

2022 | AGRONOMY IN ACTION
RESEARCH REVIEW



THIS IS HOW WE LISTEN

“The greatest compliment that was ever paid me was when one asked me what I thought and attended to my answer.”

Henry David Thoreau

At Golden Harvest we firmly believe everything we do should start with listening. There’s no better way to understand the wants and needs of our farmers. The 2021 Research Review started with listening as well, and we wanted to get started by sharing what we learned when we asked a group of farmers what they thought about the importance of agronomic management practices to help inform this year’s review.

We surveyed 101 Midwestern corn/soybean farmers about what management practices most influenced corn and soybean yields on their farms over the last ten years, and what practices they felt would be most important to drive increased yields over the next ten years. Most participants (92%) agreed that crop yields are increasing at or ahead of the normal 1.9 (corn) and 0.5 (soybean) bushel per acre per year genetic gain rates.¹

Not surprisingly, farmers say continued improvement in corn and soybean genetics has been the largest contributor to increased yields (Figure 1). Although new technologies have been extremely important, the farmers we surveyed felt improved management practices were the second greatest contributor to yield gains after improved genetics. To better understand what specific management practices growers believe will be most important in the future, they were asked to prioritize a list of agronomic management practices for productivity gains in corn and soybeans (Figures 2 and 3) over the next ten years. There were similarities in farmer prioritization of agronomic practices across crops, such as the importance of more precise planting practices. However, there were many differences in the importance of specific management practices by crop.

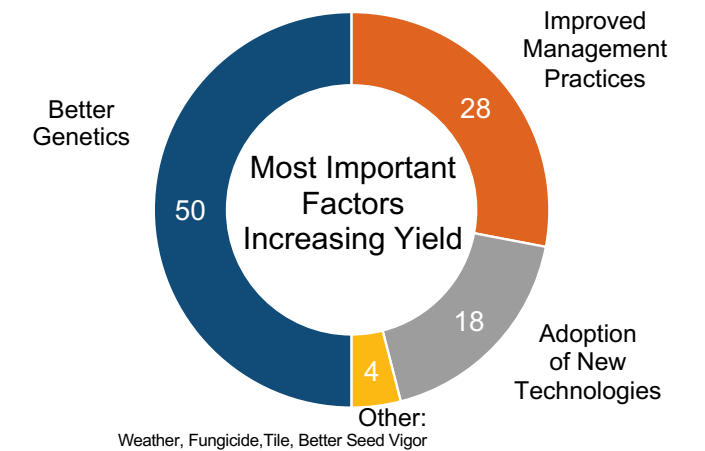


Figure 1.

FARMER INSIGHTS ON CORN MANAGEMENT PRACTICES

- Fertility management has been and will continue to be key for future productivity gains in corn. Three of the top four ranked practices were related to fertilizer placement, in-season management and use of micronutrients.
- The use of foliar fungicides and biologicals to enhance growth and plant nutrition will be even more important in the future than it was over the past ten years.
- Surveyed farmers deemphasized the need to plant any earlier and the role of further increases in corn seeding rates for future productivity gains.

FARMER INSIGHTS ON SOYBEAN MANAGEMENT PRACTICES

- Increased fertility management was viewed as less important for soybeans compared to corn.
- Seed treatments, foliar fungicides, more precise planting practices and earlier planting have been, and continue to be, viewed as the most important management practices for soybeans.
- Soil management practices for soybeans are viewed with less importance in the future compared to the prior ten years.

Corn Management Practices - Impact Over Next 10 Years (#) = relative ranking over last 10 years

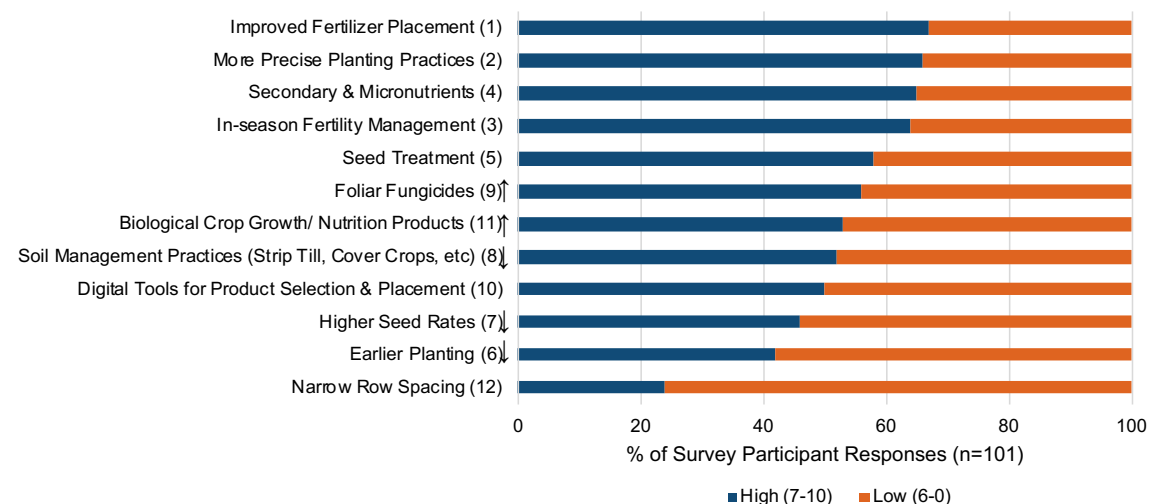


Figure 2. Survey participants ranking of corn management practices importance for next 10 years. Numbers in parenthesis indicate ranking of importance from prior 10 years.

Soybean Management Practices - Impact Over Next 10 Years (#) = relative ranking over last 10 years

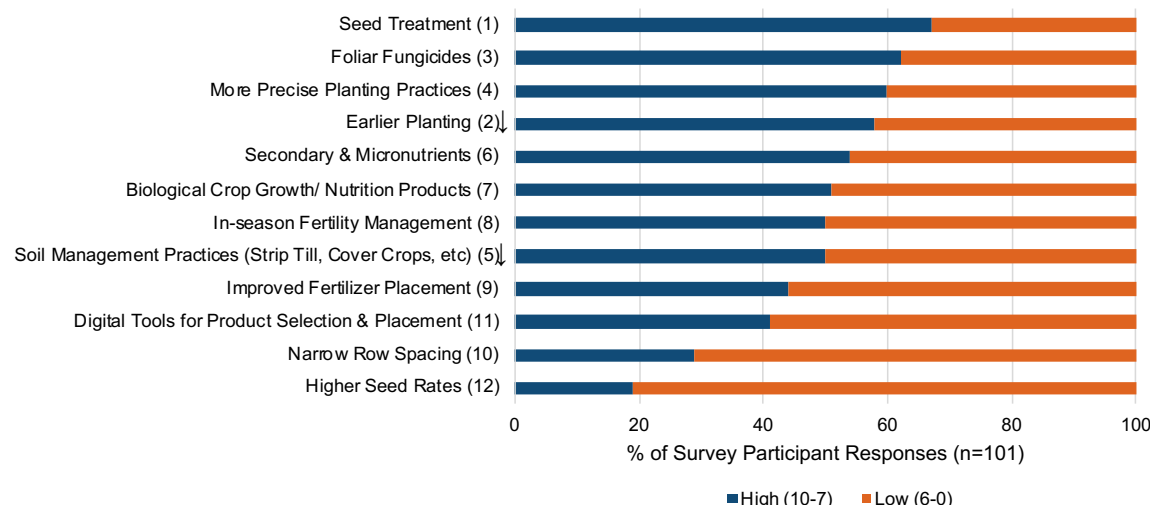


Figure 3. Survey participants ranking of soybean management practices importance for next 10 years. Numbers in parenthesis indicate ranking of importance from prior 10 years.

LEARNING FROM WHAT YOU HEAR

After listening, we drew upon the perspectives and insights from the farmers we surveyed to help focus our 2021 Agronomy in Action research initiatives. One new trial we specifically added this year to better serve management needs expressed by farmers in the survey, was designed to understand how corn hybrids respond differently to fertilizer placement in and around the root zone. Another

trial developed based on growing interest of biologicals and plant nutrition looks closer at some of the newest microbial products which help provide supplemental nitrogen to the plant. Look for more about both of these trials and many others in this edition of the Research Review.

As a genetics provider, we view every hybrid/variety as being unique in how each should be placed and managed

How Critical is Customizing Management Practices to Specific Hybrid/Varieties?

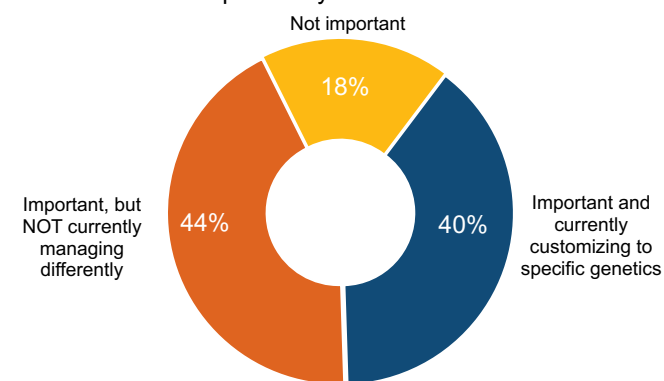


Figure 4.

but we were interested in knowing what farmers thought. We asked survey participants to tell us how important they feel it is to manage hybrids differently. More than 80% of participants agreed that it is critical to customize management to specific genetics, however just under half of them are doing so today (Figure 4). One of the biggest challenges farmers face with managing to specific genetics needs is knowing their differences in response to management practices. Many are receiving information from seed providers or conducting their own on-farm research, but often they are using a combination of the two approaches. Golden Harvest is committed to learning as much as possible about our products before each one is sold. Ongoing trials to better understand seeding rate and fungicide response are summarized and used to help local seed advisors have the most up-to-date information to place and manage hybrids. We are also in the process of scaling up the trials we conduct each year to better understand and characterize how our seeds portfolio responds to fertility management practices.

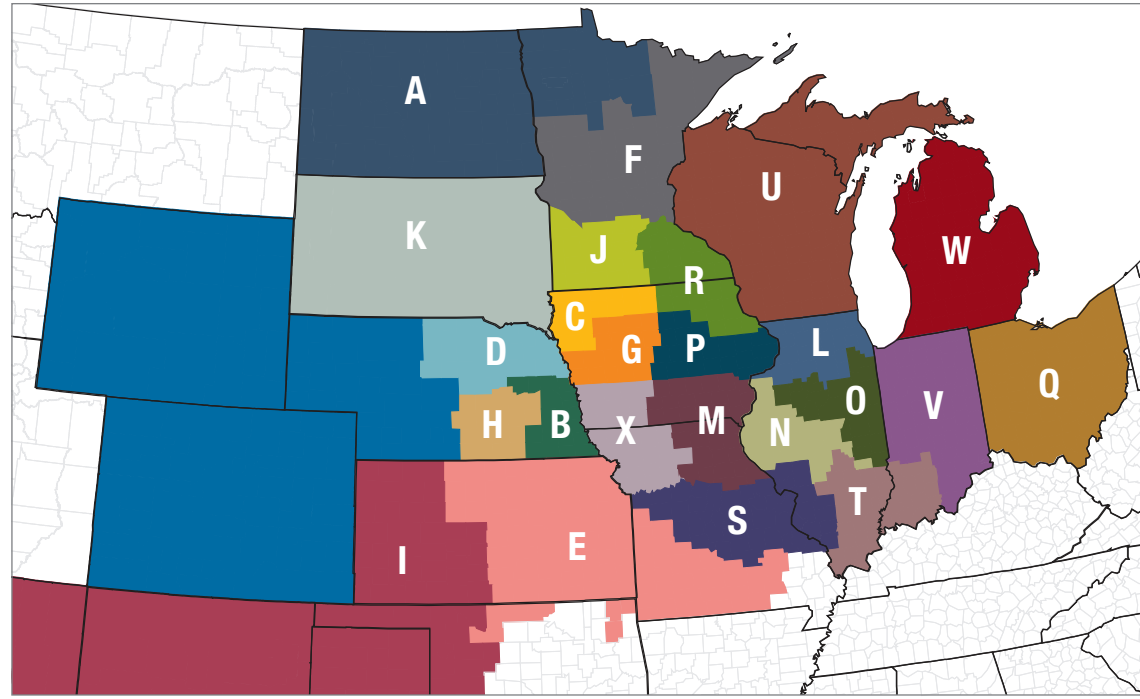
Many thanks to the farmers who participated in the agronomy survey for helping us better understand where to place our research emphasis. We are excited to bring to you, all of our customers and Seed Advisors, another insights-packed edition of the Golden Harvest Agronomy Research Review.

Thank you for partnering with Golden Harvest in 2021 and well wishes for your best crop ever in 2022!

