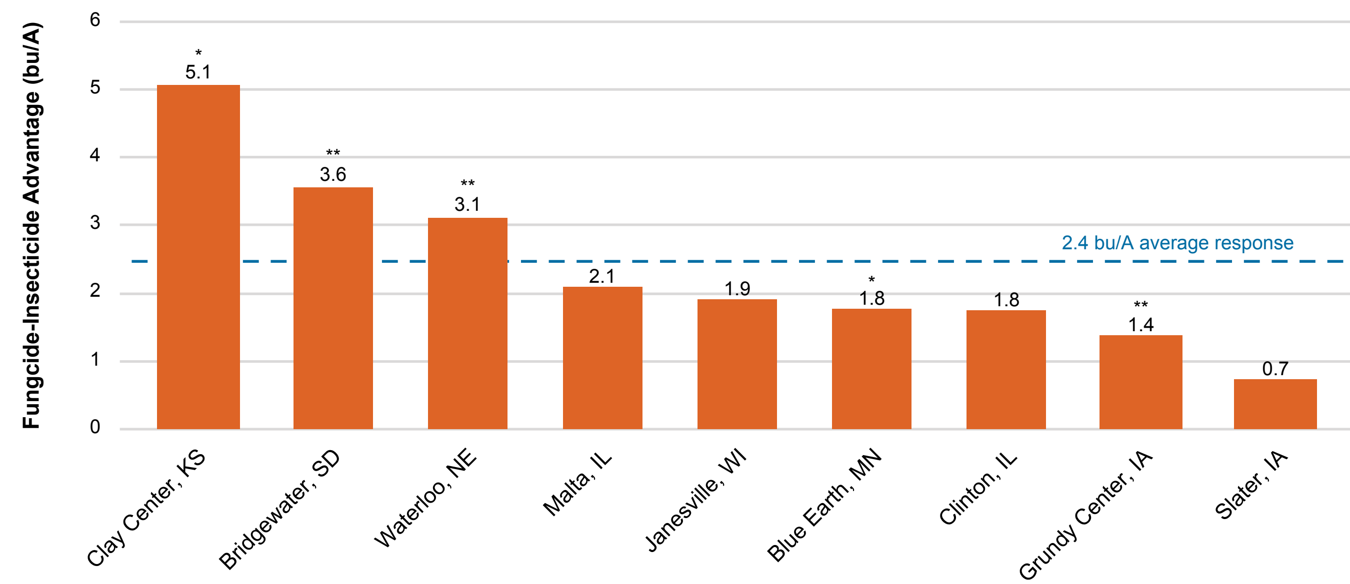
SOYBEAN MANAGEMENT TRIAL DETAILS

Research trials were conducted at nine Agronomy in Action sites in 2023. Replicated trials were designed to evaluate response to fungicide-insecticide, enhanced fertility and the combination of the two. A standard fertility practice was applied across the entire trial based on the host farmers' normal fertility program and additional fertilizer was applied at time of planting to specified strips within the trial. Enhanced fertility strips consisted of the baseline fertilizer in combination with NACHURS Triple Option® at 15 gal/ac (22 lbs/A P_2O_5, 29 lbs/A K_2O, and 2 lbs/A S) and AVAIL® T5 additive (1% of total tank mix) applied through the planter. Planter fertilizer applications were applied using a 2×2×2 placement to provide nutrients in proximity of developing roots while avoiding direct contact with seed and 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.

To test for varietal response to fungicide-insecticide and fertility, six varieties with ranging agronomic characteristics, disease tolerance scores and herbicide tolerance traits



Graph 1. Response to incremental fertility, fungicide-insecticide tank mix or the combination of both averaged across nine sites in 2023



Graph 2. Yield advantage from 2023 fungicide/insecticide applications. *significant difference at p = 0.10, **significant difference at p = 0.05

(Enlist E3® soybeans and XtendFlex® soybeans) were selected for each maturity group (MG) region. Soybean varieties were blocked together and split into check, fungicide-insecticide, fertilized and fungicide-insecticide + fertilized plots. Fungicide-insecticide plots received a broadcast application of Miravis® Neo fungicide at a rate of 13.7 oz/A and Endigo® ZCX at 4 oz/A at the R3 growth stage.

ENHANCED FERTILITY RESPONSE

Janesville, WI was the only site out of the nine testing locations that observed a significant response to adding incremental fertilizer (1.8 bu/A) alone. Six of the nine locations had an average increase of 1.1 bu/A from pairing extra fertility with fungicide-insecticide applications when compared to fungicide-insecticide alone, but none of the increases were statistically significant. However, the small increases from combining extra fertility with fungicide-insecticide was enough to get a significant response over the base fertility plots at Blue Earth, MN (2.3 bu/A) and Clinton, IL (2.3 bu/A) when there was not a significant response from either input alone. Both Clinton and Blue Earth sites had relatively high soil phosphorous (P) levels, but medium to low potassium (K) levels (<200 ppm) as well as higher yields of 96 and 75 bu/A respectively, that would have demanded more nutrients. Overall, response to incremental fertility was infrequently observed, similarly to trials done in 2022.

FUNGICIDE-INSECTICIDE RESPONSE

Averaged across all locations and fertility programs there was a 2.4 bu/A response to R3 fungicide-insecticide applications (Graph 1), although responses ranged from 0.7 up to 5.1 bu/A depending on location (Graph 2). Similar fungicide responses of 3.7 bu/A and 1.3 bu/A were observed in 2021 and 2022 Agronomy in Action trials respectively. No notable insect pressure observed at any of the locations in 2023. Although disease and insect pressure was generally low at all sites in 2023, delayed plant senescence within treated plots was observed at many locations which likely extended pod fill and contributed to yield gains (Figure 1).

VARIETY RESPONSE

Individual variety responses to fungicide-insecticide tank mixes ranged from 0.8 up to 5.5 bu/A when averaged across sites with similar relative maturity groups (Table 1). In 2023 there were some individual varieties that increased yields from fungicide-insecticide statistically more than other varieties when averaging across testing locations, although yield response by variety varied within individual locations. For example, GH1993XF brand, which was one of the overall lowest responding varieties, on average was also the most responsive variety at the Grundy Center, IA location. In addition, GH1762XF brand which responded significantly more than other varieties in 2023 was one of

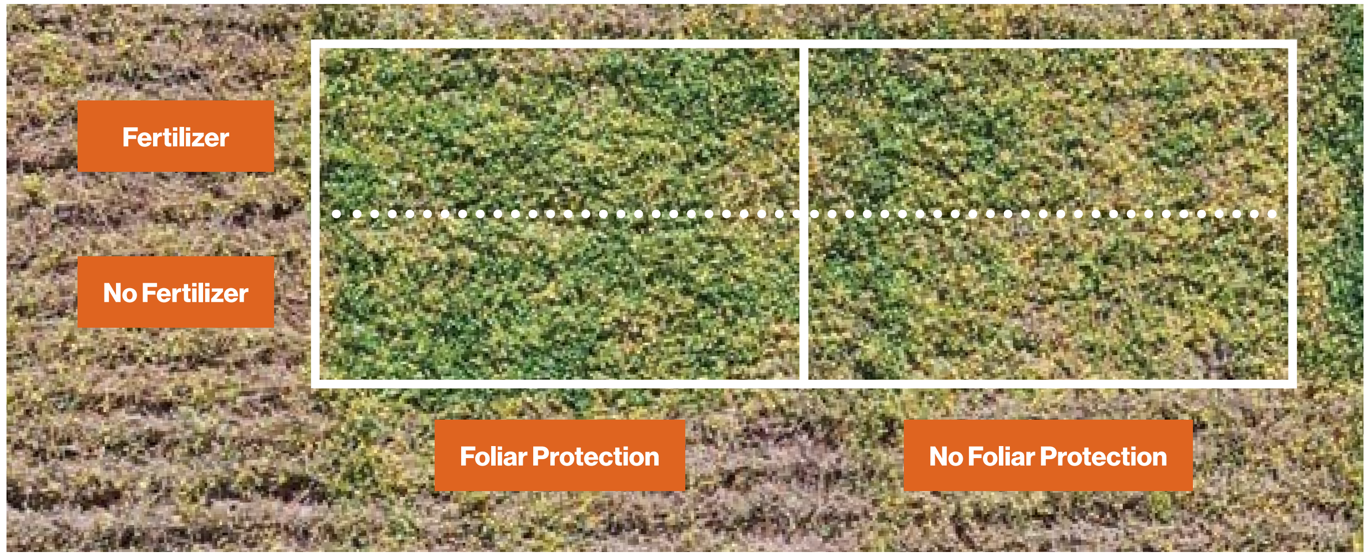


Figure 1. Delayed leaf senescence in plots where Miravis Neo fungicide and Endigo ZCX insecticide. were applied (left) compared to the untreated control (right) at Malta, IL, 2023.

the lesser responsive varieties in 2022 where GH1973E3S brand was the more responsive variety. When averaging across two years of testing, overall responsiveness of varieties was similar. Since insecticide was applied in 2023, but not 2022, there is a chance across year comparisons are biased by insect feeding. While varietal differences in fungicide-insecticide response may appear to sometimes exist, we have yet to see a single variety that consistently responds more frequently or at a higher magnitude over locations or years.

CONCLUSIONS

Fungicide-insecticide applications increased soybean yields by 2.4 bu/A on average across nine Agronomy in Action sites with low disease and insect pressure in 2023. Differential varietal response to fungicide-insecticide application was not consistent across years. Overall fungicide-insecticide response was not significantly increased with enhanced fertility. Enhanced fertility by itself rarely increased yields. If base soil fertility levels are sufficient, there is a much higher opportunity for return on investment with fungicide-insecticide applications rather than supplying incremental fertilizer to soybeans.

Maturity Grouping of Sites	Variety Brand	2023 Fungicide-Insecticide Advantage		2022 Fungicide Advantage	Two-year Average
Blue Earth, Janesville, Bridgewater, Grundy Center	GH1762XF	4.1	A	1.3	2.7
	GH2083E3S	2.1	AB	2.8	2.5
	GH1973E3S	1.8	AB	3.7	2.8
	GH1993XF	1.8	AB	-	-
	GH2004XF	1.8	AB	-	-
	GH1864XF	1.3	B	-	-
Malta, Slater, Waterloo	GH2922E3	3.2	A	2.1	2.6
	GH2814E3S	3.2	AB	-	-
	GH2674E3	2.1	ABC	-	-
	GH2653XF	1.3	BC	1.0	1.1
	GH2722XF	1.2	C	0	0.6
	GH2884XF	0.9	C	-	-
Clinton, Clay Center	GH3442XF	5.5	A	-	-
	GH3043E3	3.3	A	1.6	2.4
	GH3192XF	3.0	A	1.2	2.1
	GH3373E3S	2.9	A	1.8	2.3
	GH3132E3	2.5	A	2.4	2.4
	GH3023XF	1.6	A	-	-

Table 1. Yield advantage of fungicide-insecticide over no fungicide-insecticide averaged across fertility treatments. Varieties within maturity groups with different letters are significantly different at $p < 0.10$ for 2023.

FUSARIUM WILT IN SOYBEANS

INSIGHTS

- Fusarium fungal disease impacts many growers across the U.S. and is a complex issue that also can resemble other common soybean diseases.
- Fusarium is often the result of multiple compounding stressors that weaken the plant and make it more susceptible to infection, requiring a multifaceted management strategy.