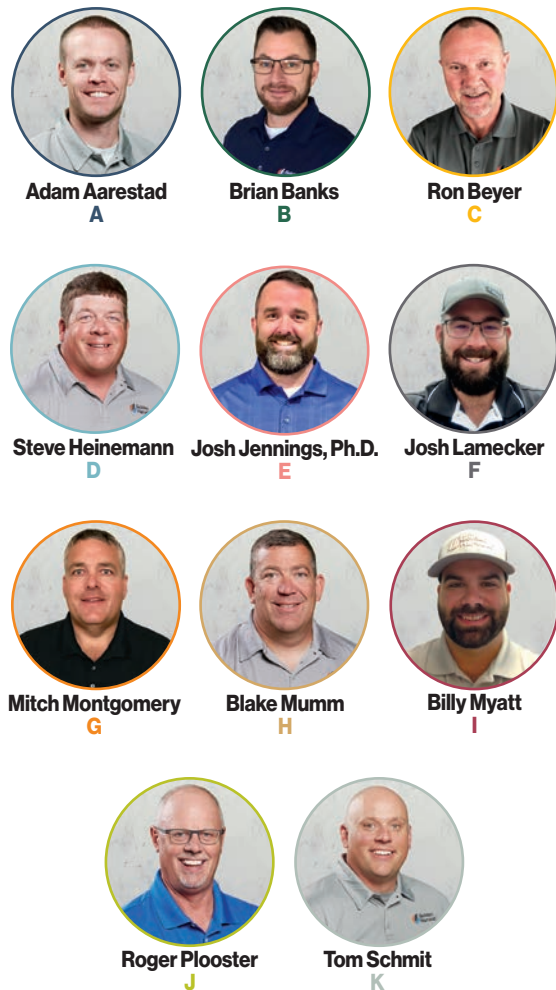
-Bruce Battles, Technical Agronomy Manager

¹ USDA-NASS Crop Production Reports

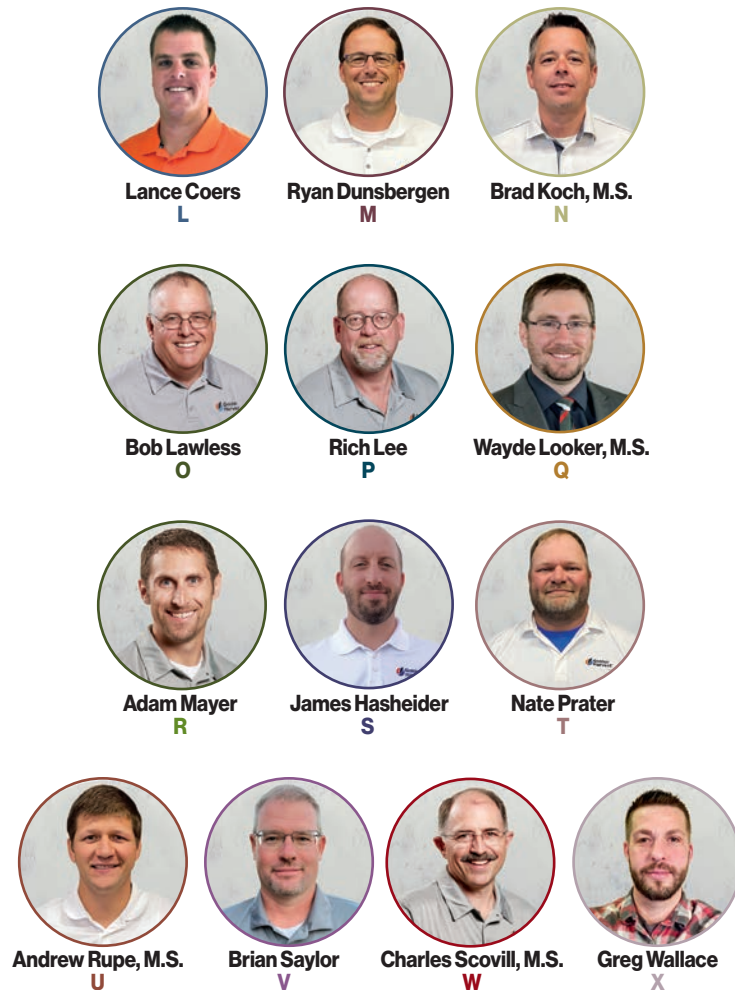




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Scan the QR codes throughout to view related agronomic video content, web agronomy articles, and agronomic tools.

☞ *Agronomy In Action Research Trial Article*

UTILIZING AERIAL IMAGERY TO MAKE ENHANCED AGRONOMIC DECISIONS

INSIGHTS

- Golden Harvest® seeds leverages technology to bring value to farmers.
- Aerial imagery brings farmers actionable crop management information.
- Images and reports help set season-long recommendations and expectations.

INTRODUCTION

Proactively monitoring fields for potential issues at just the right time is critical for timely management decisions. The biggest challenge is having the time and ability to effectively scout every field in a timely manner. Scouting corn can become even more challenging later in the season. As part of Service 365, Golden Harvest has partnered with DroneDeploy to offer aerial imagery and field reporting for timely insights and to help make difficult management decisions easier (Figure 1). In the first season, Golden Harvest agronomists were able to utilize the latest drone technology with DroneDeploy crop analytics software to fly more than 3,000 flights and deliver imagery for valuable crop insights (Figure 2).



Figure 1. Mavic 2 Pro with DroneDeploy Software

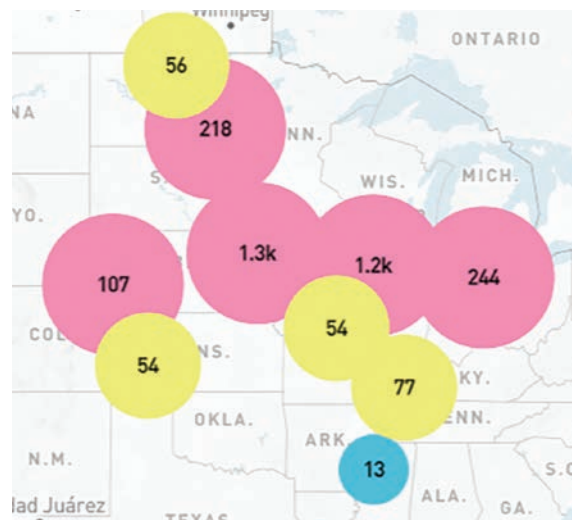


Figure 2. Summary of 2021 flights by region

ACTIONABLE CROP MANAGEMENT

Aerial imagery has proven to be an efficient, safe and effective digital tool to help streamline Golden Harvest agronomy support throughout the growing season. Aerial imagery allows agronomists and farmers the ability to cover more acres from the ground and to get a more holistic view of what is going on from the sky. Here's a closer look at three of the most popular DroneDeploy software features that help agronomists provide more accurate management suggestions and set season-long expectations.

1. Stand Counts

Early-season stand counts are an important step in the process of making replant decisions. An accurate stand count can help compare the economic trade-off with lower yield expectations of a reduced stand or replanting. However, it can take a lot of time to manually walk and assess an entire field. DroneDeploy software estimates the average number of plants and plant spacing at multiple spots across the field and quickly identifies specific areas with



USING DRONES TO TAKE STAND COUNTS

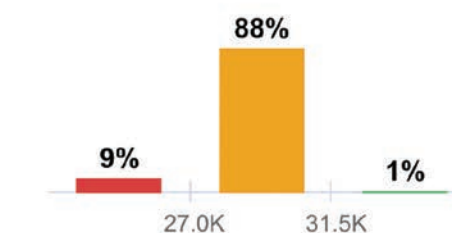
Stand Count Report

Crop Report Plan - 06/04/2021



Pilot: Samantha Teten | Images Captured: 56 | Flight Plan: Crop Report | Acres: 7

Site Population



Summary

Median Population	29,000/ac	Crop Type	Corn ↓
Median Spacing	7.15"	Median Gap Count	1,727/ac

Map



Figure 3. Stand count report from DroneDeploy after a flight

lower stands. Agronomists can quickly zoom in and view specific areas of the field to better diagnose the cause of the problem. Upon completing the flight, a report is generated that summarizes the findings and map stand estimates in each part of the field (Figure 3).

2. Plant Health

Visualizing crop stress can be invaluable for understanding field variability and evaluating how genetics respond to soil types or specific diseases. DroneDeploy Live Plant Health Maps can help quickly visualize in-season crop variation and field stress. Hundreds of photos are captured and stitched together on the fly to produce a single high-resolution standard orthomosaic RGB (red, green, and blue) map. Following the flight, a Visible Atmospherically Resistant Index (VARI) plant health map is produced utilizing green

light reflectance (Figure 4). Plant health maps can help highlight areas of stress that may otherwise be undetectable.

Areas of concern in a field can then be more precisely outlined for ground truthing the cause of the problem, calculating areas affected and creating prescription maps (Figure 5). This saves time and ensures areas of potential issues are not overlooked as may happen with random point scouting. Agronomists can generate a report containing the map, additional photos, notes and the estimated acres affected when scouting is completed.

3. Panoramas and Photos

Panoramas are a very quick way to capture a 360-degree bird's-eye view of a field when advanced analysis is not necessary. These photos can help show

how widespread a field condition is or provide a general direction of where to scout in a field (Figure 6). General photos can also be used to capture field operations such as planting and harvest or other events.

SEASON-LONG RECOMMENDATIONS AND EXPECTATIONS

The ability to use aerial imagery to get new perspectives of fields allows the Golden Harvest team to give better

recommendations throughout the growing season. It helps fine-tune herbicide and fungicide recommendations, set yield potential expectations and prioritize harvest schedules. Aerial imagery is a beneficial tool for farmers. Golden Harvest is determined to deliver the ultimate service experience from planting to harvest on every farm. Aerial imagery is another tool that helps deliver upon that goal.

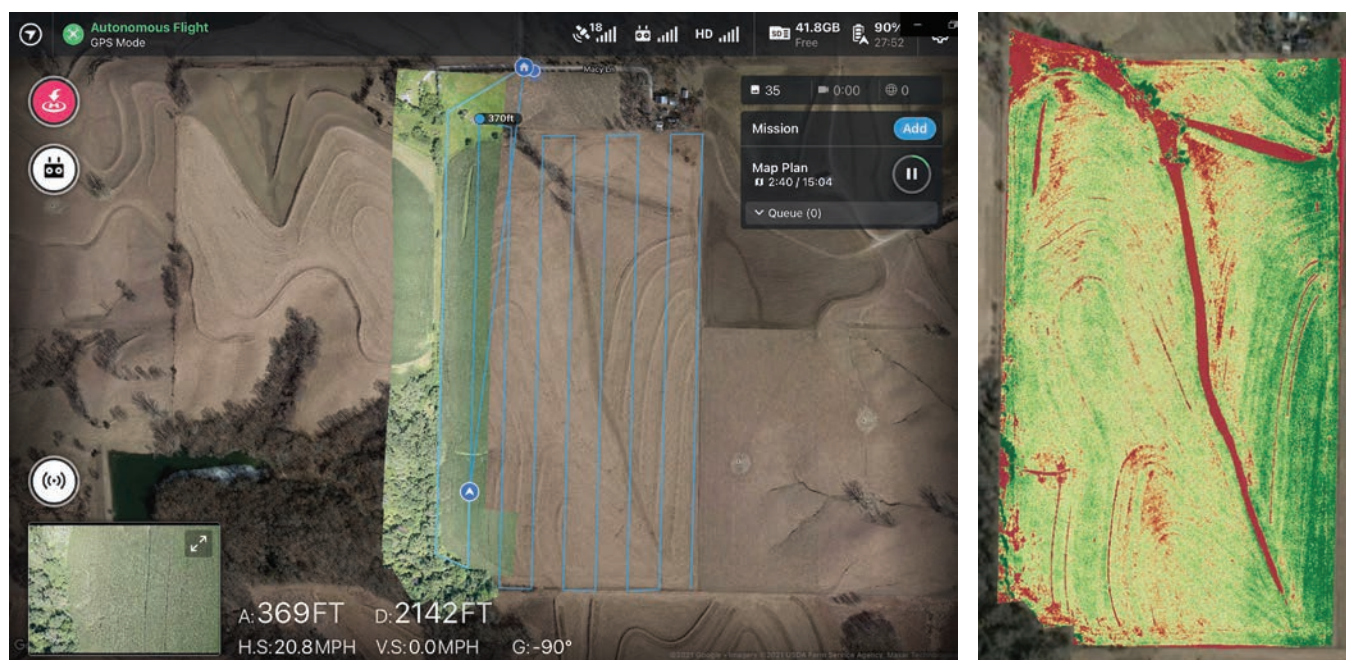


Figure 4. Live Plant Health Map partially through a flight (left) and post processed plant health (VARI) orthonosaic map (right)

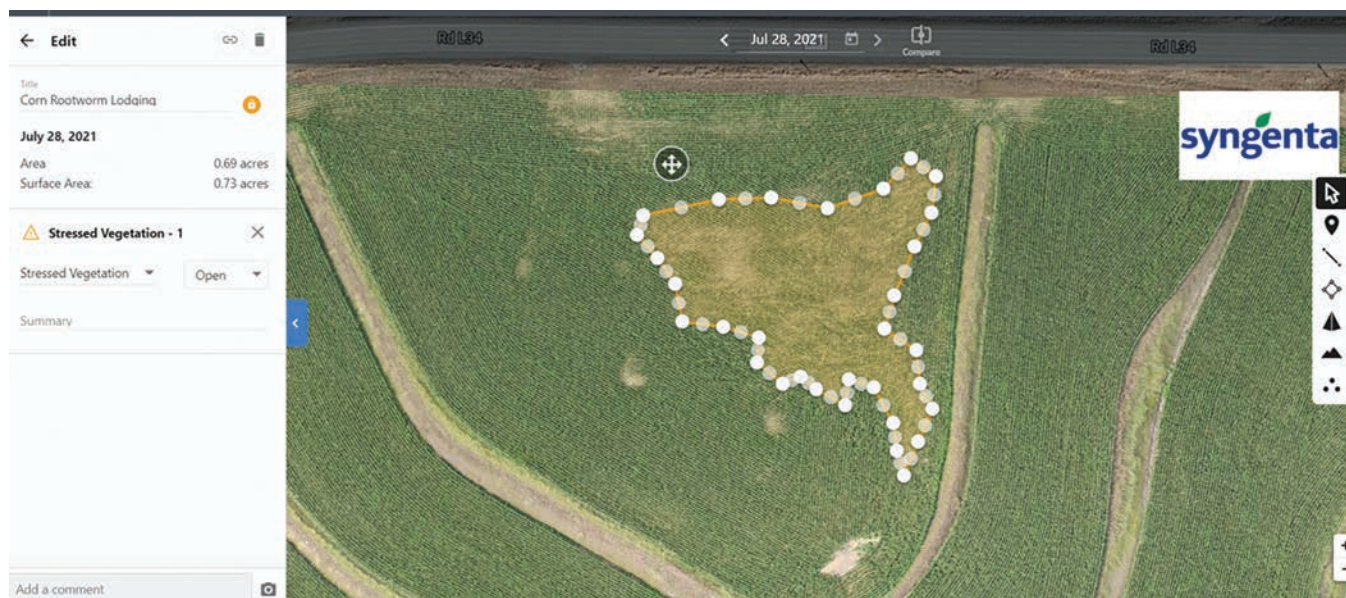


Figure 5. Using DroneDeploy software, the area of a stress-affected area can be calculated and annotated for later reference



Figure 6. Panoramic view of fields

LEAF DEFOLIATION EFFECT ON CORN YIELD AND LODGING

INSIGHTS

- Protecting the upper canopy in a corn crop is an essential step toward maximizing yield potential.
- Removing the upper canopy leaves reduced yields by 21% and 31% at the R3 and R1 timings respectively.
- Upper canopy leaf removal at R1 timing increased lodging by roughly 4 times (38-41% lodging).

INTRODUCTION

Corn plant leaves harvest sunlight for energy to use with water, nutrients and carbon dioxide to ultimately produce plant dry matter.¹ Early in the growing season the process is slow, but as plant size increases, the rate of dry matter accumulation increases. The interaction between plant leaves and grain is ultimately how yield within the plant is produced and is often referred to as a source-sink relationship.² Energy is “sourced” through photosynthesis in leaves and eventually “sinks” into developing grain kernels.

Environmental stresses that minimize leaf development will reduce photosynthetic efficiency. This reduces the overall source of energy and has an impact on the sink or grain development. Leaf damage from hail or disease can quickly minimize the leaf source and result in sugars

being moved from lower stalks or roots in efforts to meet the sink demand for developing kernels. Sourcing sugars from stalks rather than leaves can often result in weakening of the stalks and potential lodging. Protecting the upper corn canopy is an important management consideration when deciding on fungicide application and timing.



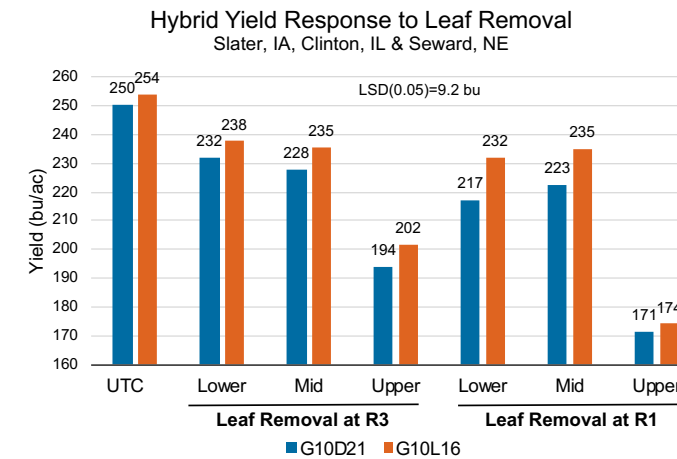
LEAF DEFOLIATION TRIALS

Trials were established at Clinton, IL, Slater, IA, and Seward, NE, to determine the effect of leaf removal at two different timings on grain yield and stalk quality. Two hybrids with similar maturities were selected to determine if hybrids differed in response to leaf removal.

Replicated treatments included an untreated check (no leaf removal), ear leaf and one leaf above and below removed, all leaves below the ear leaf removed, and all leaves above the ear leaf removed. Leaf removal treatments were performed at the growth stage timings of R1 (silk emergence) and R3 (milk stage), which occurs about 20 days after silking. To assess stalk strength, a push test was conducted on 10 plants per plot, recording the number of plants that were weak enough to break at harvest time.



Figure 1. Treatment photos: Upper canopy removed(A), Ear leaf and one above/below(B) removed, Lower canopy removed(C), Normal canopy(D).

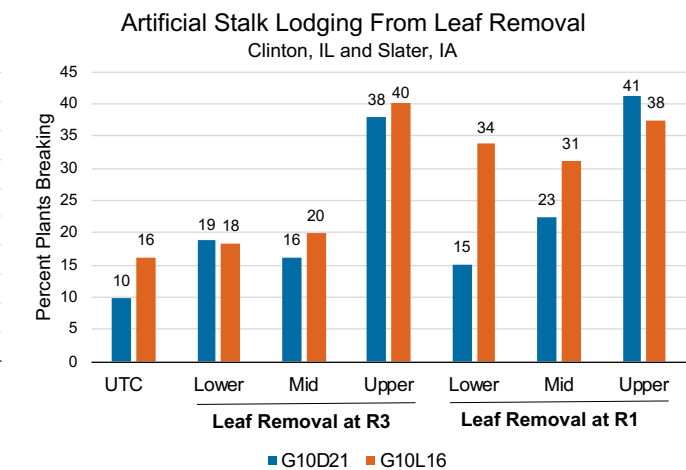


Graph 1. Hybrid yield response to leaf removal position and timing

YIELD AND LODGING RESPONSE

Yield reductions were observed at all leaf removal timings and positions. In general, all sites responded similarly and were averaged together in results shown (Graph 1). Removal of lower and mid canopy leaves at the R3 timing resulted in similar yield loss ranging from 6-8% for both hybrids. Earlier removal of the mid and lower leaves at the R1 stage similarly showed 6-7% yield loss with G10L16 although G10D21 lost 11-13% yield potential at the same timings. The most severe yield loss occurred through removal of the upper canopy with G10L16 and G10D21 both losing 20-22% at R3 timing and 31% at R1 timings. Removal of lower canopy or mid canopy reduced yields similarly, although not to the magnitude of removing upper canopy leaves, highlighting the importance of protecting the upper canopy. G10D21 was more sensitive to lower and mid canopy leaf removal at R1 timing as compared to G10L16.

Leaf removal impact on stalk strength was also monitored as reductions in photosynthesis often reduce late-season standability. Leaf removal of mid and lower canopy at R3 timing had little influence on standability for either hybrid, although lodging doubled when upper canopy leaves were removed (Graph 2). Removing leaves earlier in the grain fill process (R1) had a greater effect on standability with all three removal positions. Hybrids also responded differently to the area where leaves were removed. Standability of G10L16 worsened to 30-38% lodging across all three timings. Lower leaf removal at R1 did not affect G10D21 standability, although worsened when mid (23% lodging) and upper (41% lodging) leaves were removed.



Graph 2. Artificial stalk lodging resulting from leaf removal position and timing

These trials illustrate how different hybrids can respond differently to stress, such as leaf removal. Overall, G10L16 yield potential was less influenced by leaf removal. However, to maintain yield, it likely reallocated sugars more aggressively from lower stalks, resulting in greater potential to lodge. G10D21 was more sensitive to R1 leaf removal, as shown with yield loss results. However, other than the most severe scenario of R1 removal of upper canopy, G10D21 standability results were less impacted.

FACTORS THAT REDUCE SOURCE STRENGTH

Weather events that reduce leaf area can reduce source capacity significantly, especially when occurrences happen early in the reproductive stages. Leaf photosynthesis can be reduced several ways:

1. Reduced leaf number and size
 - Early drought
 - Nutrient deficiencies
2. Loss of physical leaf area
 - Hail
 - Root lodging
 - Insect damage
 - Disease lesions on leaves
3. Reduced photosynthesis efficiency
 - Excessive cloud cover for multiple days

Irrigation, good nutrient management and protection of upper canopy leaves with fungicide can improve plant photosynthetic efficiency and help improve sugar supply to develop heavier kernels that improve yield potential and test weights.

GREEN SNAP INJURY IN CORN

INSIGHTS

- Green snap injury in corn has the potential to significantly reduce yield potential.
- Percent-broken:percent-yield-reduction ratios are usually less than the previously published 1:1 ratio.
- The growth stage of corn when green snap happens plays a significant role in the potential damage.

INTRODUCTION

Green snap or brittle snap is the breakage (snap) of the corn stalk nodes resulting from excessive winds. Most susceptible to wind, are corn plants that are in rapid canopy growth stages, prior to pollination. Green snap is not a rare phenomenon, but relatively few acres are affected in most years. It is predominantly seen in the western and northern Corn Belt when rapid corn growth is mixed with high wind speeds.

Green snap can be seen from the lower nodes (close to the soil surface) and nodes at or above the ear. During accelerated growth, stalk internodes elongate rapidly, and the node and internode tissue is packed with water. Cell walls have not matured, and very little structural lignin has been deposited. Water-packed cell walls are quite fragile. It is at this stage that the corn plant is susceptible to high winds and breakage at the nodal "plates". Hybrids vary in tolerance to green snap and the growth stage plays a significant role in potential breakage and yield reduction.

SIMULATED GREEN SNAP STUDY

A study was conducted at York, NE, in 2021 to help understand the yield loss potential of modern hybrids associated with high wind, green snap events. Corn hybrid G11V76-5122 with a semi-flex ear rating was used for this study. A pruning shear was used to cut the corn one node below the estimated ear node at approximately the V13-V14 growth stage in four row treatment blocks with

randomized damage ranging from 0% to 70%. The corn was monitored throughout the growing season with yield taken from all entries at 17% moisture using grain weight.

YIELD LOSS ASSOCIATED WITH GREEN SNAP

Yield loss associated with green snap is based on where on the plant the breakage took place along with the number of plants affected. Stalks breaking above the ear may still produce an ear, but that ear may be restricted due to shading from nearby unaffected plants and loss of plant leaf area. Stalk breakage below the ear usually results in the complete loss of a harvestable ear. For this study, all breakage was simulated below the ear node. This loss of harvestable ears per acre is the primary cause of yield loss associated with green snap. Research has differed in yield loss potential from green snap over time. The University of Nebraska-Lincoln concluded that yield loss decreases approximately 1% for every 1% in stalk breakage (1:1 ratio).¹ However, several subsequent research studies have suggested that the yield loss from stalk breakage is generally much less severe with modern corn hybrids.

EFFECTS OF SIMULATED GREEN SNAP

The study at York showed yield loss less severe than the previously published Nebraska trials (Table 1). The simulated study saw yield losses of 0.6-0.76% for every 1% of plants broken with increasing yield loss as stalk breakage severity increased. Iowa State University (ISU) conducted similar trials assessing green snap and observed similar results as found in the Golden Harvest

STALK BREAKAGE PERCENTAGE	YIELD (BU/AC)	YIELD % OF CHECK
70% Breakage	121	53%
50% Breakage	161	37%
30% Breakage	210	18%
0% Breakage	256	

Table 1. Simulated stalk breakage data from York, NE, study

simulated trial with percent-broken:percent-yield reduction ratios ranging from 1:0.5 to 1:0.73, both being lower than losses previously published.²

SUMMARY

With only one year of data, specific conclusions should not yet be drawn. However, as the percentage of plant breakage went up, the yield reduction percentage also increased. Information from this small study, along with others, suggests that yield reductions vary. Also, modern corn hybrids have the ability to compensate slightly for the loss of neighboring plants.³ If green snap occurred above the ear, the plant is still likely to produce grain, although less than before, resulting in even less negative yield reduction.



Figure 1. Green snap study plot at York, NE



Figure 2. Fifty percent green snap 2021 trial plot in York, NE

SIMPLIFYING REPLANT DECISIONS

INSIGHTS

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

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

1. Determine Existing Stand

To estimate the stand, count the number of healthy plants in a length of row that equals 1/1,000th of an acre (Table 1) and multiply the number of plants by 1,000. Take several counts throughout the field to get an accurate final stand. If stand loss is occurring in distinct zones, focus stand count measurements only in those areas of replant consideration. A newer alternative to manually scouting fields is to leverage

ROW SPACING	LENGTH OF ROW
INCHES	FEET INCHES
15	34' 10"
20	26' 1"
22	23' 10"
30	17' 5"
36	14' 6"
38	13' 10"
40	13' 1"

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

remote sensing to quickly collect field data and identify areas where stand establishment was a problem. Golden Harvest and DroneDeploy have partnered to deliver real-time estimates of established stands using drone imagery collected by local Golden Harvest agronomists. DroneDeploy software can accurately estimate the number of plants and skips per acre anytime between the V2-V5 corn and soybean growth stages and generate customized reports (Figure 1) to determine approximate stand counts and variation in plant establishment across a field.

2. Estimate Replant Yield Potential and Compare to Potential of Existing Stand

Previous Golden Harvest planting date trials have been used to estimate the percent yield potential of delayed planting dates compared to retaining a reduced stand from an earlier planting date (Table 2). Additional factors contribute to a replant decision, such as crop insurance, the cost of replant seed, seed availability, potential pest problems, nitrogen program, cost arising from higher grain moisture at harvest and more. The cause of the original stand loss is also important. If the poor stand is due to fertilizer injury, herbicide injury, disease or insect infestation, there



PERCENT YIELD POTENTIAL OF CORN BY EMERGED STAND AND PLANTING DATE						
Northern Corn Belt Trial Response / South Corn Belt Trial Response						
ESTABLISHED STAND	PLANTING DATE					
	MAY 1 AND EARLIER	MAY 10	MAY 20	MAY 30	JUNE 10	
≥ 32,000	100 / 100	96 / 98	85 / 92	77 / 86	69 / 80	
28,000	97 / 97	93 / 95	82 / 89	75 / 83	67 / 78	
22,000	90 / 90	86 / 88	77 / 83	69 / 77	62 / 72	
16,000	82 / 82	79 / 80	70 / 75	63 / 71	57 / 65	
10,000	70 / 70	67 / 69	60 / 64	54 / 60	48 / 56	

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

Table 2. Percent yield potential

is potential for the replanted crop to also be affected. To simplify decisions, Golden Harvest has created a replant calculator that compares all input costs, as well as yield loss assumptions, using state university data specific to local areas.