DEVELOPMENT AND SYMPTOMS

Fusarium is one of the most common soil-borne diseases, mostly due to its ability to survive as mycelium in plant residue and spores in soil. Fusarium wilt can be caused by a complex of multiple soil-borne fungi, although it is most often associated with *Fusarium oxysporum*. Fusarium is common across soybean production areas with more than ten different species known to cause root rot. Root infection normally occurs in soybean early vegetative and reproductive stages and is often associated with cooler, wet soil conditions, but may occur at any growth stage. Vascular tissue inside the stem will begin to turn brown in color and continue to deteriorate as infections progress. The outer surface of roots can have a red, orange or white mycelium form on them (Figure 1). As the disease progresses, the upper leaves often show a scorched appearance and stem tips begin wilting (Figure 2). Leaves in the middle and lower canopy often show yellow spots. Wilting is a signal that vascular tissue is severely compromised and no longer able to supply sufficient water and nutrients to the leaves and stems, which is often exacerbated by drought conditions further limiting available water.

Figure 1. Left: Browning discoloration of vascular system inside the stem from Fusarium wilt. Right: White mycelium forming on outer surface of roots infected with Fusarium. Infected roots can also have red or orange mycelium.

Figure 2. Area of field with severe wilting following drought and the same variety in unaffected areas in background.

Types of stress predisposing plants to Fusarium infection:

- Soybean cyst nematode
- High soil pH
- Iron chlorosis
- Nutrient deficiencies
- Soil compaction
- Poor soil drainage (wet soils)
- Cool soils from early planting
- Herbicide injury

Figure 3. Irregular patterns of wilting across field. Improved drainage over tile lines and on elevated areas of field were less affected.

MANAGEMENT

By the time symptoms are visible, there is little that can be done in that season, although several management options can reduce the risk of future problems. Seed applied fungicides create a protective layer that can reduce early season infection around young seedling roots. Fusarium-resistant soybeans are not available, although choosing varieties with defensive traits against other pests can indirectly reduce Fusarium infections.

Root damage from soybean cyst nematode (SCN) feeding often serves as a point of entry for pathogens such as Fusarium. Addressing SCN problems with resistant varieties and nematicide seed treatments can help suppress nematodes and indirectly Fusarium. Fusarium is often the result of multiple compounding stressors that weaken the plant, making it more susceptible to infection. Poorly drained soils (Figure 3), compaction, iron deficiency chlorosis and herbicide injury are examples of stress that may predispose soybeans to Fusarium infection. Managing these stressors can often indirectly reduce future risk of Fusarium wilt.

EASILY CONFUSED DISEASES

Fusarium wilt may be easily mistaken for other diseases with similar symptoms. Correctly identifying the disease can be an important first step since management options can be different depending on the pathogen. The following chart can help rule out some diseases (Table 1). For example, Fusarium wilt can look similar to Phytophthora at first glance but when examining exterior stems closely, you will see dark brown lesions extending up several nodes on the stem with Phytophthora infection, whereas stems with Fusarium wilt will look healthy.

Disease	Roots	Exterior Stem	Interior Stem	Leaf Symptoms
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 stem and surrounding entire stem	Brown internal discoloration on plants at any stage	Leaves yellow and wilt, remain attached
Sudden Death Syndrome	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
Brown Stem Rot	Healthy	Healthy	Brown discoloration in pith (center of stem)	Interveinal chlorosis and necrosis

Symptom expression table recreated from Cropprotectionnetwork.org "Stem canker"

Table 1. Soybean disease symptom table.

MAIN MENU

RED CROWN ROT OF SOYBEANS

INSIGHTS

- Red crown rot is a soybean fungal disease recently observed in Midwestern states caused by early season infection of *C. ilicicola*.
- Key diagnostic feature is reddish discoloration of stem at soil line that may include bright, red-orange colored perithecia or reproductive structures appearing as tiny red balls.
- Management options include using a seed treatment, crop rotation, root nematode management and potentially delayed planting.

Red crown rot is a relatively newer soybean disease observed in the Midwest (Figure 1) that is caused by a soil-borne fungal pathogen, *Calonectria ilicicola (anamorph: Cylindrocladium parasiticum)*. Red crown rot was first observed in Illinois in 2017 but occurs worldwide in warm-temperate and tropical regions. The same pathogen also impacts other crops such as peanuts, ginger and blueberries and has been found in the Southern U.S. since the 1970s. Red crown rot is characterized by the fungal reproductive structures on the crown or lower stem at the soil line which give a reddish appearance.

INFECTION

C. ilicicola can survive as microsclerotia in the soil for several years. Infection is favored by wet conditions around planting and the disease depletes resources in the roots and stem of the soybean plant. Warm, wet growing season conditions will continue to drive progression of the disease. Symptoms will often first show up in poorly drained or low areas of the field. Soil temperatures of 77°–86°F favor disease development, but infection decreases as soil temperatures increase above 86°F. Foliar symptoms will appear later in the season as toxins from the pathogen begin to accumulate in the leaves, causing interveinal chlorosis and necrosis. Secondary disease spread can be caused by the ejection of mature ascospores from the perithecia (reddish, orange structures) on the stem from rainwater splash or runoff. *C. ilicicola* microsclerotia are spread by the movement of infested plant debris or soil particles carried by wind, equipment or livestock.

Counties Confirmed with Red Crown Rot in Soybeans in 2022–2023

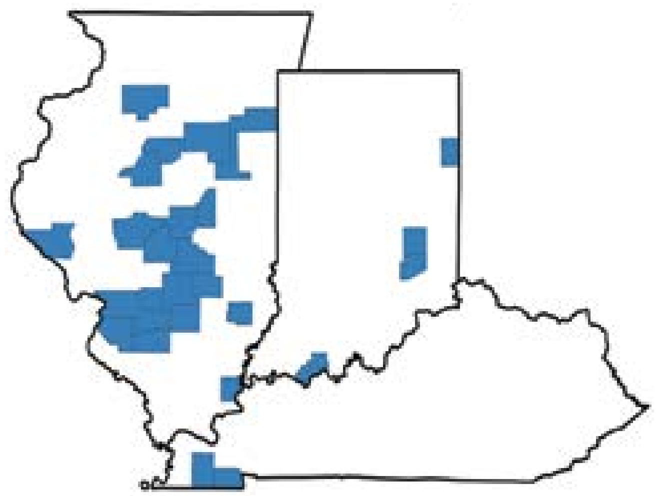


Figure 1. County level confirmation provided by verbal communications from Dr. Steven Clough USDA-ARS, Diana Plewa University of Illinois Plant Clinic, Whitney Welker (Student), Dr. Carl Bradley University of Kentucky and Dr. Darcy Telenko Purdue University

SYMPTOMS

- Fungal symptoms usually don't appear until later at the R3 to R7 growth stages.
- Infected plants or small patches are generally found randomly throughout the field.
- Key diagnostic feature is reddish discoloration of stem at soil line that may include bright, red-orange colored perithecia or reproductive structures appearing as tiny red balls (Figures 3 and 4).
- The vascular tissue inside the stem may appear gray brown in color (not white) and the roots of the plant may become rotted in later stages of disease development.
- Yellowing of leaves can occur after R3 growth stages but may not always be observed. Severely affected plants will prematurely senesce, with leaves remaining attached afterwards.
- This disease has similar foliar symptoms to sudden death syndrome (SDS) and brown stem rot (BSR) where interveinal chlorosis then necrosis appears (yellow blotches between leaf veins – Figure 2). It is important to inspect stems and roots to help determine the causal pathogen.
- Late season disease identification of dead plants may be challenging. For help identifying red crown rot in soybeans send a plant sample to your state's plant pathology identification lab.

Figure 2. Interveinal chlorosis and necrosis caused by red crown rot of soybeans. Image by A. Peterson, IL Soybean Assoc.

Figure 3. Red discoloration at soil line on a soybean stem caused by red crown rot. Image by N. Prater, Syngenta.

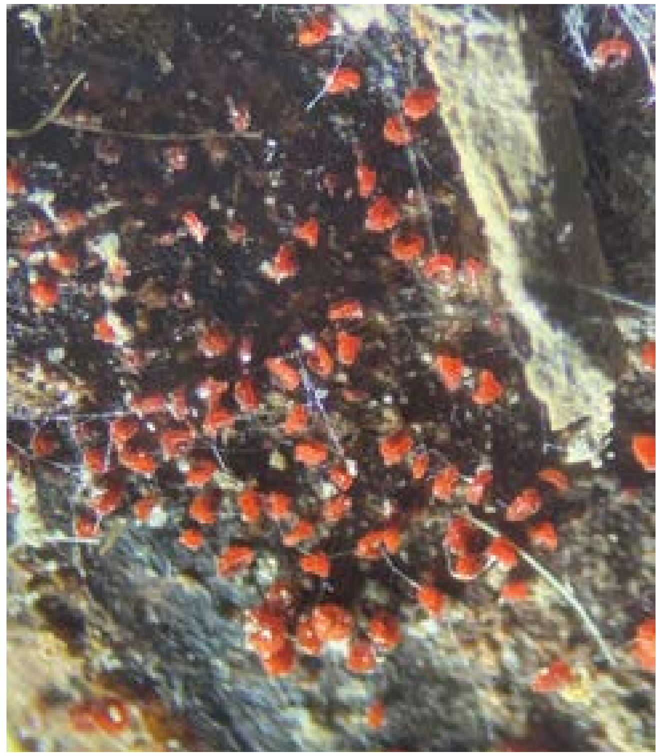


Figure 4. Red-orange colored perithecia caused by red crown rot of soybeans. Image by N. Prater, Syngenta.

MAIN MENU

MANAGEMENT

- Yield potential can be significantly impacted (up to 30% has been documented in fields where red crown rot has been present for years).
- Crop rotation to a non-host crop for one or more years may help decrease inoculum in the field and decrease risk of red crown rot presence.
- Delayed planting may help lessen the severity of red crown rot infection.
- Sanitize equipment before leaving a field if there is known infection to help avoid mechanical transmission.
- Manage root damaging nematodes to help lessen the access points for this fungal pathogen.
- A few seed treatments have recently been granted Section 2(ee) labels in specific states to help manage against early seedling infections. As of 11/3/23, Saltro® seed treatment has received special labels for Arkansas, Illinois, Indiana, Iowa, Kentucky, Missouri and Tennessee for suppression of red crown rot. On-farm trials in 2023 have shown delayed disease development and improved yields from Saltro when red crown rot was present (Figure 5). Always refer to product label for the most current information.

Figure 5. Saltro performance on red crown rot in soybeans (1.428 oz/unit) compared to a competitor seed treatment; Split planter field design; August 16, 2023, Southern Illinois; See the difference – Saltro seed treatment +8.8 bu/A compared to competitor seed treatment.

On farm trials – Southern IL – 8/16/2023

MCG – 08/2023. Results may vary by geography.

Product performance assumes disease presence. Performance assessments are based upon results or analysis of public information, field observations and/or internal Syngenta evaluations. Trials reflect treatment rates commonly recommended in the marketplace. All photos are either the property of Syngenta or are used with permission.

UNDERESTIMATING WHITE MOLD IN SOYBEANS AND HOW TO MANAGE IT

INSIGHTS

- White mold is a prominent and potentially devastating soybean disease in certain parts of the growing region.
- Variety selection is the first step in effective white mold management.

White mold is a soybean disease that kills stems from the point of infection up, impacting yield. It is caused by the soilborne fungal pathogen *Sclerotinia sclerotiorum*, which can survive in soil for years. Because white mold symptoms do not appear until it is too late in the season to effectively manage, it is important to know the factors that encourage infection early enough to act.

WHITE MOLD DEVELOPMENT

The fungus overwinters as thick, walled structures known as sclerotia (1) either in or on the soil or in infected plant tissue. Sclerotia that are within the top five centimeters of the soil surface can germinate to produce trumpet-shaped apothecia (2), or the fruiting bodies that contain asci and ascospores (Figure 1).[1]

Asci are filled with ascospores (3), which are forcibly released into the air. Some airborne spores land on susceptible soybean flowers, germinate and infect the plant (4). Since infection occurs through flowers, white mold infection occurs early in the season before pods begin to develop, but symptoms don't show up until after flowering is completed. Flower infections extend into the stem and kill the tissues above the infections (5). Typical symptoms of white mold are flagging or dead plant tops. The fungus will grow on and/or in the plant and develop more sclerotia for survival over the winter (6).

Figure 2. Cottony, white growth on soybean from white mold.

WHITE MOLD IDENTIFICATION

White mold first appears on soybean stems as lesions, gray to white in color, at the nodes. It then develops into fluffy or cottony white growth on the stems and eventually dark black sclerotia along the stem or bean pods (Figure 2). Foliar symptoms (yellow or brown leaves) appear later after the fungus has progressed enough to kill the plant. As soybeans become dry or die, the stems will seem bleached, or light in color.

1. The fungus overwinters as sclerotia
2. Sclerotia germinate to produce trumpet-shaped apothecia
3. Apothecia contain numerous asci containing ascospores
4. Ascospores are forcibly discharged and travel to young susceptible flowers
5. Flower infections allow the fungus to enter the stem and kill plant tissues above
6. More sclerotia develop (blue are young sclerotia and black are mature) to allow the fungus to survive over the winter

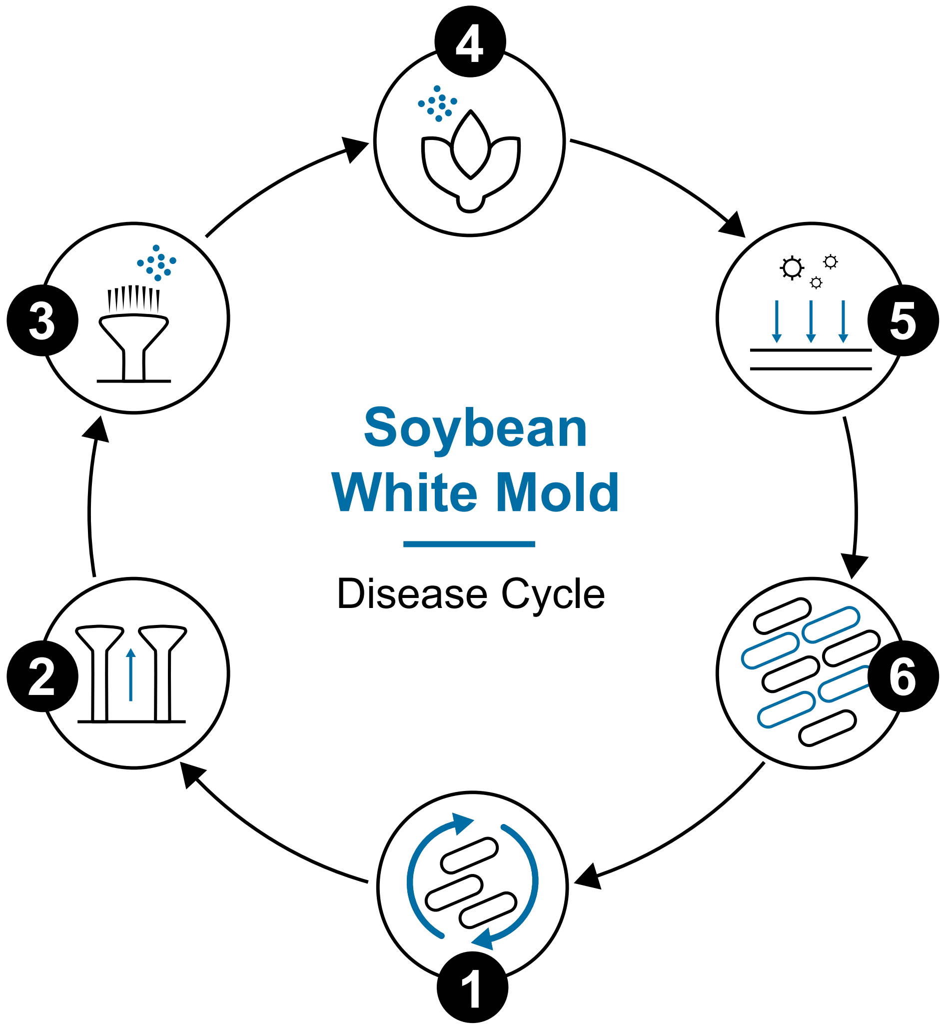
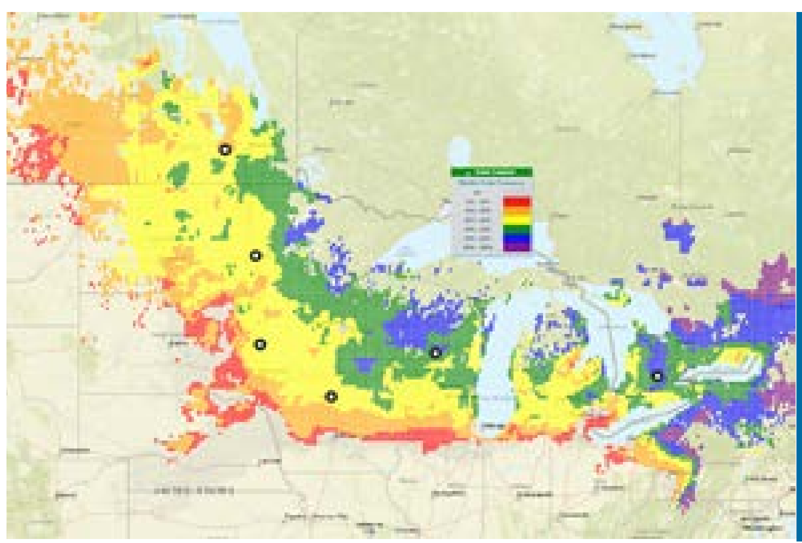


Figure 1. White mold lifecycle.



Golden Harvest White Mold Screening

- Seven evaluation sites are annually used to evaluate pre-commercial varieties for white mold tolerance.
- Research sites are strategically positioned in areas with conducive environmental conditions.
- Trials are inoculated with *Sclerotinia sclerotiorum* and irrigated throughout flowering to intensify disease occurrence.
- All Golden Harvest® seed varieties are well characterized for white mold tolerance. Talk to local seed advisors for more advice on locally adapted varieties.

Figure 3. Areas with environments conducive to white mold (yellow, green, blue) due to frequency of cool, wet weather and corresponding trial locations (frequency map from 2021).

FAVORABLE CONDITIONS FOR WHITE MOLD DEVELOPMENT

- Rain during soybean bloom, along with cool temperatures (less than 86°F)
- High relative humidity and moist soil
- Prolonged periods of low soil temperatures (41–59°F)
- Moderate air temperatures and frequent rain just prior to flowering
- To help determine if conditions are favorable for development, consider downloading the University of Wisconsin Sporecaster app at ipcm.wisc.edu/apps/sporecaster/

BEST PRACTICES FOR WHITE MOLD MANAGEMENT

Variety Selection:

- No varieties offer complete resistance but select Golden Harvest® varieties have high levels of tolerance and can be effective for managing white mold.

Cultural practices:

- Crop rotation: A minimum of two to three years of a non-host crop, such as corn or small grains, can reduce sclerotia in the soil.
- Tillage: Inconclusive
- Canopy management: Early planting, narrow rows, high plant populations and high soil fertility all accelerate canopy closure and conditions that favor disease development. Reduced plant populations and wider rows will help reduce white mold risk in advance.
- Irrigation: Avoid excessive irrigation until after flowering.

Chemical control:

- Weed control: Many common broadleaf weeds, such as henbit, velvetleaf and common lambsquarters, are also hosts of *S. sclerotiorum*,[1] making weed control an equally important component of disease control.
- Cobra® herbicide is known to reduce crop canopy, making it less conducive for fungal development and infection.[2] Studies have also shown that it may enhance soybean immune system response which helps produce plant defense compounds that allow it to better defend against *Sclerotinia sclerotiorum* infections.[3] Current labels only claim suppression of white mold. Prior studies have also observed reduced yields when Cobra was applied in the absence of white mold, so use cautiously if disease incidence is low or absent.[2]
- Fungicides: Some can help suppress white mold with proper application timing to protect the flowers from infection. It is usually recommended to make applications from R1 to R3 growth stages.
- Peroxide-based products are being applied by growers in some areas at first signs of white mold disease development to help suppress further development. Limited data is available to validate efficacy of these approaches.

Manage white mold with a fungicide when disease is present and conditions are favorable for disease development. Apply Miravis® Neo fungicide at early bloom (R1) to full bloom (R2). If favorable conditions for white mold development continue, apply a second application of Miravis Neo 10 to 14 days after first application. Adjust the rate based on severity of the disease pressure and conditions. An adjuvant may be added at recommended rates. To obtain thorough coverage, apply in sufficient volume.

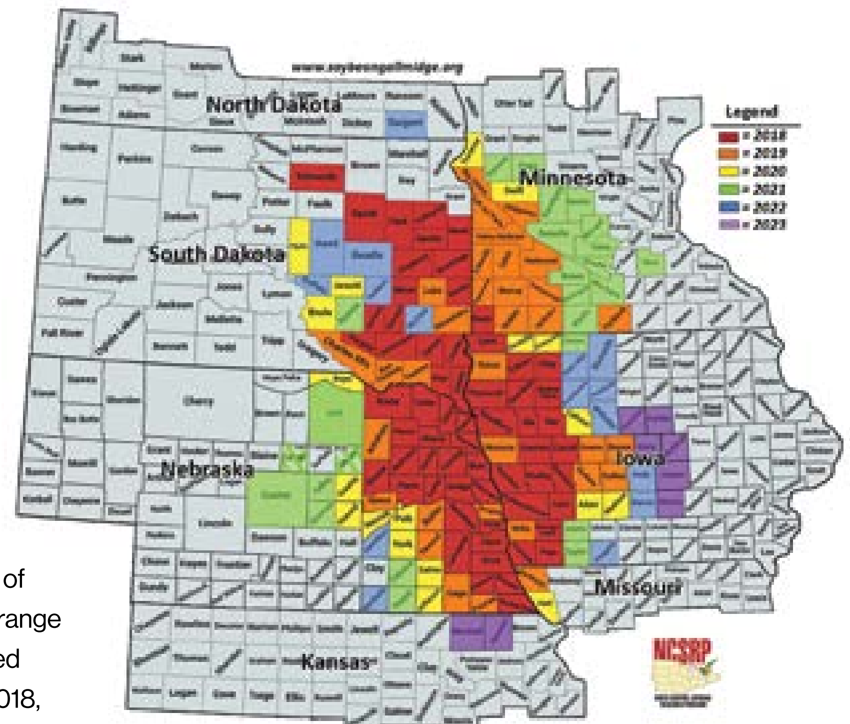
Effective white mold management begins with variety selection and detailed record keeping of fields for future planning. Unfortunately, white mold can persist in soils for a long time so field history helps set white mold risk expectations. Other management considerations help keep the disease levels lower to protect yield potential.