3. Decide if Relative Maturity should be Reduced for Replant

Once the decision to replant corn has been made, selecting the maturity of the new hybrid is important. Choose a hybrid that can reach maturity prior to the first frost. Although the growing season has been shortened in replant situations, hybrids compensate for planting date and will reach black layer within fewer growing degree units than if planted earlier. There may

not be a need to switch to earlier maturing hybrids since the increased yield potential of a fuller season hybrid typically outweighs costs of drying grain. If grain drying is not an option, slight reductions in RM may be advisable. Based on drying costs, expected yield and corn prices, suggestions based on Golden Harvest Agronomy Research trials are :

- Plant full-season hybrids adapted for a given area until the last week in May.
- Change to a mid-season hybrid (4-7 RM earlier than full-season hybrid) the last week in May.
- Never switch to hybrids 8-11 RM earlier than adapted full-season hybrid unless drying grain is not an option.

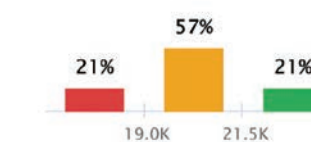


Stand Count Report

Crop Report Plan - 05/13/2021

Pilot: David Schlake | Images Captured: 20 | Flight Plan: Crop Report | Acres: 21

Site Population



Summary

Median Population
20,000/ac

Crop Type
Corn

Median Spacing
9.16"

Median Gap Count
3,583/ac

Map



Figure 1. Example stand count report utilizing drone technology

CORN RESPONSE TO PLANTING DATE AND RELATIVE MATURITY

INSIGHTS

- Corn yields declined rapidly when planting after the last week of May.
- Full-season hybrids maximized yield at all planting dates except the first week of June.
- Later planted corn required fewer growing degree days to reach maturity making it possible to maintain similar relative maturity (RM) hybrids as with earlier planting dates.

PLANTING DATE EFFECTS

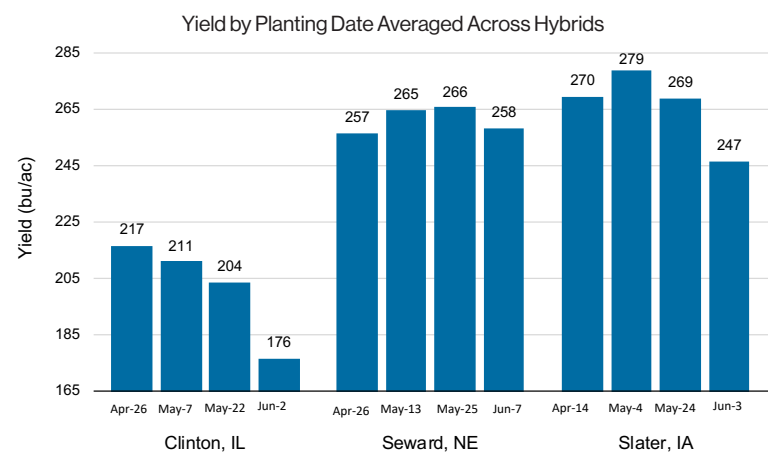
The greatest opportunity for high yield potential in corn comes from planting a full-season relative maturity hybrid early! Later planting dates generally decrease yield potential, increase kernel moisture, and speeds up corn plants vegetative development. Increased grain moisture from delayed planting also often results in reduced test weight. Test weight is a volumetric measurement that can be influenced by the size, shape and density of kernels. Stress from disease and insect damage, in addition to an early frost, can lower test weights by prematurely ending the grain fill period.²

AGRONOMY IN ACTION TRIALS

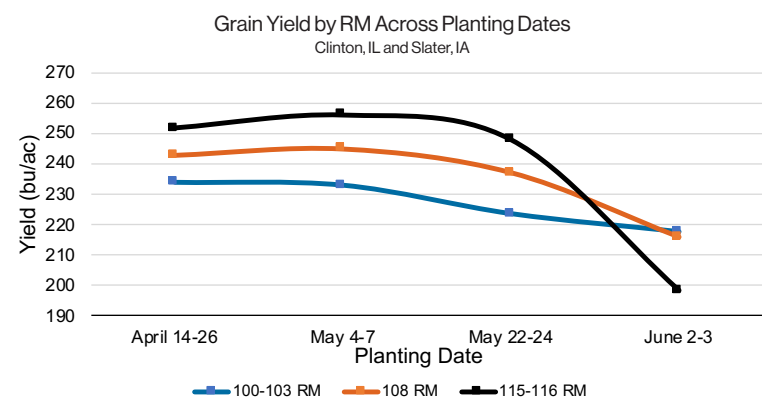
Golden Harvest® Agronomy In Action research trials studying corn planting date were established at 3 separate locations in Illinois, Iowa and Nebraska in 2021 (Figure 1). Two hybrids were selected within early (100-103 RM), mid (108 RM), and late (115-116 RM) groups to better understand hybrid response to planting dates. The first date was planted in the last half of April as soil conditions allowed, and the subsequent three planting dates were performed at two-week intervals thereafter. Each of the four planting dates were replicated four times in a split-plot design, where hybrids were grouped by maturity at each



Figure 1. Corn planting date trial in Clinton, IL, 2021



Graph1. Yield response from planting date in 2021 at three locations (averaged across RM)



Graph 2. Comparison of different RM hybrids at four planting dates in 2021

site. Flowering and black layer dates were recorded for each plot, and trials were harvested with a research combine to assess yield, moisture and test weight. All planting dates were harvested when the earliest maturing hybrid in the first planting date reached 15.5% moisture.

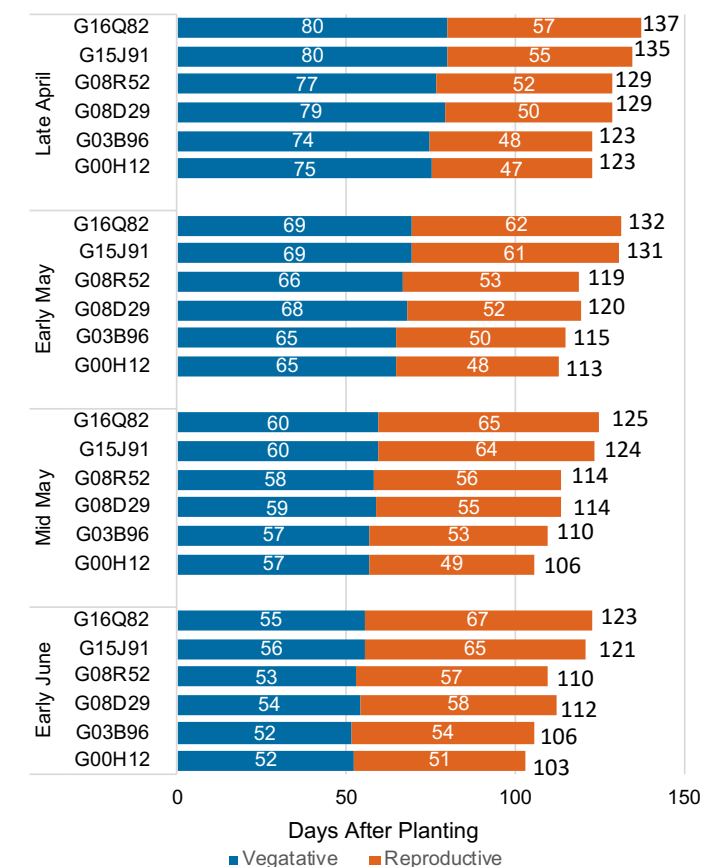
EFFECT OF PLANTING DATE ON CORN YIELD

In all 2021 trials, April and May planting dates generally yielded similarly at all three locations except for Clinton, IL, where yields started to decline more rapidly with the May 22 planting date (Graph 1). Yields started declining more rapidly when planting was delayed until the first week of June except for at Seward, NE, where there was little difference among planting date yields. Planting fuller season hybrids through May 24 provided yield advantages over mid (108 RM) and short (100-103 RM) season hybrids (Graph 2) at Clinton, IL, and Slater, IA. After May 24, mid- and short-season hybrids yielded similarly, although short-season hybrids had the benefit of drier grain at harvest. Adjustments in RM prior to the last week of May were not warranted other than for grain moisture benefits.

WAYS HYBRIDS ADJUST TO PLANTING DATE

June planting dates were seeded roughly 51 days after, yet reached maturity within 26 days of the April planting dates, indicating fewer growing degree units (GDUs) were needed to reach black layer with late-planted corn. The ability of corn plants to reduce the total number of days needed to reach maturity was achieved by shortening the total amount of time normally spent growing vegetatively by 20-25 days as compared to April planting dates (Graph 3). However, reproductive growth stages increased slightly in days with each delay in planting date, although fuller season hybrids always maintained a longer reproductive period than shorter hybrids at all planting dates. Full-season hybrids utilize the extended grain fill time to translocate sugars, which are converted into starch in developing kernels typically resulting in additional yield potential. Planting full-season hybrids early also usually allows plants to flower in advance of heat or drought stress and reach physiological maturity earlier in the fall. Reaching physiological maturity earlier in the fall creates more opportunity to utilize warmer August temperatures to reduce grain drying costs and increase overall profitability. Uncertainty of harvest weather conditions and overall grain handling capacity can be reasons to select multiple RM's to spread out workload and ease drying costs in later planted corn.

Planting Date Influence on Days in Vegetative and Reproductive Stages Averaged across Clinton, IL & Slater, IA



Graph 3. Planting date influence on days in vegetative and reproductive stages

In general, as planting date was delayed, harvest grain moisture increased across all hybrids. Grain test weight declined steadily as planting date was delayed. Earlier planted corn had more time for starch development in the kernel, leading to an overall increase in test weight.

SUMMARY

Regardless of planting date, choosing a high yielding hybrid that is adapted to a given environment is the first step in maximizing yield potential. Fuller season hybrids should be utilized as much as possible prior to the last week of May to help extend the grain fill period and maximize yield potential. Relative maturity selection strategies should attempt to plant the fullest season hybrids for the area while also considering factors such as harvest and grain drying capacity. Areas with higher fall frost risk may need to transition quicker to earlier RM hybrids, although reducing 5-6 RM earlier than a normal full-season hybrid is usually sufficient.

CHARACTERIZING HYBRIDS FOR RESPONSE TO INTENSIFIED MANAGEMENT

INSIGHTS

- Hybrids should be selected based on grower management style, or management adjusted to fit the hybrid.
- Understanding elasticity of kernel number and weight can help characterize hybrid response to management.
- Intensified management can increase grain yield potential and sometimes improve hybrid agronomics.

Hybrids 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 farms, but also aid in management decisions throughout the growing season.

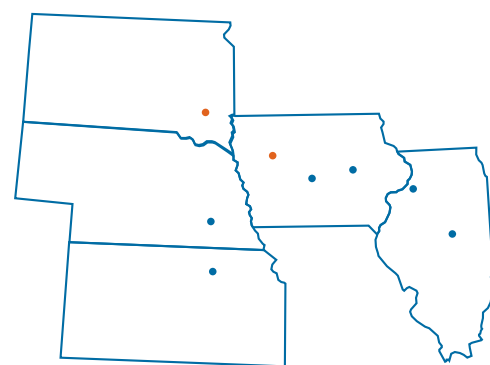
Corn grain yield is the product of plants per acre, kernels per plant and weight per kernel. Plant population is the yield component most under the farmer's control. Kernels per plant and weight of individual kernels are mostly affected by environmental conditions but can also be influenced through agronomic management practices. From V4-V16 the number of kernels the ear will produce is being set. However, if stress occurs during grain fill, kernel abortion or "tip-back" can reduce the number of kernels previously produced. Kernel weight can also be influenced by stress during the grain-filling process.

Understanding when in the life cycle of the corn plant each of the yield components is determined can help farmers make management decisions based on specific hybrids. For example, if a hybrid is known to set a high number of kernels per plant but typically produces lighter kernels, focusing on management practices such as sidedressing nitrogen (N) and applying foliar fungicides can help

improve late-season plant health and kernel weight. On the other hand, if a hybrid produces fewer kernels but with more weight per kernel, early-season management such as planter-applied fertilizer may reduce early stress, triggering higher kernel counts per ear. Knowing how a given hybrid responds, whether it be in kernel number or kernel weight, can provide guidance on hybrid management regarding environmental stresses.

AGRONOMY IN ACTION RESEARCH TRIAL

In 2021, the Golden Harvest Agronomy in Action research team implemented a trial to characterize Golden Harvest hybrids for their response to intensified management. Five hybrids suited for the given geography were planted in three management systems at both 34,000 and 44,000 plants per acre (Figure 1).



SHORT-SEASON HYBRIDS	FULL-SEASON HYBRIDS
G02K39	G10D21
G03B96	G10L16
G03R40	G12S75
G07G73	G13P84
G08R52	G15J91

Figure 1. Corn trial locations where the short-season hybrid set was planted in orange and full-season hybrid set in blue

The three management systems included:

- Farmer standard**
 - Farmer's normal fertility practice
 - No fungicide application
- Early-season management** (Figure 2)
 - Farmer standard +
 - In-furrow 6-24-6-.25Zn applied at 5 gal/acre
 - UAN (32-0-0) surface dribbled 3 inches on each side of the row with planter at 17 gal/acre and ATS (12-0-0-26S) at 5 gal/acre
 - 2x2x2 placement of NACHURS Triple Option® (4-13-17-1S) at 15 gal/acre
- Early + late-season management**
 - Early-season management +
 - UAN sidedressed at 60 lbs of N/acre surface banded next to the row on both sides at V5-V6 timing
 - R1 foliar fungicide Miravis® Neo



PLACEMENT	N	P ₂ O ₅	K ₂ O	S	ZN
	LBS/ACRE				
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

Figure 2. Visual image and table showing the amount of nutrients applied with the planter and the placement of the fertilizer in relation to the seed for early-season management

At harvest, grain yield was recorded, and subsamples of the harvested grain were collected. Grain subsamples were used to measure the weight of individual kernels and calculate the number of kernels per area.