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.
- Mitigation measures such as mowing field edges, spring tillage, delayed planting and properly timed insecticides (foliar and seed treatments) can help lessen impact.



Source: Soybean Gall Midge Alert Network

Figure 1. Counties with soybean gall midge detection in 2018-2023 163 counties have been documented as infested as of 10/23/2023. 8 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 163 counties in six 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: 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. The life cycle (Figure 3) begins in the soil when the overwintering third instar larvae development stage pupates from silken cocoons in the spring and subsequently emerge as adults in early- to mid-June. The first detection of an adult gall midge for the 2023 growing season was observed on May 26.

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. Larvae feed on stem tissues disrupting water and nutrient uptake in the plant. SGM have a total of three instars; the first and second are whiteish colored and small and the third instar is bright orange and comparatively larger (Figure 4). These orange larvae then fall off the plant and pupate in the soil. After pupae transformation to adults is complete, they emerge and repeat the cycle multiple times per growing season.

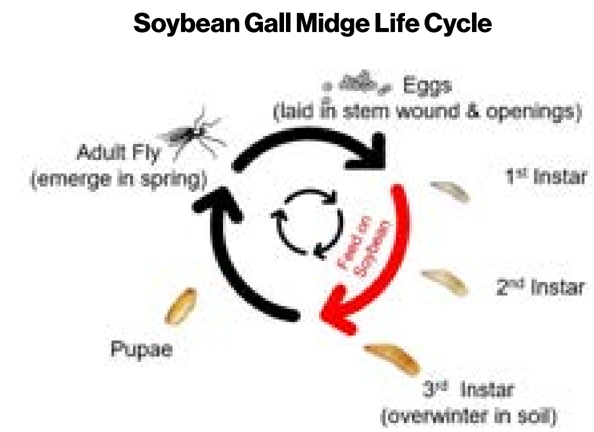


Figure 3. Soybean gall midge life cycle

Figure 4. Field view diagram. Source: Justin McMechan, University of Nebraska-Lincoln. (a) Third instar larvae are orange; (b) First and second instar larvae are white; (c) Sporadic feeding damage (dead plants) in a field.

SCOUTING CONSIDERATIONS

- Confirmed alternative hosts of SGM include alfalfa, sweet clover, dry bean and lima bean.
- Scouting should begin within two weeks after the first adult detection — register to receive alerts from soybeangallmidge.org.
- 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 (Figure 4c).
- Split the soybean stem and peel back stem epidermis while looking for larvae under surface (Figure 4a).

MANAGEMENT

Information gathered from university and industry research in 2019 and 2022 has revealed key management 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. Research has shown that "hilling" can be a strategy to control SGM infestation, but it is difficult to implement at the V2 stage and not cover small soybean plants.
- Monitor SGM adult emergence activity across NE, IA, SD and MN via soybeangallmidge.com reports from the in-season adult emergence cage trapping network.
- 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® insecticide or pyrethroid-containing Endigo® ZC insecticide showed some efficacy up to 11 days after first adult emergence but has not been consistent. Foliar-based treatments should be confined to the first 60–120 feet of the field, since SGM is a field edge pest.

SOYBEAN PEST MANAGEMENT
MAIN MENU

COVER CROP TERMINATION METHODS IN SOYBEANS

INSIGHTS

- Established cover crops can reduce soil erosion, improve water infiltration and suppress weed pressure.
- Delaying cover crop termination closer to planting date reduced soybean yield in this trial when stubble remained standing.

INTRODUCTION

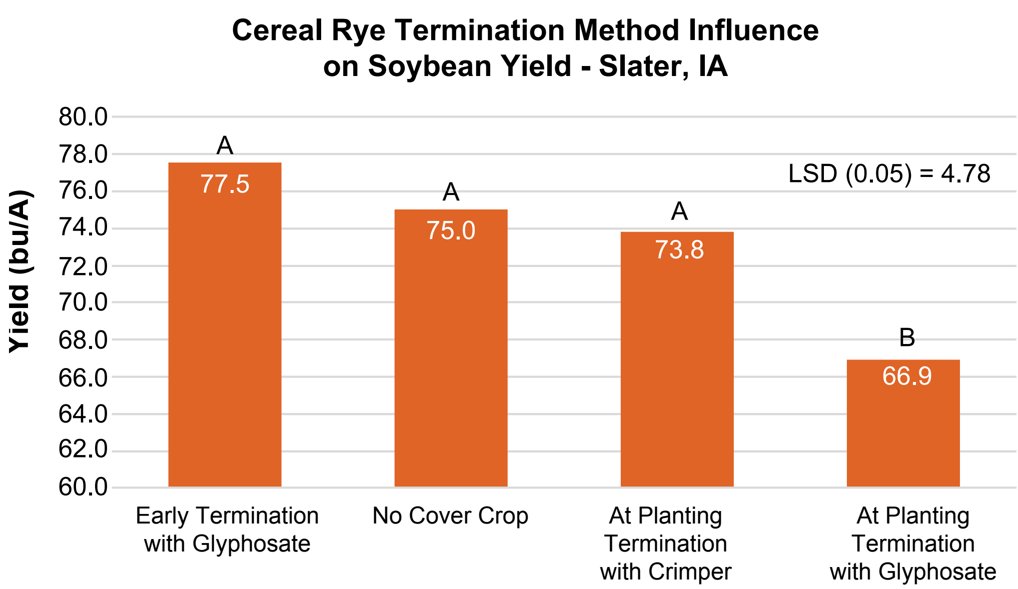
Cover crops can provide a wide variety of soil health benefits and help protect against erosion. The root structure of a growing crop promotes the development of soil structure, holds soil in place to guard against wind and water erosion, and increases water infiltration. Cover crops also provide the opportunity to scavenge nutrients from the soil that are at risk of being lost and later after decomposing return nutrition to the following crop. Cereal rye has been a popular choice for a cover crop because of its ability to overwinter and grow vigorously in cooler early-spring temperatures. Although there are many benefits to using cover crops, how they are managed and integrated into current management practices can have a negative impact on cash crop yields. Termination of cover crops prior to planting can be delayed due to weather resulting in a decision to further delay planting or terminate afterward planting. A better understanding of these agronomic impacts can help make the most economical decision.

2023 RYE COVER CROP-SOYBEAN TRIAL

An Agronomy in Action Research trial was designed to evaluate the effects of fall established rye cover crop termination timing and method. Soybeans were planted into areas with or without a fall seeded rye cover crop. Within the area planted to rye, the cover crop was terminated with glyphosate either two weeks prior to or on the day of planting soybeans. An additional termination method using a roller-crimper just before planting was also evaluated. Termination methods were compared to a check treatment where no cover crop was established. Four soybean varieties (GH2505E3, GH2922E3, GH2610E3, GH2722XF) were no-till planted in 30-inch rows to understand if varieties responded differently to termination method and timing.

2023 COVER CROP TRIAL RESULTS

Results from this trial showed that there were no significant soybean yield differences between terminating cover crops two weeks prior to planting or crimping the day of planting compared to no cover crop (Graph 1). Terminating with glyphosate the day of planting greatly reduced yields in this trial. At time of soybean planting, rye had reached 40 inches in height. The extra residue from delaying termination with glyphosate or crimping improved overall weed control, but also suppressed early soybean growth and development (Figures 1 and 2). Even though crimping and glyphosate termination the day of planting had equivalent amount of rye residue to contend with, crimping improved soybean yields, by reducing in-season light competition from standing rye (Figure 2). The later termination timing and crimping method also reduced soybean emergence as result of the heavy biomass. All four soybean varieties responded similarly within termination timing and methods.



Graph 1. Soybean yield by cover crop termination method.

SUMMARY

One of the additional benefits from establishing a cover crop in soybeans was a notable difference in weed suppression in areas where cover crops were planted. Allelopathic chemicals are released by rye and can inhibit germination and early growth of small-seeded plants. General recommendations suggest terminating cereal rye at least 14 days ahead of planting to avoid any allelopathic or residue management concerns although planting soybeans into rye the day of termination is often widely recommended. While delaying termination and creating a thick layer of residue can be a good weed management strategy, these results indicate there is potential for soybean yield loss to occur.

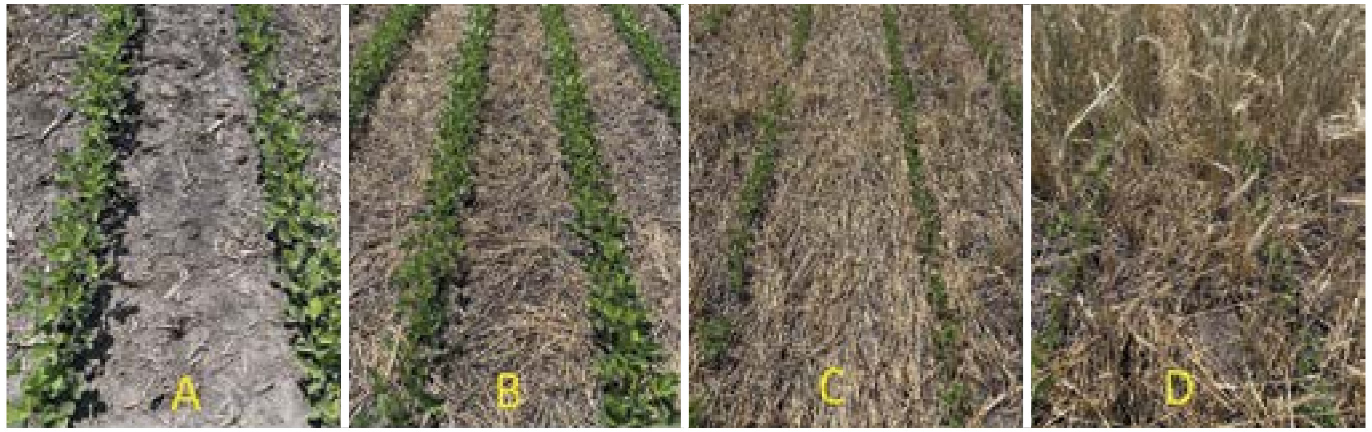


Figure 1 (above, below left). Early growth differences of soybean plants, 2023: A) no cover crop, B) cover crop terminated two weeks prior to planting, C) cover crop terminated by crimping, D) cover crop terminated with glyphosate day of planting.

Figure 2. 2023 trial: no cover crop (front left), crimped rye (front right), glyphosate termination day of planting (upper right) and glyphosate termination two weeks prior to soy planting (upper left).

IMPACT OF CHANGES TO SOYBEAN GROWTH HABIT OF YIELD POTENTIAL

INSIGHTS

- Soybeans can compensate for in-season stresses, however, in general, stress has a negative effect on yield potential.
- Cutting, Cobra® herbicide and dicamba herbicide treatments frequently reduced yields in these trials.
- Crop stage and environment play a critical role in the ability of soybeans to overcome stress events.

SOYBEAN GROWTH RESPONSE INFLUENCE ON YIELD POTENTIAL

The apical meristem or growing point directly influences the growth habit and architecture of a soybean plant. Soybean plants will predominately produce a single main stem from the original apical meristem if not damaged. Any environmental or production practice that stresses or stunts the plant can affect its growth habit. Soybeans can compensate during stress or damage to the apical meristem by producing branches at axillary buds which can produce trifoliate leaves and reproductive structures. Branching could potentially have positive or negative influences on grain yield that is hard to quantify and predict.

SOYBEAN GROWTH HABIT TRIAL

The Golden Harvest Agronomy in Action Research team conducted trials at Blue Earth, MN, Grundy Center, IA, Malta, IL, Slater, IA and Waterloo, NE to evaluate how changes to soybean growth habit can affect yield potential. Either soybean variety GH2292E3 brand or GH3043E3 brand was planted depending on the geography at a target rate of 140,000 seeds/A. Five treatments specifically chosen to alter plant growth or physiology were compared to an untreated control:

1. **Rolling at V1:** Soybeans were rolled at the V1 growth stage using either a drum roller or tires of a utility vehicle (Figure 1). Rolling soybeans to press rocks into ground and level soil surface has become a common practice in areas of the Midwest with a goal of improving soybean harvestability. Rolling soybeans can also lay plants over, delay growth and in some cases break the main stem resulting in branching.
2. **Cobra at V3**: Cobra was foliar applied at rate of 8 oz/A combined with 2 pts/A of crop oil at 20 gal/A spray volume. Cobra is a PPO Inhibitor herbicide which may result in soybean injury (burn or necrotic leaf tissue) when applied postemergence. Injury symptoms are typically worse when applied during hot and humid conditions in conjunction with crop oil. In some cases, the meristematic tissue can become injured resulting in branching.
3. **Dicamba at V3**: Dicamba was foliar applied to non-dicamba-tolerant soybeans at 1/1000th the labeled rate for effective weed control to simulate off-target movement. Herbicides containing the active ingredient dicamba are considered synthetic auxin herbicides. Auxin is one of the five major plant growth regulator (PGR) groups. When non-dicamba-tolerant soybeans are exposed to dicamba, injury symptoms such as cupping and strapping of newly emerged leaves occurs. Depending on the degree of exposure, plant height reductions and injury to the growing point can occur, creating branching.
4. **Cut at V3:** Scissors were used to physically cut the main stem off directly above the unifoliate leaves to mimic hail or deer damage. Removing the growing point causes the soybean to branch (Figure 4).
5. **Ascend²® at V3 and R1:** Ascend² was foliar applied at a rate of 3.4 oz/A at V3 and again at R1. Ascend² contains three categories of PGRs (cytokinin, gibberellin and abscisic acid) that positively affect plant hormones to stimulate plant growth.


Figure 1. Soybeans rolled with drum roller at Slater, IA (left) and ran over with the tire of a utility vehicle at Malta, IL (right).


Figure 2. Soybeans with visual leaf burn from an application of Cobra.

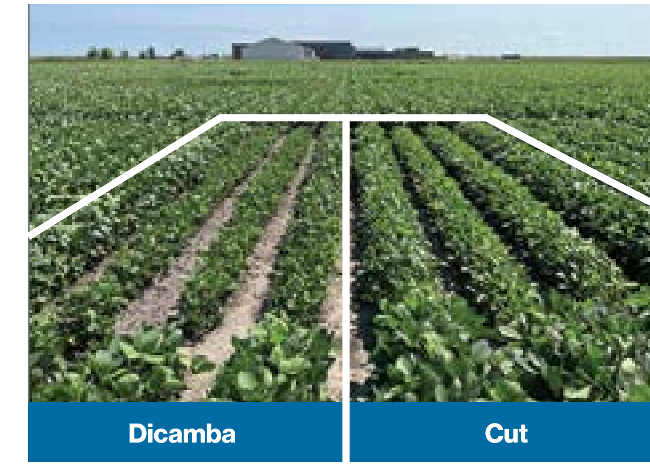


Figure 3. Stunted soybeans from either dicamba or being cut caused a longer duration before canopy compared to the surrounding untreated plots at Malta, IL in 2023.

Figure 4. Soybean plant four weeks after being cut at the V3 growth stage resulting in a "Y-branch" at Malta, IL in 2023.

VISUAL IN-SEASON GROWTH HABITS

Malta and Waterloo used a utility vehicle to mimic rolling soybeans which tended to provide more down pressure than the drum roller used at Blue Earth, Grundy Center and Slater. Plants were laid over after rolling but gradually sprung back up during the following days. There were no broken plants using the drum roller. Using the utility vehicle method resulted in an average of 20,000 plants/A that were broken off and dead. Final stands were still above 100,000 plants/A so yield potential was not affected. Around the R1–R2 growth stage the plots that received the rolling treatment looked visually the same as the untreated plots.

Depending on the location, the severity of the Cobra leaf burn symptoms differed. Brown and necrotic areas of

Treatment	Blue Earth, MN	Grundy Center, IA	Malta, IL	Slater, IA	Waterloo, NE	Average (excluding Malta)
Untreated	69.3	47.8	54.8	85.0	61.6	65.9
V1 Rolling	68.9	47.2	50.1	87.1	59.9	65.8
V3 Cobra	69.0	47.4	51.2	75.7*	62.0	63.5*
V3 Dicamba	58.3*	46.2	67.9*	76.7*	65.7*	61.7*
V3 Cutting	59.8*	42.1*	57.2	72.0*	61.5	58.9*
V3 and R1 Ascend²	70.6	47.0	46.5*	82.5	60.9	65.3
LSD (0.10)	3.2	3.0	7.7	5.9	2.8	1.9

Table 1. Effect of growth habit changing treatments on yield at five Midwest locations.
* Indicates treatment was statistically different than the untreated check within that location at P=0.10 level.

the leaf were visual the next day following the application (Figure 2). Plant growth was slightly delayed for a couple days while the soybeans recovered from the stress. After 4 to 6 days new trifoliate leaves emerged with green tissue. By the R1–R2 growth stage, plots that received Cobra were visually the same as untreated plots.

The low dose rate of dicamba significantly stunted plant growth. These soybeans were behind in height and maturity all season long. Dry weather following the application at Blue Earth, Grundy Center, Malta and Slater delayed the ability of the soybean to grow out of the stress. At Waterloo, plants were stunted but adequate moisture and growing conditions accelerated the recovery process. Nodes were stacked closer together on the main stem and it took weeks longer for stunted plants to canopy compared to untreated plots (Figure 3).

Similar to the application of the dicamba, physically cutting off the main stem of the soybean plant directly above the unifoliate leaves at the V3 growth stage resulted in significant stunting. The original growing point was removed resulting in two new main stems growing from apical buds creating a "Y-branch" (Figure 4). These plants were behind in biomass and maturity the entire growing season compared to untreated plants (Figure 3).

No visual above-ground plant growth effect was noticed in the soybeans that received multiple applications of Ascend².

YIELD RESULTS

Soybeans at Malta, IL experienced heavy pressure of white mold. The level of severity was spatially dependent within the trial leading to variability in yield. Despite the variability in yield, plots at Malta that received the dicamba or cutting treatment tended to increase yield (Table 1). Soybeans in these plots were significantly behind in growth all season and canopied much later than untreated plots. The delayed canopy increased air flow within the rows and slowed the development of white mold. White mold presence in these plots were visually lower than plots that received the other treatments. In this unique situation, the typical negative effects of delaying soybean development was beneficial by reducing the severity of white mold in these plots ultimately resulting in higher yield. The rolling and Cobra treatments also stunted soybean growth, however, the delay in canopy was not enough to affect white mold development.

Malta, IL was excluded from the multi-location analysis due to the unique effect of heavy white mold pressure. When averaged across Blue Earth, Grundy Center, Slater and Waterloo, soybeans treated with Cobra, dicamba or were cut significantly reduced yield by 2.4, 4.2 and 7.1 bu/A, respectively. Applying the low dose rate of dicamba or cutting off the growing point of a soybean plant stunted the development of the plant likely reducing pod number and seed weight. These plants matured later than soybeans in all the other treatments (Figure 5 and 6).

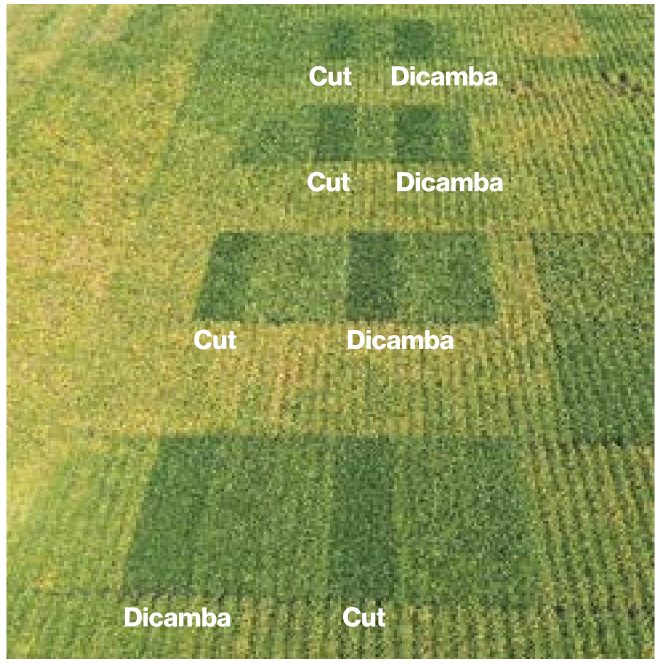


Figure 5. Plots labeled with dicamba or cut treatment for each rep at Slater, IA in 2023. Plots are four rows wide. Plants in the dicamba and cut treatments were stunted and behind in growth all season resulting in delay in maturity compared to other treatments.

Soybeans that received the rolling treatment were able to recover quickly, even the more aggressive rolling method at Waterloo, NE did not impact yield potential (Table 1). Rolling soybeans early at the V1 growth stage is optimal for plants to spring back and recover. Rolling too early during emergence can break off the cotyledon and kill the plant.

Ascend² applied at V3 and again at R1 did not significantly affect yield at any location. Only at Blue Earth, MN did Ascend² tend to increase yield by 1.3 bu/A (Table 1).

At Waterloo, NE, the low dose rate of dicamba significantly increased soybean yield compared to the untreated (Table 1). Under certain environmental conditions dicamba exposure during early growth stages can increase yield potential, however it is an uncommon occurrence. The vast majority of peer reviewed research studies show a negative or no yield response when a low dose of dicamba is applied to non-tolerant soybeans during early vegetive growth (Griffin et al. 2013, Foster et al. 2019, Osipitan et al. 2019 and Scholtes et al. 2019). However, there are cases when a yield increase has been observed in certain environments (Castner et al. 2021a, Castner et al. 2021b and Meyeres et al. 2021). In these published articles, most concluded that as soybeans reach mid-vegetative into reproductive stages, yield decreases from dicamba exposure becomes greater. A study conducted at the University of Missouri found that irrigating and maintaining adequate soil moisture levels significantly reduced injury symptomology and yield losses following a low dose rate of dicamba (Dintelmann et al., 2022). Waterloo, NE was the only location in this study that was irrigated, likely accelerating the recovery time of the dicamba-injured soybeans. It is important to remember applying dicamba herbicides off label is illegal.