TRIAL RESULTS

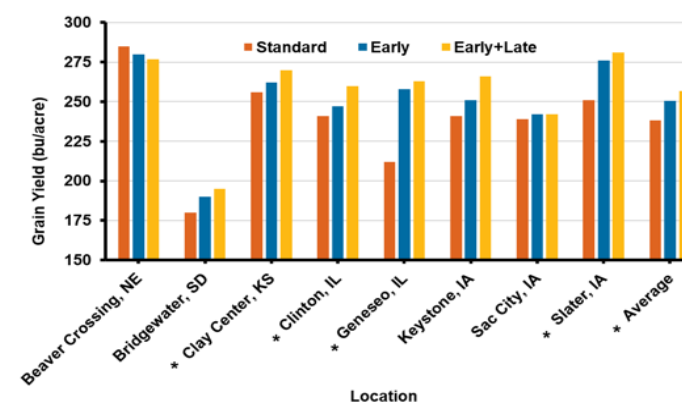
There was a significant effect of management system on grain yield at 4 of the 8 locations (Graph 1). Slater, IA, and Geneseo, IL, were the two locations where hybrids



Figure 3. Image compares standard management on left to early + late-season management on the right at Geneseo, IL

responded the greatest to early-season management increasing yield by 24 and 46 bu/acre, respectively. Plants that received planter-applied fertilizer were visually greener, taller, and one growth stage more advanced compared to the farmer standard (Figure 3).

Responses to early-season management may not always require an increase in fertilizer rate. Reallocating a portion of current broadcast fertilizer into a precision placement near the seed is the key. Precision fertilizer placement increases availability to plants and improves nutrient efficiency to help drive yield responses with equivalent or sometimes reduced overall rates.



* Significant effect of management system on yield at $\alpha = 0.05$.

Graph 1. Yield response to management at 8 locations averaged across 5 hybrids and 2 populations

Hybrids planted at Clinton, IL, and Keystone, IA, tended to respond more to additional nitrogen applied at V6 followed by an R1 foliar fungicide application. No yield response was observed at Beaver Crossing, NE, likely due to adequate fertility, and irrigation creating a low stress environment as indicated with standard management yields exceeding 280 bu/acre.

On average across all locations there was a 13 bu/acre yield advantage to the early-season management system over the standard management system. Adding late-season management to the early-season management system increased yields by an additional 6 bu/acre.

ALL HYBRIDS ARE NOT CREATED EQUAL

When averaged across all locations, there was a significant interaction between hybrid and management system as well as hybrid and population for the full-season hybrid set (Table 1).

G10D21 was the most responsive hybrid to increased population. In a standard management system, the yield

response to the higher population was 7 bu/acre whereas in the early-season management system the population response was 14 bu/acre. Management system also had a significant effect on G10D21, increasing yields 18 bu/acre with early-season management and an additional 5 bu/acre from fungicide and nitrogen sidedressing when averaged across populations.

Despite G10L16 and G10D21 both being 110-day relative maturity hybrids, they are quite different in how they should be managed. G10L16 did not respond to population and had a marginal response to additional fertility and foliar protection. Although G10L16 yield responses were minor, plant health and agronomic improvements from management were huge. The more intensive fertility program at Geneseo, IL, greatly reduced the degree of lodging of G10L16 caused by high seeding rates and late-season winds (Figure 4). In addition, the foliar-applied fungicide reduced leaf disease symptoms and improved plant health.

G15J91 was the most responsive hybrid to both early-season management and the addition of late-season

HYBRID	34,000 (PLANTS/ACRE)			44,000 (PLANTS/ACRE)		
	Standard	+ Early Management	+ Late Management	Standard	+ Early Management	+ Late Management
Short-Season Set	bu/acre	bu/acre +/- from standard	bu/acre +/- of Early Management	bu/acre	bu/acre +/- from standard	bu/acre +/- of Early Management
G02K39	199	-2	+11	199	+12	+3
G03B96	197	+4	+7	206	-2	-5
G03R40	208	+14	-1	217	-2	-14
G07G73	217	+9	+2	213	+7	+13
G08R52	225	+6	+3	214	+20	+1
Full-Season Set	bu/acre	bu/acre +/- from standard	bu/acre +/- of Early Management	bu/acre	bu/acre +/- from standard	bu/acre +/- of Early Management
G10D21	246	+14	+4	253	+21	+5
G10L16	251	+8	+5	255	+4	+6
G12S75	257	+14	+2	254	+15	+11
G13P84	243	+12	+5	249	+13	+14
G15J91	234	+24	+9	236	+17	+15

Table 1. Hybrid yield response to plant population and management system averaged across 2 locations for the short-season hybrid set and 6 locations for the full-season hybrid set

Short-season set LSD (0.05) = NS

Full-season set LSD (0.05) = 9



Figure 4. Images from Geneseo, IL, illustrating how management can improve agronomic characteristics of hybrid G10L16. Top left is standard management at 34,000 plants/acre. Bottom left is standard management at 44,000 plants/acre. Top right is early + late-season management at 34,000 plants/acre. Bottom right is early + late-season management at 44,000 plants/acre.

management. Planter-applied fertilizer increased yield by 21 bu/acre and sidedressed nitrogen followed by a foliar-applied fungicide increased yield by an additional 12 bu/acre, averaged across both seeding rates. G15J91 prefers early fertility to set a high yield potential and foliar protection to maintain it. Interestingly, a high population was not needed to achieve maximum yield potential. The short-season hybrid set did not have a significant interaction between hybrid and management system or population. Hybrid responses were less consistent between the two locations compared to the full season set with six locations.

Both G07G73 and G08R52 tended to show good response to management at 34,000 plants/acre. However, at the higher population, late-season management was critical to maintain yield potential for G07G73 while intensive early-season fertility was key to increasing yield potential for G08R52.

HYBRID YIELD COMPONENT ELASTICITY

Hybrid yield components, both kernel number and weight, can be useful to predict when yield response from management may occur in a hybrid.

The G10D21 yield increase from early-season management was driven by an increase in kernel number (Table 2). Increases in kernel number with this hybrid commonly come by forming a second viable ear in absence of stress. It has the potential to produce a lot of kernels with proper fertility and has the agronomics to fill those additional kernels with late-season plant health.

G15J91 is unique in that it has tremendous flex in both kernel number and kernel weight to both early and late-season management. The ability of this hybrid to flex greatly to management is likely the reason why it does not respond to population. It can flex its ear depending on the degree of stress from plant population or environmental conditions.

Yield potential increases from the addition of late-season management with G07G73 was not driven by kernel weight but rather an increase in kernel number. This would suggest the yield response was likely from the additional 60 lbs of N/acre sidedressed which mitigated nitrogen stress from R1-R3 and reduced kernel abortion. If weather is causing sidedress delays, effort should be focused on G07G73 first when conditions improve.

G08R52 had an increase in kernel number and kernel weight resulting in the yield increase to early-season management. The enhanced plant nutrition with planter-applied fertilizer not only set a higher yield potential but the healthier and more robust plant was able to fill those additional kernels.

CONSIDERATIONS FOR FARMERS

Golden Harvest is committed to providing information on how hybrids respond to different management systems. Informed farmers can use this information to either select hybrids that match their management style or adjust their management system to fit their hybrids. If a farmer is not set up to provide early nutrition near the seed, then selecting a hybrid that varies kernel number based on management might be risky. A hybrid that flexes kernel weight may be a better fit to management style. On the other hand, if a farmer is set up well to provide season-long management but cannot get across all the necessary acres due to weather delays, this information can be used to identify hybrids that may respond to nitrogen or foliar disease management.

HYBRID	KERNEL NUMBER		KERNEL WEIGHT	
	+ Early Management	+ Late Management	+ Early Management	+ Late Management
Short-Season Set	kernels/ft² +/- of Standard	kernels/ft² +/- of Early Management	oz/1000 seed +/- Standard	oz/1000 seed +/- Early Management
G02K39	+5	+7	+0.10	+0.09
G03B96	+11	-4	-0.18	+0.17
G03R40	+13	-23	-0.01	+0.07
G07G73	+6	+20	+0.21	-0.12
G08R52	+12	+1	+0.32	+0.10
Full-Season Set	kernels/ft² +/- of Standard	kernels/ft² +/- of Early Management	oz/1000 seed +/- Standard	oz/1000 seed +/- Early Management
G10D21	+28	-2	+0.11	+0.18
G10L16	+2	+4	+0.19	+0.12
G12S75	+13	+1	+0.22	+0.22
G13P84	+1	+17	+0.42	-0.02
G15J91	+21	+18	+0.32	+0.10

Table 2. Hybrid yield component response to management system averaged across 2 populations and 2 locations for the short-season hybrid set and 6 locations for the full-season hybrid set

Short-season set kernel number LSD (0.05) = NS

Short-season set kernel weight LSD (0.05) = NS

Full-season set kernel number LSD (0.05) = 6

Full-season set kernel weight LSD (0.05) = NS



Figure 5. Response to planter applied nutrients at Geneseo, IL trial location. Stark differences due to insufficient soil sulfur levels at site.

SEEDING RATE MANAGEMENT TO OPTIMIZE CORN YIELDS

INSIGHTS

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

Yield potential of corn hybrids continue to increase yearly with introduction of new genetics. It is easy to credit these gains entirely to breeding efforts, however the change of management practices such as seeding rates have also played a critical role in yield gains.

Average seeding rates have increased by over 24% in the last 30 years, although this would not have been possible without advances in stress tolerance through breeding. Due to this continued trend and the inherent differences in how hybrids respond to seeding rate (Figure 1), the Golden Harvest® Agronomy In Action research team has conducted trials (Figure 2) since 1992 to provide hybrid specific guidance on seeding rates. Determining the best seeding rate for a field or zones within a field is not a simple process and requires understanding of multiple factors that drive final outcome.

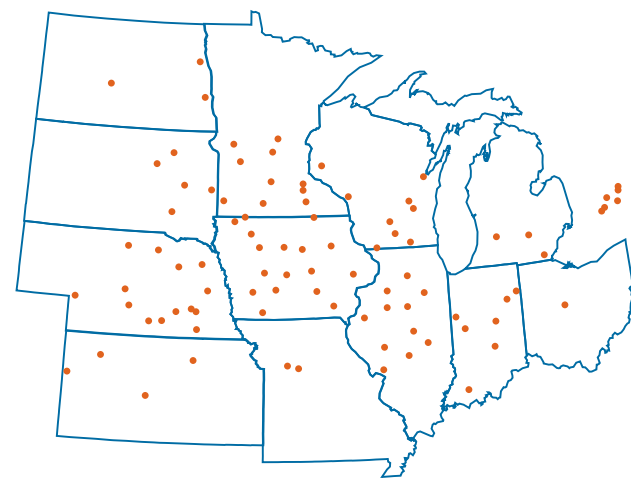
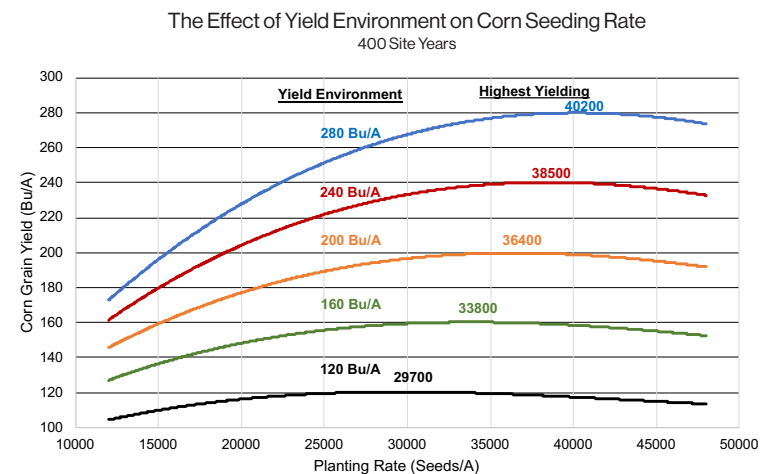


Figure 2. 2021 replicated corn Seeding rate trial sites



Graph 1. Yield environment influence on seeding rate

POPULATION RESPONSE FACTORS

1. Yield Environment

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

2. Hybrid Response

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

3. Economic Factors

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

DETERMINING OPTIMUM SEEDING RATES

1. Table 1 estimates the optimum seeding rate for anticipated yield potential and grain pricing. When estimating yield environment, consider the proven historical yield of the field across multiple years.

Example: A 200 bu/A yield environment and \$4.00/bu grain price = 32,300 seeds/A optimum seeding rate.

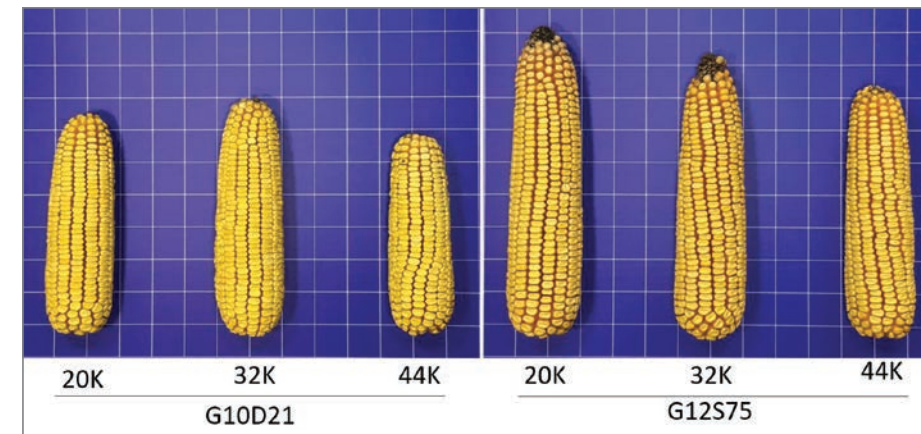


Figure 1. Hybrid differences in response to changing seeding rates

2. Work with a local Golden Harvest® Seed Advisor to adjust seeding rate up or down from optimum found in Table 1 for specific hybrids based on Golden Harvest multi-site and multi-year seeding rate trial results.
3. Consider individual hybrid root and stalk strength scores to determine if the hybrid will have suitable agronomic characteristics to support increased seeding rates (lower scores indicate more suitable).
4. For more insight, use the Golden Harvest Corn Seeding Rate Selector tool to help estimate the most economical seeding rate for individual hybrids and yield environments.



one year of data helps to better account for outlier years caused by drought or flood prone areas. When yield data isn't available, soil productivity data can be useful in predicting areas of the field with different potential. Small increases and decreases in seeding rates with higher and lower yield zones will typically help maximize returns on investment potential, but always take individual hybrid characteristics into consideration.