SUMMARY

Soybean is an indeterminate plant meaning the plant continues to grow vegetatively while simultaneously in the reproductive stages. The indeterminate nature of soybeans is why yield is determined over an extended period of time within the growing season. Flowers and pods can abort while new flowers and pods are formed. The ability to form new flowers and pods makes soybeans able to compensate or overcome stresses throughout the season.

Results from this study demonstrate that the environment and growth stage play a critical role in the ability for soybeans to overcome different levels of stress. In general, most stresses have a negative impact on yield. However, given the correct environment and level of stress, soybeans can compensate for early-season stress and potentially increase yield potential.

Figure 6. Difference in soybean senescence between untreated (left) and cut soybeans (right) at Slater, IA in 2023.

IMPORTANCE OF END-OF-SEASON IRRIGATION MANAGEMENT IN SOYBEANS

INSIGHTS

- Satisfying water needs up to maturity is critical for maximizing irrigated soybean yields.
- Terminating irrigation at R5 or earlier reduced yield by ≥5%, even when late-season precipitation was substantial.
- Irrigation management should not be prioritized less during "wet" years.

The goal of a successful final irrigation schedule is to meet plant water demands while limiting unnecessary costs associated with overwatering. Season water requirements of irrigated soybeans typically ranges from 20 to 26 inches, with over 65% of the demand occurring during reproductive stages.[1] It is tempting to reduce or even prematurely terminate final irrigation passes, especially in hot, dry summers where seasonal irrigation costs are high. Understanding the yield responses of terminating irrigation early is necessary when weighing whether one more irrigation pass is profitable.

To quantify soybean yield responses to final irrigation termination, a trial was conducted at an Agronomy in Action site near Waterloo, NE. The site is comprised of a silty clay loam soil, with total available water of 5.4 inches in the 3-foot rooting profile when at field capacity.[2]

Two soybean varieties, GH2722XF and GH2884XF brand, were planted on May 11. Water was applied with a linear sprinkler irrigation system beginning at the R1 growth stage using rates based on crop water demand for that growth stage, soil water holding capacity and recent rainfall events (Table 1). All treatments received two 1-inch irrigation events during the R1 and R2 growth stages (Graph 1). Irrigation continued to be applied based upon crop demand, although four individual irrigation

Growth Stage	Growth Stage Length	Daily Water Use[3]	Water Demand	Amount Irrigation Applied
	Days	Inches		
R1 (Beginning Bloom)	5	0.20	1.00	
R2 (Full Bloom)	11	0.25	2.75	
R3 (Beginning Pod)	10	0.28	2.80	
R4 (Full Pod)	10	0.32	3.20	2.00
R5 (Beginning Seed)	17	0.33	5.61	2.00
R6 (Full Seed)	16	0.25	4.00	1.00
R7 (Beginning Maturity)	9	0.15	1.35	0.75
R8 (Full Maturity)	7	0.10	0.70	
Total	**85**		**21.4**	

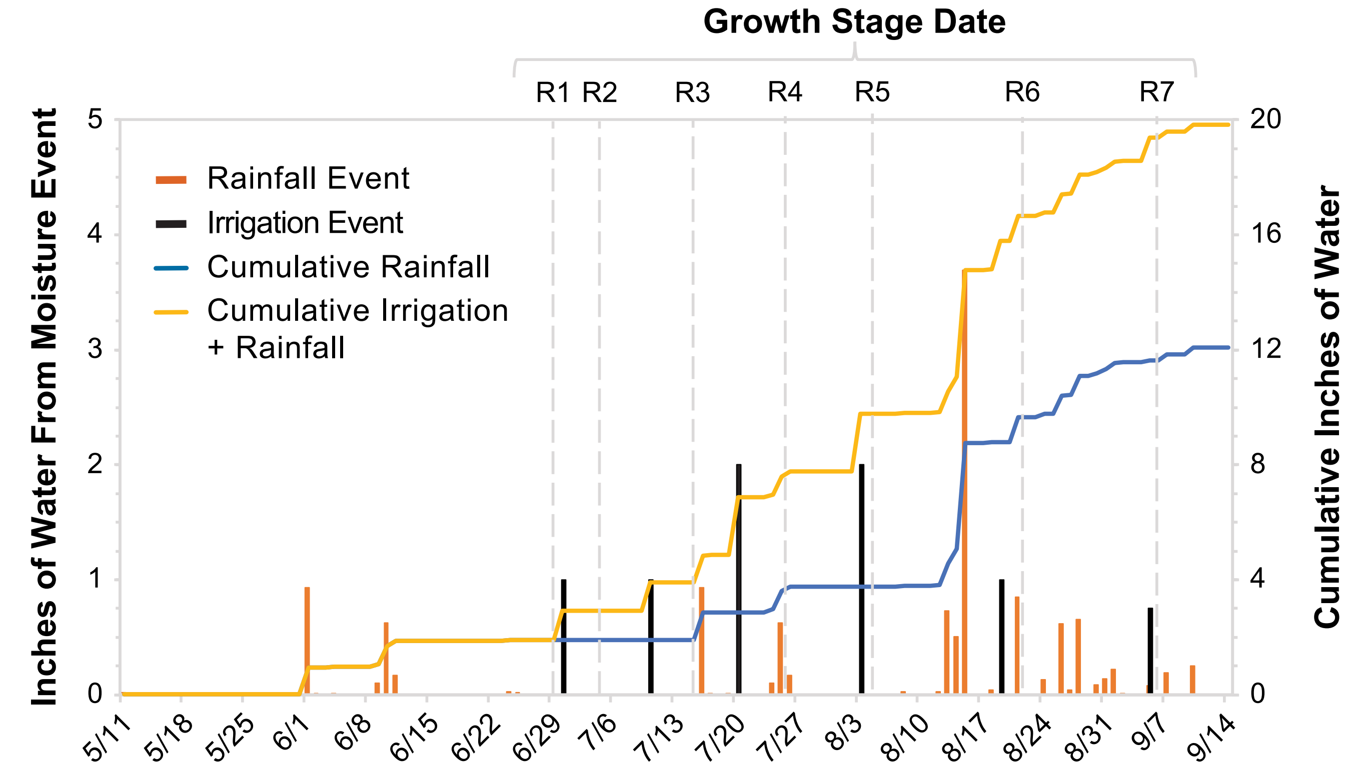
Table 1. Estimated soil water demand by growth stage of soybeans grown at Waterloo, NE in 2023.

regimes were established within the trial according to the crop stage in which the last event occurred. Final irrigation treatments occurred at one of the following growth stages:

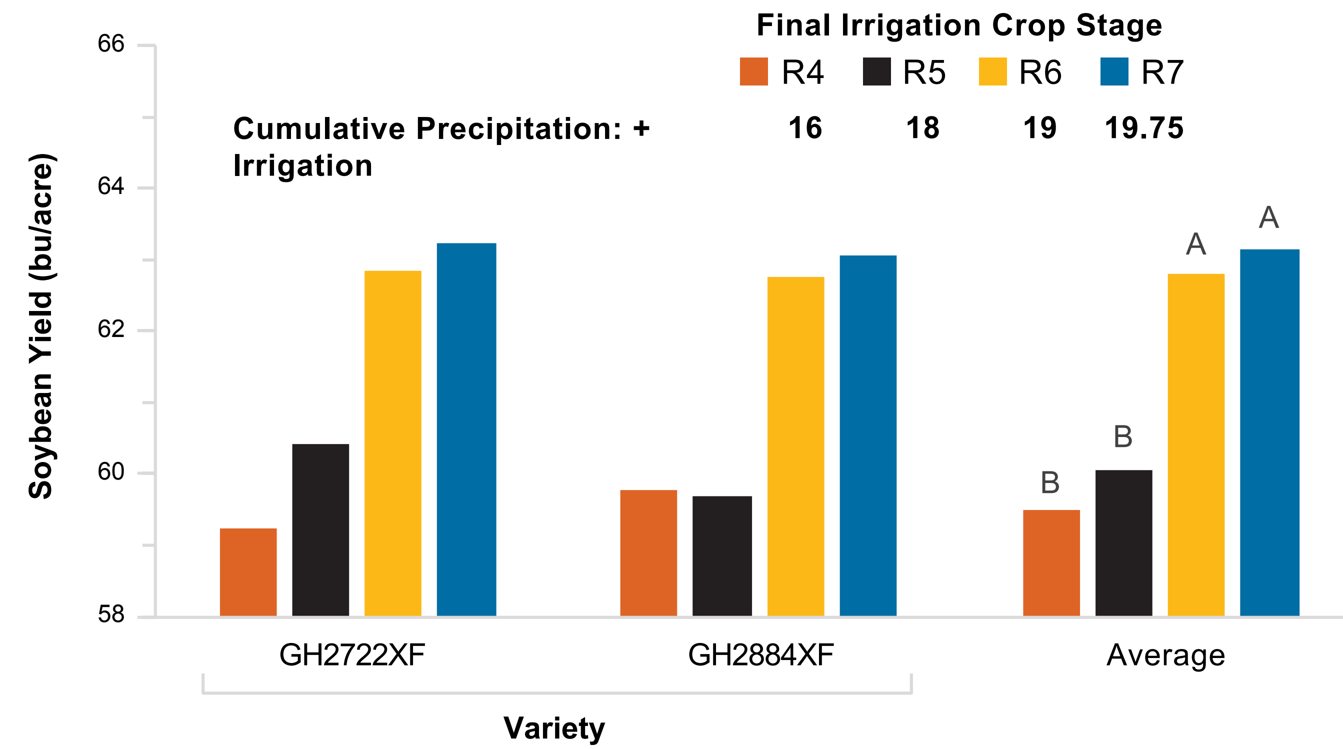
- R4 (Full Pod)
- R5 (Beginning Seed)
- R6 (Full Seed)
- R7 (Beginning Maturity)

TRIAL RESULTS

The trial site received below-average precipitation during the growing season, as only 12.1 inches of rainfall was recorded from 5/11 to 9/14 (Graph 1). However, 84% of the seasonal precipitation occurred after July 15, during the



Graph 1. Cumulative rainfall, total precipitation (rainfall + irrigation), rainfall and irrigation event timing and amounts, and dates of observation of soybean reproductive growth stages at Waterloo, NE.



Graph 2. Response of soybean yield to irrigation termination. Letters denote differences between irrigation treatments, P≤0.05.

Figure 1. Leaf senescence differences of GH2722XF brand soybeans with final irrigation events at R4 (left) and R7 (right) on September 5th, 2023, at Waterloo, NE.

key periods of pod development and seed fill. The timely rainfall occurring throughout reproductive development stages undoubtedly minimized yield differences between irrigation regimes. Both soybean varieties responded similarly to final irrigation timing, so only the irrigation treatment means are discussed.

Despite substantial 2023 late-summer rainfall events, the importance of supplying ample water to soybeans up to physiological maturity was still demonstrated. The trial found that a final irrigation at the R6 growth stage (Graph 2) optimized soybean yield at 62.8 bu/A. Growth rate of beans is rapid and total pod weight will peak during this growth stage, making it important to ensure adequate water is still available. At R7, soybeans are beginning to mature and one pod on the main stem should be brown or tan in color. Dry matter accumulation begins to peak in individual seeds, making them less sensitive to water or nutrient deficiencies at this point. No statistical or economical yield responses were observed from additional irrigation applications at the R7 stage. Conversely, terminating irrigation at or before the R5 growth stage resulted in a ≥5.3% yield reduction (≥3.3 bu/A). When irrigation was terminated at or before R5, soybeans senesced earlier, shortening the period of time available to photosynthesize and translocate biomass to developing seeds (Figure 1). Ceasing irrigation at R4 did not further reduce soybean yield in comparison to the R5 timing.

Despite the late-season rainfall, the results do still underscore the importance of adequate water supply during pod development and fill stages. Soybeans in this experiment required an estimated 9.6 inches of water during the R5 and R6 stages, which represents 45% of the total water demand during reproductive development (Table 1). Despite significant rainfall during the R5 stage (~5 inches from 8/13 to 8/15) (Graph 1), the yield response to subsequent irrigation at R6 suggests that either 1) water deficit-induced yield reductions occurred before the significant rainfall event, or 2) a water deficit still existed even after the rainfall event.

SUMMARY

Peak water demand for soybeans occurs throughout the R5 and R6 growth stages, which typically aligns with the month of August in the Midwest. This trial further emphasizes the value of a timely additional irrigation or rain event during this critical period. Yield reductions associated with stopping soybean irrigation too early is highly dependent on timing of local rain events and soil water reserves. Additional yield potential from irrigation may still be possible even when late-season precipitation is substantial. This underscores the importance of astute irrigation management to ensure plant-available water is never limiting, regardless of recent weather events.

SCHEDULING FINAL IRRIGATION EVENTS FOR CORN AND SOYBEANS

INSIGHTS

- Soil water holding capacity plays a role in estimating plant water availability to help schedule final irrigation events.
- The goal of the final irrigation event should be to provide adequate water to support reproductive development, yet allowing for proper soil profile depletion once plants reach physiological maturity.

Attention on irrigation is often focused on critical periods of pollination and kernel development. However, yield reductions of corn or soybeans can occur at any point prior to physiological maturity if the crop water demand is not satisfied. Conversely, excessive watering near maturity potentially reduces return on investment (ROI) from greater energy costs and can create logistical harvest issues if fields remain excessively wet.

UNDERSTANDING AVAILABLE SOIL WATER

Soil serves as the primary water reservoir for plant uptake. Approximately 50% of the soil profile is comprised of pore space (the area between soil particles), which serves as the area of soil water retention. As pore space fills with water, the soil reaches its saturation point and forces oxygen needed for root growth and nutrient uptake out of the profile. Any extra water will percolate down through the profile by gravitational force. After 24 to 48 hours, gravitational water movement will begin to cease as soil water returns to field capacity.

The remaining water is held in place by adhesive bonds with soil particles and electrostatic cohesive bonds between other water molecules, preventing further drainage of the soil profile. Soil water holding capacity will vary by soil particle size. Smaller sized silt and clay soil particles have more binding sites available for water molecules to adhere to, increasing water holding capacity compared to larger sand particles. However, not all water in soil is accessible to plants due to the strong adhesive relationship between water molecules and soil particles. When plant roots cannot overcome the remaining moisture bond with soil, it is referred to as reaching the permanent wilting point.

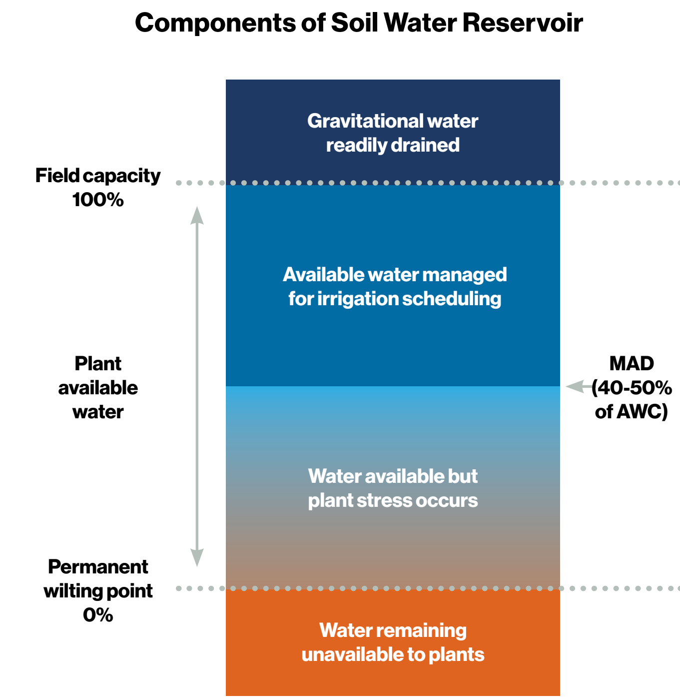


Figure 1. Components of the soil water profile.

The amount of water held by the soil between the permanent wilting point and field capacity is referred to as plant available water. Soil texture again dictates the capacity of this pool, which is a function of its electrostatic properties and pore sizes (Figure 1). Table 1 shows representative available water contents for common soil textures found in the Corn Belt.

Since not all water in the soil profile is available for plant uptake, it is recommended to maintain varying minimum amounts of profile water to avoid stress prior to the next

Soil Texture	Plant Available Water[1] (Field capacity minus wilting point): Inches H_2O per foot soil	Soybean Rooting Zone (in H_2O/ 3 ft soil)	Corn Rooting Zone (in H_2O/ 4 ft soil)
Fine sand	1.0	3.0	4.0
Sandy loam	1.4	4.2	5.6
Silt loam	2.5	7.5	10.0
Silty clay loam	1.8	5.4	7.2
Silty clay	1.6	4.8	6.4

Table 1. Available water at field capacity and total available water in rooting zones of corn and soybeans on soils with varying soil textures.

Crop	Growth Stage	MAD (%)[2]
Corn	VE to V12	60–70
	V12 to R1	40–50
	R1 to R5	50
	R5 to R6	60–70
Soybeans	VE to R1	65–70
	R1 to R3	60–65
	R3 to R5	50
	R6 to R7	50–70

Table 2. Maximum allowable depletion (MAD) by growth stage for corn and soybeans.

irrigation event. The maximum allowable depletion (MAD) point indicates how much of the total available water in the profile can be utilized before the crop begins to undergo water stress. A conservative rule of thumb is to maintain MAD levels of 50%. However, they can be as high as 70% at early vegetative crop growth stages when plant water use rate is lower (Table 2). For example, a silty clay loam soil at field capacity with corn in the V8 growth stage can extract more water per foot of soil at 70% MAD levels before needing irrigation than could have been extracted if using 50% MAD levels (1.8 inches H_2O/ft soil AWC × 70% MAD = 1.3 inches; versus 1.8 inches H_2O/ft soil AWC × 50% MAD = 0.9 inch). In comparison, only 1.0 inch per foot of soil could be extracted from a field with a sandy loam soil (1.4 inches H_2O/ft soil × 70% = 1.0 inch).

CROP WATER REQUIREMENTS

Crop water use is a function of two micrometeorological principles: 1) water evaporation from the soil surface, and 2) plant transpiration, which is the exchange of water vapor for carbon dioxide by openings in plant leaves (stomata). Approximately 70–80% of crop water use is attributed to transpiration, with the remaining related to evaporation. Crop growth stage, weather conditions (e.g., temperature, humidity, wind speed) and management practices (e.g., tillage, crop residue, plant density) all affect daily crop water use. However, the greatest proportion of the total water requirement occurs during reproductive development (70% and 85% for corn and soybean, respectively).

Crop	Growth Stage	Daily Water Use Rate (in/day)[3,4,5]	Growth Stage Requirement (in)
Corn	VE (Emergence)		0.8
	V4 (4-leaf)	0.10	1.8
	V8 (8-leaf)	0.18	2.9
	V12 (12-leaf)	0.26	1.8
	R1 (Tassel)	0.32	3.8
	R2 (Silking)	0.32	3.8
	R3 (Blister)	0.32	1.9
	R5 (Beginning dent)	0.24	3.8
	R5.5 (Full dent)	0.20	3.8
	R6 (Maturity)	0.10	1.4
Soybeans	VE (Emergence)		1.0
	V2 (2nd trifoliate)	0.08	0.6
	V4 (4th trifoliate)	0.09	0.6
	V6 (6th trifoliate)	0.14	1.0
	R1 (Beginning bloom)	0.20	2.0
	R2 (Full bloom)	0.25	1.8
	R3 (Beginning pod)	0.28	2.0
	R4 (Full pod)	0.32	3.2
	R5 (Beginning seed)	0.33	3.3
	R5.5 (Mid seed)	0.32	3.2
	R6 (Full seed)	0.25	1.8
	R7 (Beginning maturity)	0.15	1.5
	R8 (Full maturity)	0.10	1.0

Table 3. Daily and total water use by growth stage for corn and soybeans.

Daily water demand during reproductive development does decrease as corn and soybeans approach maturity. However, it does not reach zero until full maturity is reached. For example, according to Table 3, one inch of water is still required by soybeans from R7 (denoted by the observation of one mature pod on the main stem) and R8 (95% pod maturation). Although slight, yield reductions can still potentially occur if this water demand is not satisfied at these crop stages.

PLANNING THE FINAL IRRIGATION EVENT

The goal of the final irrigation event should be to provide adequate water to support reproductive development, yet allowing for proper soil profile depletion once plants reach physiological maturity. A theoretical and economical goal is for available soil water to be depleted to 40% of available water capacity by physiological maturity. To effectively estimate the amount of water applied by the last irrigation, the following information is needed: predicted crop maturity date, estimated remaining crop water demand and current available soil water in the profile. Although rainfall can periodically influence this final irrigation event, it is often best to omit it from the final water balance unless it can be estimated with high confidence. Once crop growth stage is determined, the remaining total water requirement for either corn or soybeans can be estimated before any credits are applied using the workflow in Table 3. Accurate estimation of remaining soil water occurs through use of soil water sensors. Measurements should be taken at 48 inches for corn and 36 inches for soybeans, as most water uptake by roots occurs with those depths. When multiple soil types are present in the field, the soil with the least water-holding capacity should be used to ensure that the soil's contribution to the water balance is not overestimated. Once these input variables are collected, the amount of water required for the final irrigation event, if any, can be determined through the workflow in Table 4.

An effective final irrigation event meets final crop water demand while minimizing excessive water application. Crop growth stage, current soil water balance, soil physical properties and future weather events all impact the final amount of irrigation water required, meaning field-by-field calculation is necessary. Contact your Golden Harvest Seed Advisor or Agronomist for further help fine tuning final irrigation events.