TIPS FOR DEVELOPING A FIELD PRESCRIPTION

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

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

CREATING VARIABLE RATE PRESCRIPTIONS

Most planters now offer a way to vary seeding rates to specific zones within a field. Many sources of data are available to help interpret zone productivity such as: fertility, drainage, topography, NDVI imagery, soil type and yield maps. Multiple years of individual field yield data will best predict high and low yield zones. Using more than

YIELD ENVIRONMENT (BU/A)	HIGHEST YIELDING SEEDING RATE (SEEDS/A)	OPTIMAL SEEDING RATE (SEEDS/A) BY COMMODITY PRICE (\$/BU) (SEED COST = \$200/80K UNIT)		
		\$3.00	\$3.50	\$4.00
280	40200	36600	37100	37500
240	38500	34100	34700	35100
200	36400	31000	31700	32300
160	33800	26900	27700	28400
120	29700	20900	21900	22700

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

COVER CROP CONSIDERATIONS

INSIGHTS

- Timely establishment and termination of cover crops is key to realizing benefits without yield reduction.
- Hybrids may respond differently to cover crops.

Cover crops have quickly become a well-established practice over the last decade. The latest USDA Census of Agriculture done in 2017 reported cover crop acres at 15.4 million, a 50% increase from 2012. Eight states doubled cover crop acres over that same timeframe. Use of cover crops is growing in part due to their ability to build soil organic matter, improve soil structure, reduce erosion and help suppress weeds. Cereal rye is one of the most popular cover crop species being used. However, it may negatively impact corn production if not managed correctly. There are factors to consider when using cereal rye cover crops prior to planting corn.

CEREAL RYE CONSIDERATIONS

- **Reduced soil moisture:** Drought-prone soils could be dried out further by rye moisture uptake.
- **Increased pest pressure:** Delaying termination of rye until after planting can result in a “green bridge” for disease and insects to relocate from cover crop to newly seeded crop after die-back begins. Pythium, wheat stem maggot, black cutworm and armyworm have been observed to cause worse crop damage after cover crop termination.
- **Reduced nitrogen availability:** Corn planted directly into green rye can often have a yellow, sickly appearance when emerging. It is believed that previously applied nitrogen may be tied up in the rye cover crop and not available until the rye dies and begins to be mineralized back into the soil.
- **Allelopathy:** Allelopathic chemicals are released by rye and are known to inhibit germination and early growth of many smaller-seeded plants. Terminated rye begins to degrade and release allelopathic chemicals into the upper soil surface. Field effects of allelopathic



chemicals on large-seeded crops like corn and the impact on germination and early growth are not well understood. Lab studies have indicated a possibility of reduced early growth or germination; therefore, it is often recommended to terminate rye at least 2 weeks before planting.

- **Hybrid sensitivity:** There is not a great understanding as to why corn planted into rye will sometimes have a negative yield impact. The effect of rye mulch on soil warming and drying, in combination with other factors such as nitrogen tie-up and soil pathogens, likely all interact to potentially create a negative response. Due to this, understanding the reason for hybrid differences is even more challenging.

2021 HYBRID AND COVER CROP INTERACTION TRIAL

An exploratory trial was established at Seward, NE, in 2021 to better understand differences in hybrid sensitivity to planting following a cereal rye cover crop. Nitrogen was applied pre-plant in spring of 2021 at a rate of 180 lbs per acre. Twenty hybrids ranging from 106- to 115-day relative maturity (RM) were planted on April 16 within randomized strips with no cover crop and strips with cereal rye that was established in October 2020. Corn was planted into green cereal rye 2-3 inches in height with stems beginning to elongate. Termination of the cereal rye was attempted immediately following planting with a burndown and preemergence herbicide program. However, due to cool and wet weather following application, a second herbicide application 2 weeks after planting was necessary to achieve complete termination of the cereal rye.

TRIAL RESULTS

Areas planted into cereal rye and areas without cover crops both established similar final plant stands, although early growth and development in cover crop strips was delayed by roughly one leaf stage early in the trial. On average, hybrids planted into cereal cover crops at Seward yielded 7% less than if planted into no cover crop. Yield losses were higher than anticipated considering the robust nitrogen rate applied in spring and the relatively

small amount of mulch that was present at time of planting. Individual hybrid yield loss associated with cereal rye ranged from 1-15%. Hybrids indicated with asterisks were more severely affected (Table 1). Interestingly, hybrids in 106-109 RM were impacted more negatively (9.6%) than fuller season 113-115 RM hybrids which averaged a 4% yield loss. Hybrid management decisions based on this single trial should be limited, although results are pronounced enough that future trials will be conducted to understand if hybrid differences are repeatable.

Hybrid	Yield		Δ Difference	α	
	No Cover	Cereal Rye		0.05	0.1
G06Q68-5222	232.6	207.7	24.9		*
G07F23-3111	251.2	235.7	15.5		
G07G73-5122	247.7	218.1	29.6		*
G08D29-5122A	252.6	215.5	37.1	*	*
G08R52-3220	263.6	239.4	24.2		
G09Y24-5222A	239.1	226.4	12.7		
G10D21-5332	247.3	230.4	16.9		
G10L16-5122A	267.6	240.4	27.2		*
G11B63-3120A	237.9	235.5	2.5		
G11V76-5122	278.3	251.1	27.3		*
G12S75-5122	264.2	238.9	25.4		*
G13D55-5222	242.9	230.7	12.2		
G13H15-5122	254.3	248.6	5.7		
G13P84-3120	255.9	238.6	17.3		
G13T41-5122	261.9	249.1	12.8		
G13Z50-5222	275.7	251.4	24.3		*
G14N11-5222	264.1	258.9	5.3		
G14R38-3120	256.6	250.4	6.2		
G15J91-3220	240.2	230.1	10.0		
G15L32-5222	241.7	237.5	4.1		
Average	253.8	236.7		Δ LSD (0.10) = 24.2	Δ LSD (0.05) = 30.9

Table 1. Hybrid yields from trial with no cover crop and cereal rye cover crop

TIPS FOR PLANTING INTO GREEN COVER CROPS

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

- Allow corn or soybeans to germinate prior to terminating cover crop.
- Total nitrogen should not need to change, but timing 30-60 pounds per acre of highly available nitrogen at or around planting, close to the seed may reduce tie-up in rye.
- Apply in-furrow nitrogen containing starter or higher rates of nitrogen in 2x2, 2x2x2 or dribbled to the side of



Figure 1. Established cereal rye cover crop strips prior to planting



Figure 2. Corn emerging from cereal rye and strips without cover crops

- row at planting and consider additional early sidedress, if needed.
- Scout for insects and be prepared to manage pests that could become an issue in the emerging crop, such as armyworm and black cutworm.
- Pay extra attention at time of planting to:
 - ✓ Adjust down pressure and depth adjustment. Seed depth changes due to cover crop residue.
 - ✓ Use opening wheels, coulters, trash whippers or other planter attachments to clear cover crop debris.
- Consider planting rye cover crop into wider, 30-inch rows to allow for clean corn/soybean planting strips the following spring.
- Always make sure soil conditions are optimum for good seed germination and growth.
- Larger, maturing cover crops can be hard to control with herbicides. Ensure adequate application rates are used while plants are actively growing.
- Consider the planting restrictions of herbicides that could be used to terminate a cover crop.
- Maximize spray volume and ensure application weather conditions are good to get the best control of cover crops.
- Tillage can be an option for certain species, but multiple passes may be needed which negate the benefits the cover crop is providing.

MANAGING LATE-SEASON DROUGHT-STRESSED CORN

INSIGHTS

- Drought stress can cause a loss in yield potential anytime during the growing season, depending on duration, but is especially impactful around pollination and grain fill.
- Reduced root growth, combined with drier soils that are unable to diffuse potassium (K) into soil solution, can cause K deficiency symptoms in soils with adequate K levels.
- Evaluating corn ears a couple weeks after pollination or during grain fill helps estimate yield potential and determine if harvesting as grain or silage is most profitable.

INTRODUCTION

The chance of drought somewhere across the U.S. exists every year. Understanding drought severity, duration and stage of crop growth while under drought can be helpful in setting proper yield expectations and for determining if harvesting early as silage will provide more value than grain. Overall, monitoring conditions and yield potential of the crop throughout the season can help assess options for harvest.

EFFECTS OF DROUGHT STRESS TO CORN

Knowing the timing and duration of drought stress helps determine risk and severity of yield loss. Early-season drought often shortens plant height and limits the number of ovules (potential kernels) in developing ear shoots, but typically has minimal impact on yield potential if precipitation is received prior to pollination.

The impact of drought on yield is much greater in the weeks just prior to and after pollination. Drought occurring throughout reproductive stages can cause 10-50% yield losses depending upon what specific reproductive stage

the crop is in when stress occurs (Table 1). Drought stress just prior to silking can delay silk exertion from husks resulting in poor pollination. Asynchronization between pollen shed and silking is one of the main reasons peak yield reductions (40-50%) occur from drought stress at this timing. Drought stress occurring closer to the end of pollination commonly results in ovules not being pollinated, causing barren ear tips, or aborting kernels after pollination.

Drought stress occurring after a successful pollination can still cause premature death of leaf tissue and kernels, resulting in a shortened grain fill period and lighter kernel weights. It can also cause ear shanks to prematurely collapse, resulting in drooping ears and discontinuing movement of sugars to the ear before physiological maturity (black layer) is reached. Additional drought stress after black layer will have no impact on grain yield.

DROUGHT INFLUENCE ON NUTRIENT AVAILABILITY

In addition to drought limiting the biological processes that require water, it can also limit nutrient availability from the soil. Uptake of all nutrients can be lessened due to reduced root development under severe drought. However, of the main three nutrients, potassium (K) is the most likely to become deficient. Positively charged K cations in the soil

STAGES OF DEVELOPMENT	% YIELD REDUCTION
Early Vegetative	5–10%
Tassel Emergence	10–25%
Silk / Pollen Shed	40–50%
Blister Kernel	30–40%
Dough	20–30%

Table 1. Influence of moisture stress at various growth stages on corn grain yield.¹

solution become tightly bound to negatively charged soil particles. Reduced root growth, combined with drier soils that are unable to diffuse K into soil solution, can cause K deficiency symptoms in soils with adequate K levels.

DROUGHT INFLUENCE ON DISEASE AND INSECTS

Corn plants can be more susceptible to some very specific insects and diseases when under moisture stress. Spider mites and grasshoppers thrive in hot, dry weather, requiring a need to monitor crops closely for pest development in these conditions. Disease complexes are typically associated with wet conditions. However, there are pathogens such as charcoal rot, Fusarium root rots and rusts that favor droughty conditions and can cause significant damage. Drought conditions can also promote certain types of ear mold development and increase risk of mycotoxins in grain. Aspergillus and Fusarium molds are both more likely to occur in hot, dry years. Aspergillus is responsible for the production of aflatoxins whereas Fusarium molds have the potential to develop into fumonisins. The risk of grain infection increases when kernels are previously damaged by insect feeding. Feeding grain that has mycotoxin levels exceeding thresholds to livestock can impact milk production, reproduction and immunity. Always test grain suspected of having mycotoxins prior to feeding.

HARVEST DECISIONS FOR DROUGHT-AFFECTED CORN

Under severe drought conditions, where grain yields will be limited, it may be better to repurpose the crop as silage. Evaluating ears 7-10 days after pollen shed for developing kernels helps indicate potential grain production. Elongating silks that remain green and continue to grow



after pollen shed are a good indicator of poor pollination. Successfully pollinated kernels can still be at high risk of aborting if drought persists. If pollination is poor, or if kernels begin to abort after pollination, the field may be best considered for silage harvest.

Harvest management decisions depend on estimated remaining yield potential and risk of stalk rot development that may influence standability and harvest losses. It is important to estimate the yield potential of each individual drought-stressed field since each has unique conditions that impact yield. Also factor in crop insurance policy coverage and harvest requirements before finalizing your harvest decision.

CORN RESPONSE TO WESTERN CORN BELT HIGH PH SOILS

INSIGHTS

- Soil pH is a critical component to understanding soil nutrient availability.
- Corn hybrid response to soil pH varies by the actual pH level and from genetic tolerance.

WHAT IS SOIL PH?

Soil pH is measured using a scale of 0 to 14, with pH less than 7 considered acidic and pH greater than 7 considered alkaline or basic. pH is a measurement of the concentration of hydrogen ions.¹² Soil pH is affected by several factors. Environmental factors, such as precipitation, temperature and the soil composition, both physically and chemically, play a role in soil pH. Rain, specifically, is naturally slightly acidic due to atmospheric CO₂. The soil composition or the parent material will determine subsoil pH based on chemical composition. Other factors related to crop management also directly impact soil pH. Nitrogen fertilizers may form ammonium in the soil, which, if not absorbed by a plant, will cause soil acidification. Legumes like soybeans and alfalfa will uptake more positive-charged cations than negative-charged anions, which leads to soil acidification. The application of lime (calcium carbonate) to soil will cause a chemical



Figure 2. High soil pH symptoms still present on susceptible hybrid late in season

reaction forming a strong base (calcium hydroxide) and a weak acid (carbonic acid), making the soil more alkaline or raising the pH.