Input Variable and Description	Example: Corn on silt loam soil at R5 with 75% moisture in top 4 feet
Total Available Water (TAW) The amount of water remaining in the profile available to the crop. Multiply available water content (AWC) inches H_2O/ft per soil type (Table 1) by rooting depth and % water content.	2.5 inches H_2O/ft (Table 1) × 4-foot rooting depth × 75% water content = 7.5 inches available
Crop Water Demand (CWD) Sum of the inches of water needed per growth stage(s) remaining (Table 3).	3.8 inches (R5-5.5) + 1.4 inches (R5.5-6) = 5.2 inches needed by crop
Minimum Soil Water Content (MWSC) Multiply available water content (AWC) inches H_2O/ft per soil type (Table 1) by rooting depth and minimum % soil moisture content before crop stress begins.	2.5 inches H_2O/ft (Table 1) × 4-foot rooting depth x 40% = 4.0 inches needed to finish
Water Balance (WB) The amount of water remaining after deducting the estimated crop water demand. TAW - CWD = WB	7.5 inches (TAW) - 5.2 inches (CWD) = 2.3 inches remaining
Water needed to finish season Determined by subtracting the water balance from the minimum soil water content needed to finish. WB - MWSC = excess (+) or deficit (-) water after removing minimum needed from water balance. Apply an additional irrigation event equivalent to the amount deficient.	2.3 inches (WB) – 4.0 inches (MWSC) = -1.7 inches deficit to finish season

Table 4. Workflow for estimating amount of water needed to finish season without water stress.

IMPORTANCE OF HARVEST TIMING ON SOYBEAN YIELD AND PROFITABILITY

INSIGHTS

- Shattering caused by excessively dry pods is a primary source of physical soybean harvest yield loss.
- Yield reductions from pod shattering and grain shrinkage reduced maximum gross revenue by 4% for every 1% decrease in harvest moisture below the suboptimal range.
- Harvesting at moistures at or above optimal moistures and proper combine settings and speed can minimize harvest-associated yield losses.

INTRODUCTION

Soybean yield losses and subsequent reduced profitability from improper harvest management can easily be underestimated. This is probably because these yield losses aren't as visually apparent as in-season factors like weed or disease pressure. However, because of more emphasis placed on soybean management, and subsequent increases in input costs, maximizing the amount of grain delivered to the elevator is critical.

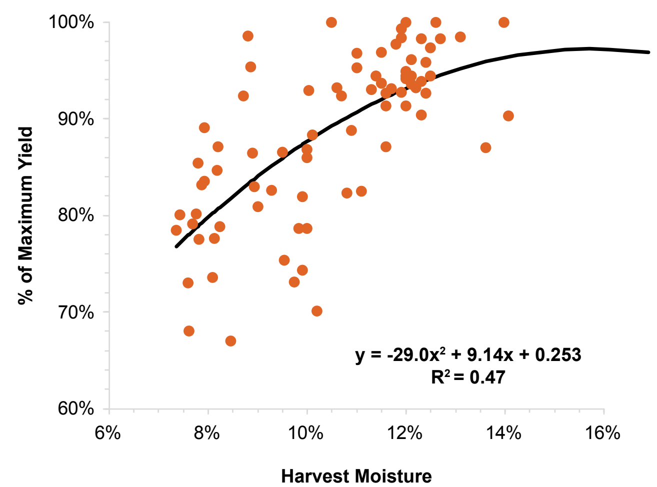
Yield losses at harvest are most often associated with pod shattering. Once physiological maturity is reached, the seam along of the edge of pod begins its degradation. Continued drying beyond optimum harvest moistures weakens its strength of the bond, thus making it more susceptible to break. Wetting and drying cycles from precipitation also further its degradation. Other abiotic (drought, fertility) and biotic (disease, insect damage) factors can also increase the potential and magnitude of loss from pod shattering.

Although it is known that yield losses occur when soybeans are harvested at suboptimum moistures, the magnitude of those losses is not well quantified, which may also factor into why the importance of proper harvest management could be overlooked.

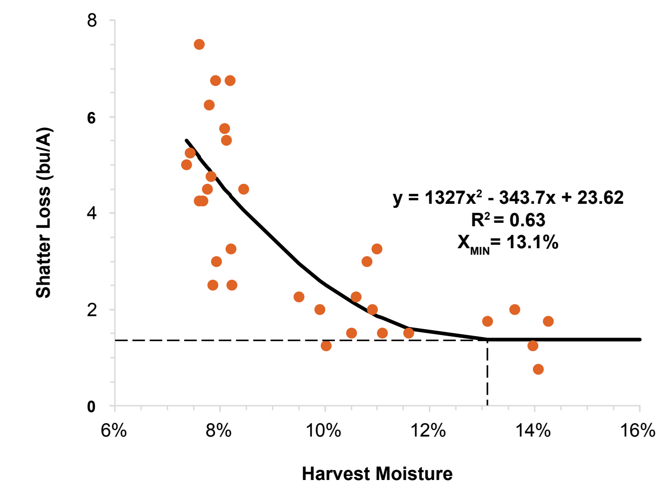
SOYBEAN HARVEST TIMING TRIAL

To quantify yield and gross profitability losses associated with delayed harvest timing, field trials were established at two Agronomy in Action research sites (Slater, IA and Waterloo, NE). Two Golden Harvest® soybean varieties with similar pod shattering resistance ratings, GH2505E3 and GH2610E3 brands, were planted at both sites. Harvest timing treatments were applied according to target moistures:

1. Optimal (~14%)
2. 2% moisture loss (12%)
3. 4% moisture loss (10%)
4. 6% moisture loss (8%)



Graph 1. Relationship between % of maximum soybean yield and harvest moisture.



Graph 2. Relationship between shatter loss and harvest moisture at Waterloo, NE. Dashed lines identify minimum moisture where shatter loss was minimized and the amount at that moisture.

YIELD RESPONSE TO SUBOPTIMAL HARVEST MOISTURE

To account for variability in harvest timings across locations, a regression analysis between the percent of maximum yield (PMY) and harvest moisture was used. PMY decreased quadratically as harvest moisture declined (Graph 1). For example, the regression predicted that PMY would decrease by 3.3, 9.0 and 17.2% when harvest moisture decreased from an optimum of 14% to 12, 10 and 8%, respectively. This translates to yields of 67.7, 63.7 and 55.9 bu/A at 12, 10 and 8% harvest moistures compared to 70.0 bu/A at 14%.

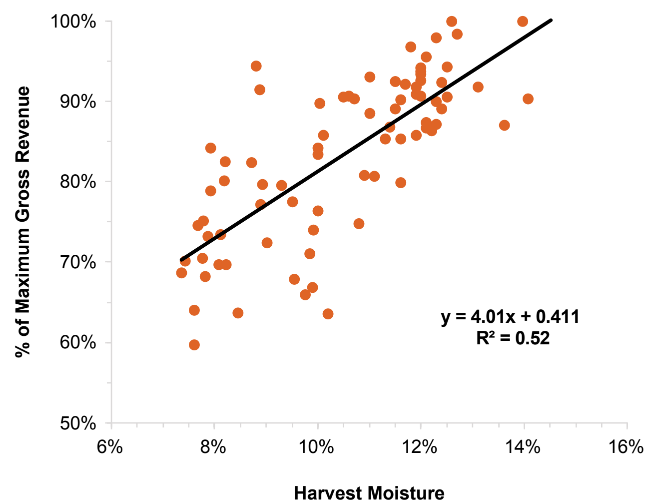
The relationship between shatter loss and harvest moisture was also evaluated via regression analysis. The analysis found that shatter loss increased quadratically as harvest moisture decreased (Graph 2). Based on the regression, yield losses from shattering increased 0.2, 1.2 and 3.3 bu/A at 12, 10 and 8% harvest moisture, respectively, over the optimum 14% moisture. The regression also predicted shatter loss would be minimized at a moisture of 13.1% or greater. However, it still predicted a harvest loss of 1.3 bu/A at that moisture. All combined-specific variables (concave/sieve settings, harvest speed, real speed) were all adjusted accordingly to maximize harvest efficiency in the trial, suggesting that eliminating harvest loss at the header is not practically attainable (Figure 1).

RELATIONSHIP BETWEEN GROSS REVENUE AND HARVEST MOISTURE

Harvesting at suboptimal moistures carries risk for decreased gross revenue due to lower soybean yield from pod shattering and/or shrink. Shrink refers to the weight of grain below an elevator's base moisture content (typically 13%) that is unaccounted for when the grain is sold, resulting in fewer bushels paid. Graph 3 shows the relationship between gross revenue and harvest moisture in this trial and found a linear decrease in the percent of maximum gross revenue (MGR) and harvest moisture. Specifically, the relationship predicted that MGR would

Figure 1. Harvesting at optimum moisture with proper combine harvest settings and speed still does not eliminate harvest loss. Approximately 0.5 bu/A loss is depicted.

MAIN MENU



Graph 3. Relationship between % maximum gross revenue and harvest moisture.

Harvest Moisture	Yield (bu/A)†	Gross Revenue‡	Source of Revenue Loss‡	
			Pod Shatter	Shrink
	Dryland			
13.0%	60.0	$840.00	-	-
11.5%	58.1	$801.20	$26.60	$12.20
10.0%	55.3	$750.97	$65.80	$23.23
8.5%	51.8	$692.57	$114.80	$32.63
7.0%	47.4	$623.78	$176.40	$39.82
	Irrigated			
13.0%	80.0	$1,120.00	-	-
11.5%	77.4	$1,067.35	$36.40	$16.25
10.0%	73.8	$1,002.20	$86.80	$31.00
8.5%	69.0	$922.53	$154.00	$43.41
7.0%	63.2	$831.71	$235.20	$53.09

Table 1. Yield, gross revenue ($/ac), and sources of revenue loss at five different harvest moistures in a dryland and irrigated environment.

† Estimated from regression equation in Graph 1.

‡ Based on $14.00/bu soybeans.

decrease 4% for every 1% decrease in harvest moisture below the suboptimal range.

The magnitude of gross revenue loss due to suboptimal harvest moistures in a dryland and irrigated environment (based on predicted yields from the regression equation in Graph 1) is further shown in Table 1. In this example, harvesting soybeans at 11.5% would result in a loss of $38.80 and $52.65 per acre in a 60 bu/A dryland and 80 bu/A irrigated environment, respectively. Of that value, $12.20 and $16.25/A, respectively, or the value of nearly a bushel of soybeans, would be attributed to shrink alone, which represents 31% of total revenue loss. Revenue loss became more extreme as harvest moisture continued to decrease below the optimal range. For example, harvesting at 8.5% moisture would decrease gross revenue by 18% ($147.43 and $197.47/A for the dryland and irrigated environment, respectively). Although shrink now accounted for 22% of the loss, it was still predicted to be $32.63 and $43.47/A respectively. In comparison, gross revenue loss at this moisture due to agronomic reasons was $114.80 and $154.00/A for dryland and irrigated, respectively. These results show that revenue loss through improper harvest management can be substantial.

SUMMARY

Yield and subsequent profit losses from improper harvest management of soybeans can easily be underestimated, and the results from this trial underscore its true importance, as even slight moisture reductions (e.g., 1.5%) from the optimum moisture range can decrease overall profitability. Unfortunately, soybean moisture can decrease over a very short time when conditions are favorable (e.g., high temperatures, low humidity, windy conditions), meaning some profitability loss due to suboptimal harvest moistures is sometimes inevitable. However, proper planning, field prioritization and combine harvest settings and speed can help reduce these potential losses. Also, results from this study suggest that any moisture dockage associated with soybeans delivered above 13% far outweighs the agronomic (pod shatter) + shrink revenue losses from soybeans harvested at suboptimal moistures.

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