WHY IS SOIL PH IMPORTANT?

In agriculture, soil pH plays a major role in crop production. Plants obtain 14 of their 17 essential nutrients exclusively from the soil. Soil pH influences those nutrients' solubility, and thus availability, in the soil (Figure 1), leading to plant stress from deficiencies (Figure 2) or toxicities. Basic soils (pH > 7) lead to toxicity of aluminum while acidic soils lead to toxicity of manganese where these elements are present in sufficient amounts. Slightly acidic soils quickly begin to hold on more tightly to essential elements like phosphorus, calcium and magnesium, which makes them less available to the plant.

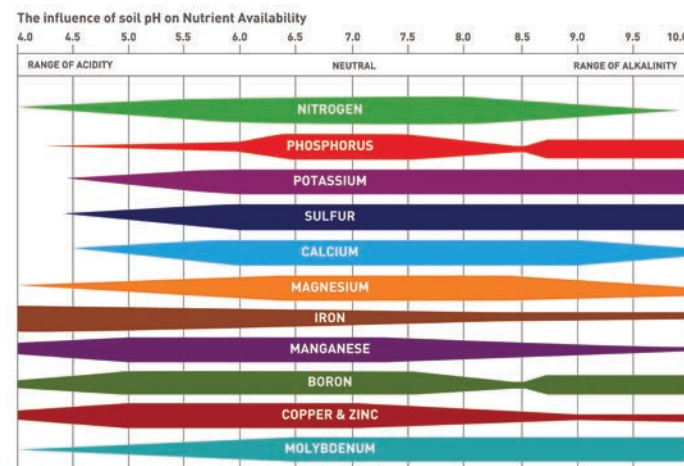


Figure 1. Soil pH effects on nutrient availability



Figure 3. Non-tolerant hybrid (left) and tolerant hybrid (right) showing how high soil pH can shorten the plants

Soil pH can also impact potential plant pests and pathogens, such as certain fungi and soybean cyst nematode (SCN). Many fungi (*Pythium* spp. in particular) seem to perform well in slightly acidic soils.³ According to Michigan State University studies, basic soils have been shown to harbor higher populations of SCN than slightly acidic and neutral soils.⁴ Low pH in soils causes many plant nutrients to be less accessible, but can also interfere with the breakdown of certain pesticides, leading to carryover issues and reduced efficacy. Low pH in soils can be managed by applying lime.

The optimum soil pH range for corn is 5.6 to 7.5. Soil pH levels of 7.8 or greater can limit corn growth and yield potential. The severity of corn response to soil pH higher than 7.8 is greatly influenced by the amount of available

calcium (also expressed as excess lime and/or percent carbonate) and sodium in the soil solution. Greater amounts of one or both of these elements are typically more detrimental to the crop. If soil pH is high enough to influence corn development, plants often appear stunted and chlorotic (yellowing leaves) and yields can be reduced. High pH tolerance due to genetic variation among corn hybrids can result in stark visual differences (Figure 3). Hybrids that are not tolerant to high pH will appear stunted and pale to bleached in color.

Hybrid selection for high pH soils requires consideration of management factors:

1. Document soil pH

- Utilize yield maps, aerial imagery and/or plant symptoms to identify potential high pH areas of a field.
- Use soil sample results to evaluate pH, excess lime rating and sodium levels. Understanding the relationship between calcium, sodium and salt in the soil is important to properly classifying a soil saline (high salt), sodic (high sodium), or saline-sodic with each classification carrying different management implications. Saline soils make water uptake more difficult and are best managed by selecting a hybrid with an optimal drought tolerance rating.
- Create a soil map from results to visualize pH distribution in the field.

2. Match hybrid to field

- Hybrid selection should be based on pH severity profile of the field (Table 1).

Consider hybrid performance, not just for pH, but also for ear and plant height. In droughty conditions, a taller plant with higher ear placement may perform better and have more harvestable ears than a shorter hybrid or a hybrid with ears too low to the ground which can be exacerbated by soil pH.

HYBRID	RELATIVE MATURITY	PLANT HEIGHT ¹	EAR HEIGHT ¹	DROUGHT PRONE ²	HIGH PH ³	HYBRID	RELATIVE MATURITY	PLANT HEIGHT	EAR HEIGHT	DROUGHT PRONE	HIGH PH
G78C29	78	4	3	2	Good	G06Q68	106	4	5	1	Fair
G80Q01	80	5	4	1	Good	G07F23	107	5	5	1	Poor
G82M47	82	4	4	3	Fair	G07V88	107	3	3	1	Fair
G85Z56	85	3	4	1	Good	G07G73	107	3	4	1	Good
G84J92	86	3	5	1	Fair	E107C1	107	1	4	2	Poor
G87A53	87	4	4	1	Good	G08D29	108	4	5	1	Fair
G88F37	88	3	5	1	Fair	G08M20	108	5	5	2	Good
G90S99	90	2	2	1	Fair	G08R52	108	5	5	1	Fair
G91V51	91	3	4	1	Poor	G09T26	109	6	4	3	Fair
G90Y04	92	2	2	1	Good	G10L16	110	5	6	1	Fair
G92A51	92	2	3	1	Good	G10K03	110	3	3	2	Good
G93A49	93	4	5	1	Fair	E110F4	110	4	3	3	Good
G94P48	94	3	2	1	Good	G11B63	111	3	3	1	Good
G95M41	95	3	4	3	Good	G11V76	111	4	6	2	Good
G95D32	95	3	4	1	Good	G12A22	112	4	3	3	Fair
G97A36	97	5	5	1	Poor	G12S75	112	2	4	3	Fair
G97N86	97	3	2	4	Fair	G12U17	112	3	3	3	Good
G98L17	98	2	2	2	Best	G13H15	113	3	3	2	Fair
G98M44	98	4	4	1	Good	G13Z50	113	4	4	2	Good
G99A37	99	3	4	2	Poor	G13D55	113	3	3	2	Good
G00A97	100	5	5	2	Good	G13P84	113	5	5	3	Poor
G00H12	100	5	5	2	Best	G14N11	114	3	2	2	Good
G02K39	102	5	5	1	Fair	G15L32	115	4	5	2	Best
G03R40	103	4	4	2	Good	G16K01	116	4	4	1	Poor
G03B96	103	4	3	3	Good	G16Q82	116	3	3	1	Good
G03C84	103	3	3	1	Fair	G17A81	117	4	3	3	Good
G05K08	105	5	6	1	Fair	G17A74	117	3	5	3	Best
G06A27	106	5	4	3	Good	G17E95	117	2	3	3	Fair

Table 1. Hybrid ratings for plant and ear height, drought tolerance, and high pH tolerance

¹Plant and Ear height based on 1-9 scale, 1= Tall, 9=Short. ²Drought Prone indicates drought tolerance on 1-4 scale, 1=Excellent drought tolerance and 4=Poor drought tolerance.

³High pH ratings, Best high pH tolerance to Poor high pH tolerance.

High Ph Ratings Chart Key: Best Good Fair Poor

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 2 of 3 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.

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, that 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% moisture¹ 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 10 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



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

trials and observations in large-scale field comparisons have repeatedly observed similar yield loss 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 industry. There is 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. Header losses are found more often as grain moisture drops below 20%.

2021 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 5 times over 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

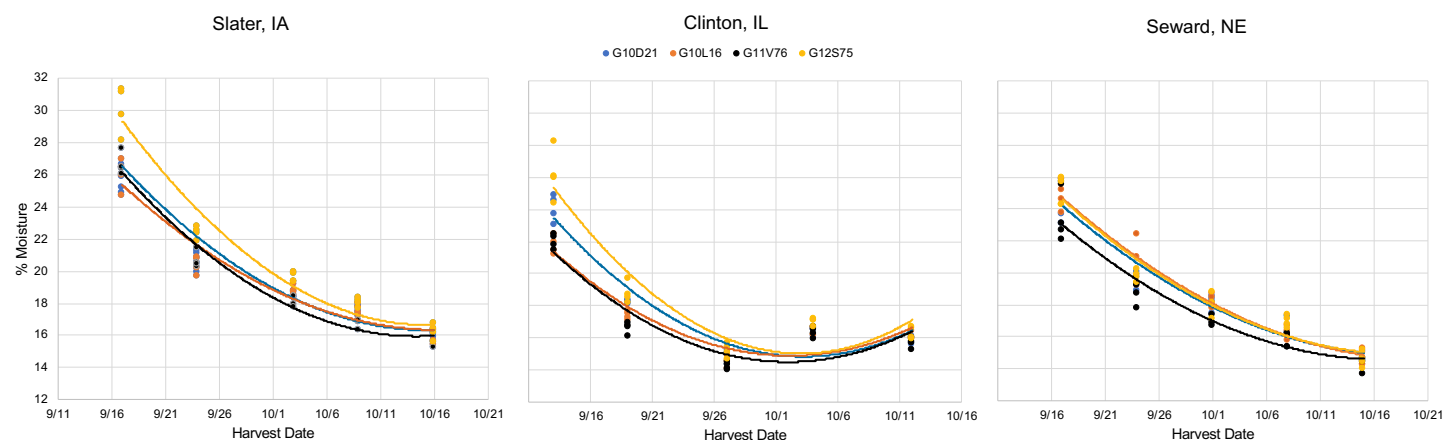


Figure 1. Hybrid drydown rates at trial locations

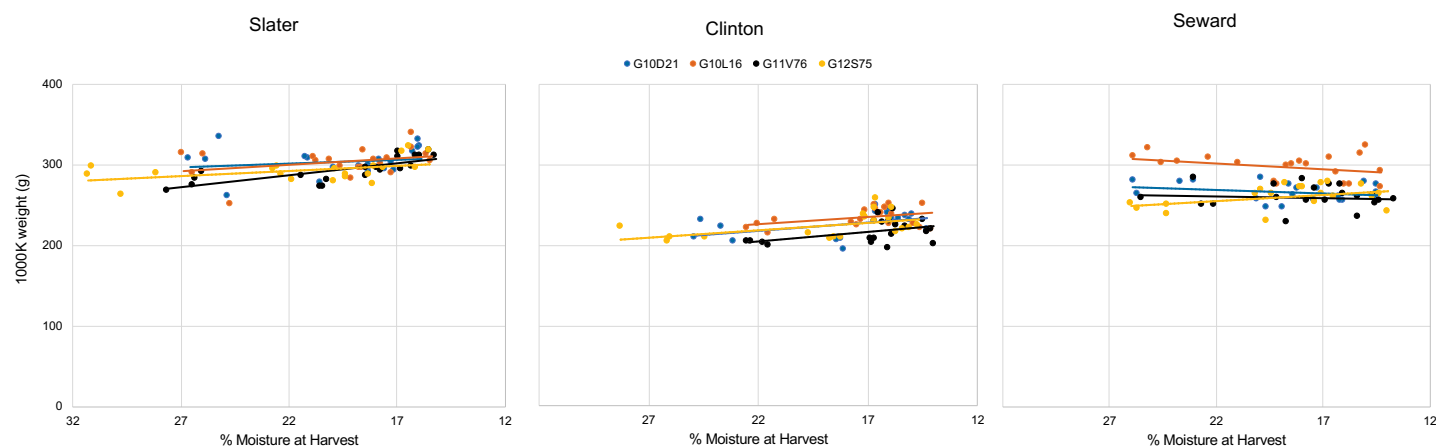


Figure 3. Kernel dry weights of individual hybrids compared to harvest moistures at trial locations

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 (Figure 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 (Figure 2). On average, trials showed a 0.6 bu/ac loss for each point of moisture removed in the field. This is similar to the 0.9 bu/ac 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 (Figure 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.



Surface residue covering 2 kernels per ft², equivalent to 1 bu/ac

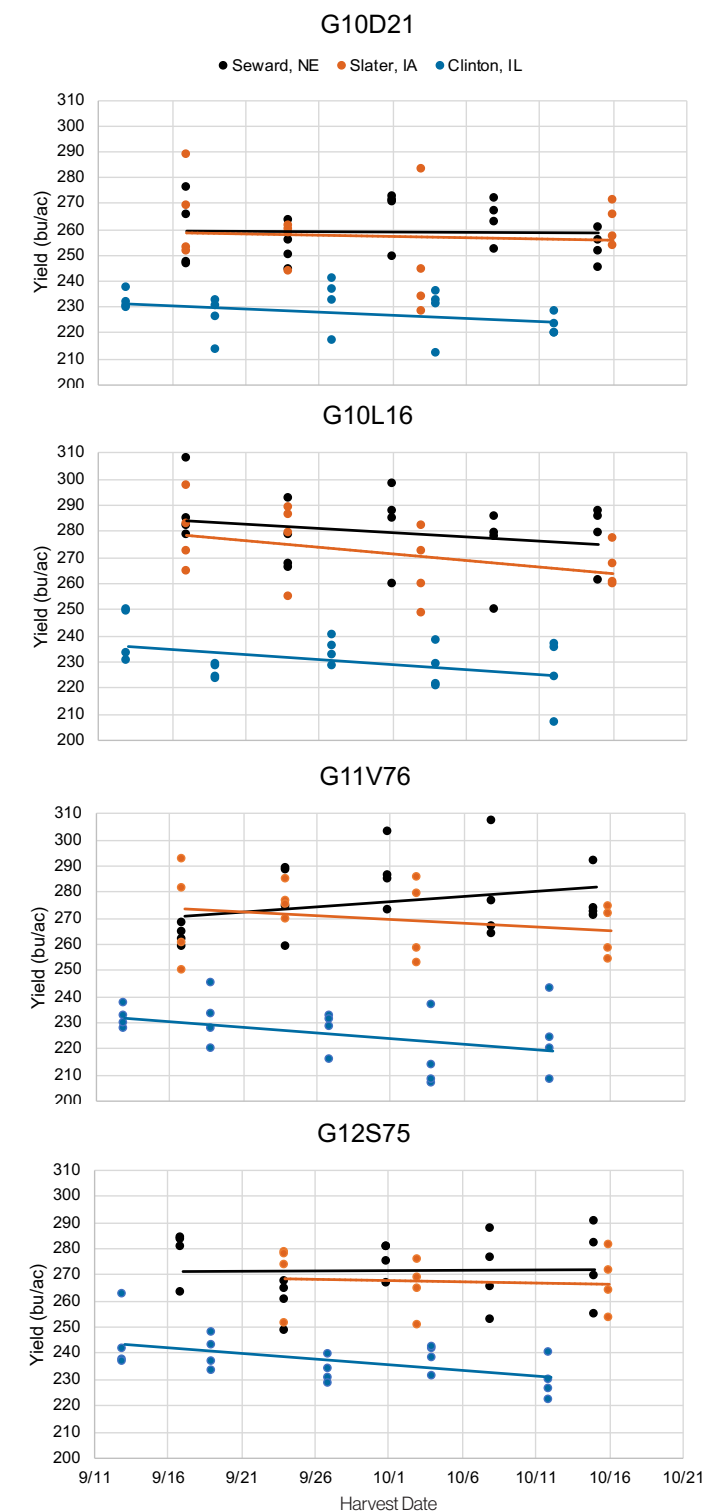


Figure 2. Hybrid yield response to harvest date

CORN HYBRID RESPONSE TO FOLIAR FUNGICIDES

INSIGHTS

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

There are many factors that go into making fungicide application decisions. Scouting and timely applications should always be the biggest drivers in the final decision. There are many levels of complexity beyond scouting that go into making farm-by-farm fungicide decisions. Golden Harvest® Agronomy in Action research conducts a yearly study that provides results to better understand the potential of individual hybrids to respond to fungicide treatment. Understanding hybrid susceptibility to a disease is extremely important in fields where disease pressure is highly predictable. It is more challenging to forecast an economic response within fields that rarely have noticeable disease presence.

ESTIMATING RESPONSE WITH LOW DISEASE PRESENCE

Fungicide trials are established each year using Miravis® Neo fungicide applied at the R1 growth stage to evaluate individual hybrid response (Figure 1). Yield response varied greatly across hybrids and locations based on differing



Figure 1. Fungicide being applied at R1, individual plots driven on were not harvested for yield

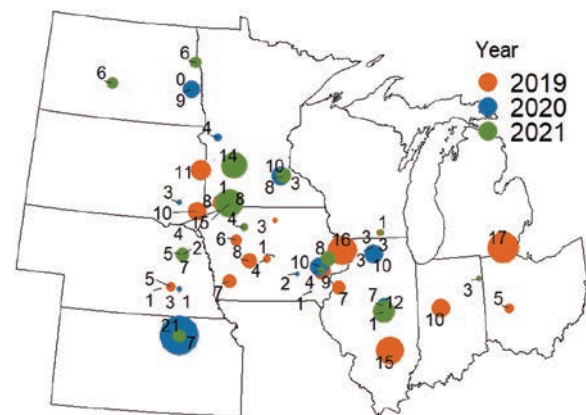


Figure 2. Differences in fungicide response across 2019 - 2021 hybrid screening trial locations; the bubble size indicates the size of response at that site

disease environments (Figure 2). The frequency and magnitude of individual hybrid response in lower disease environments was used to categorize hybrids into response categories of Best, Good, Fair and Poor.

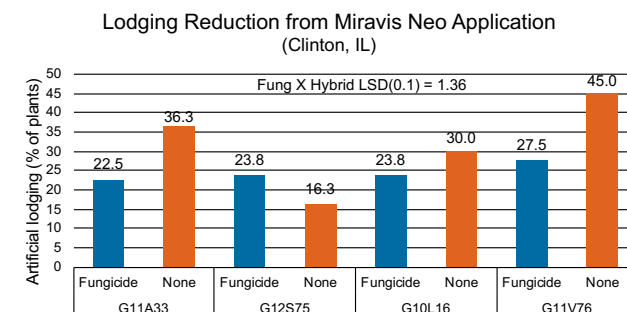
PREDICTING DISEASE RISK FOR EACH FIELD

Predicting disease can be difficult. However, timely fungicide applications prior to disease establishment almost always pay off. Selecting hybrids with good disease tolerance and utilizing foliar fungicides are important in areas with high disease risk. The following conditions can put fields at higher risk of disease development:

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

BENEFITS BEYOND YIELD – STRONGER STALKS

In addition to disease control and potential yield response benefits, fungicide applications can also help improve standability at time of harvest. Consistent force was applied to multiple stalks and plants subsiding to the



Graph 1. Improved stalk quality from Miravis Neo fungicide application in 2020 at Clinton, Illinois

pressure were recorded as % of plants artificially lodging. Multiple hybrids treated with fungicide showed significant reduction of lodging (Graph 1).

The data suggest that utilizing a foliar fungicide can:

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

An additional benefit observed with Miravis Neo is plants stay green longer, helping to extend photosynthesis and grain fill time later into the season. Also, water loss has been found to be reduced in short periods of drought, helping corn better tolerate stress.



DECISION PROCESS FOR FUNGICIDE APPLICATION

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

LOW DISEASE FUNGICIDE RESPONSE

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

HIGH DISEASE FUNGICIDE RESPONSE

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

Golden Harvest Hybrid	RM	Low Disease Fungicide Response	High Disease- Hybrid Susceptibility Rating				Golden Harvest Hybrid	RM	Low Disease Fungicide Response	High Disease- Hybrid Susceptibility Rating			
			GLS	NCLB	SR	TS				GLS	NCLB	SR	TS
G78C29	78	Good	-	-	-	-	G08R52	108	Best	5	3	-	-
G80Q01	80	Good	-	4	-	2	G08D29	108	Best	4	2	5	4
G84J92	84	Good	-	3	-	4	G09A86	109	Fair	2	5	4	4
G85Z56	85	Good	-	3	-	3	G09T26	109	Fair	4	3	4	3
G88F37	88	Best	-	3	-	-	G09Y24	109	Good	5	2	5	4
G90S99	90	Best	-	3	-	4	G10C45	110	Good	3	3	6	-
G90Y04	90	Fair	-	3	-	4	G10S30	110	Best	6	2	4	-
G91V51	91	Good	-	3	-	3	G10D21	110	Good	2	2	4	3
G92A51	92	Fair	3	4	-	4	G10L16	110	Good	4	6	4	-
G93A49	93	Good	3	4	-	4	G11B63	111	Fair	4	4	5	-
G94P48	94	Good	-	3	-	7	G11V76	111	Best	4	3	4	3
G95M41	95	Good	-	4	-	6	G12U17	112	Best	4	3	-	-
G95D32	95	Good	4	5	-	4	G12S75	112	Fair	3	3	4	2
G96R61	96	Good	-	2	-	3	G12A22	112	Good	3	3	3	4
G97N86	97	Good	4	4	-	3	G13M88	113	Fair	3	3	4	-
G98L17	98	Best	5	5	-	-	G13E90	113	Best	6	3	-	-
G98M44	98	Fair	5	4	-	5	G13Z50	113	Fair	4	3	5	-
G99E68	99	Fair	2	2	-	4	G13D55	113	Fair	3	3	3	3
G99A37	99	Good	3	3	-	3	G13T41	113	Good	4	2	4	-
G00H12	100	Good	3	5	-	2	G13P84	113	Fair	4	2	2	4
G00A97	100	Fair	3	3	-	4	G13N18	113	Best	6	4	6	-
G02W74	102	Good	3	2	-	4	G13H15	113	Poor	3	4	-	-
G02K39	102	Fair	3	4	-	3	G14N11	114	Best	5	5	5	-
G03B96	103	Best	5	3	-	4	G14R38	114	Fair	5	4	4	-
G03R40	103	Best	4	5	3	3	G15L32	115	Good	3	4	5	-
G04G36	104	Best	3	3	5	3	G15J91	115	Best	4	2	4	2
G04S19	104	Good	4	4	-	4	G16Q82	116	Best	3	3	3	5
G05K08	105	Good	4	3	5	5	G16K01	116	Fair	5	4	5	-
G06K93	106	Fair	5	4	-	-	G17E95	117	Fair	3	4	3	-
G06Q68	106	Fair	5	2	4	4	G17A81	117	Good	3	3	3	3
G06A27	106	Best	3	3	2	5	G17A74	117	Poor	3	4	4	-
G07G73	107	Good	3	3	3	5	G18D87	118	Fair	3	3	3	-
G07F23	107	Fair	3	2	6	3							

Hybrid Response Ratings: Best (Green), Good (Light Green), Fair (Yellow), Poor (Red)

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

MANAGING TAR SPOT WITH A COMBINATION OF GENETICS AND FUNGICIDE

INSIGHTS

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

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

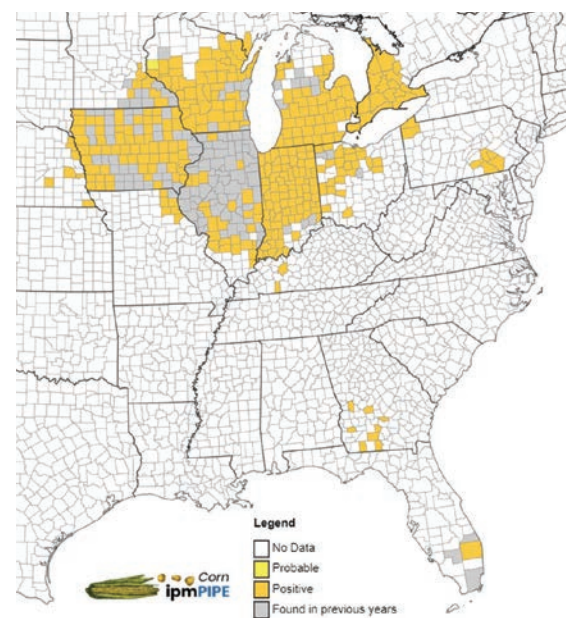


Figure 1. Counties confirmed with tar spot incidence (Corn ipmPIPE 10/14/21)

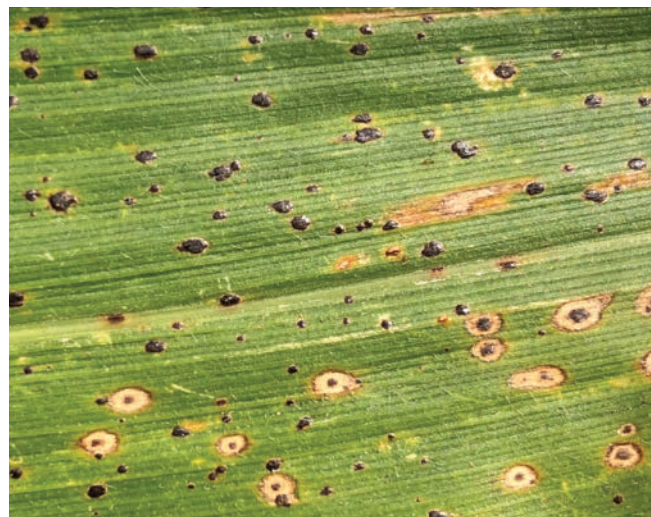


Figure 2. *Phyllachora maydis*, the fungus causing tar spot, with and without lesions forming around stromata.

FUNGAL PATHOGEN RESPONSIBLE

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

IDENTIFICATION

- Tar spot can be identified by raised black, irregular-shaped fungal structures (Figure 2) called stromata, which appear as specks of tar splattered onto the leaf surface.

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

DEVELOPMENT

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

Part of what makes potential tar spot a challenging disease is that it is polycyclic, meaning that within a 21-day period it can complete a growth cycle and form new spores that

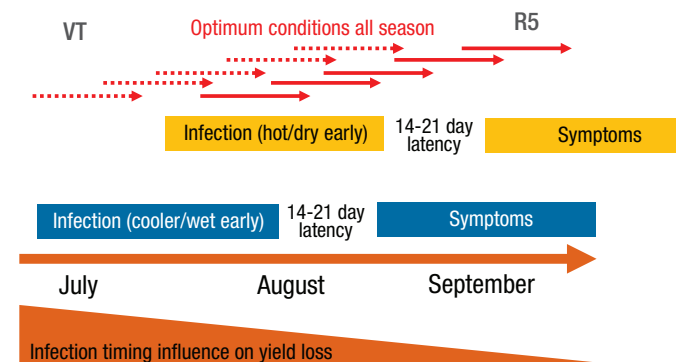
can spread and cause secondary infections. Spores move by wind and plant residue that can be carried by field equipment to other fields.

FIVE KEY FACTORS DRIVE YIELD LOSS POTENTIAL

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

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

Tar Spot Infection / Symptom Timeline Example



MANAGEMENT PRACTICES

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

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



GOLDEN HARVEST TALKS TAR SPOT

- Crop Rotation and Tillage:** Burying residue with tillage and rotating crops to avoid exposure of overwintering pathogens is a common cultural practice used to manage many diseases. Recent research on tar spot has shown small reductions in disease severity from using these cultural practices. The ability of tar spot spores to spread within the growing season is likely minimizing most benefits of using rotation or tillage. Rotation and tillage may help in some situations but are likely not effective enough to use as a standalone management practice.
- Fungicide Application:** Early fungicide applications at or before first signs of development have been effective at reducing tar spot in previous trials.³ However, infection often occurs weeks before symptoms, making timing of preventative fungicide applications challenging. Late-season curative applications of fungicides are typically not effective. Scouting, along with using the Tarspotter app to understand when conditions are most conducive for disease development, can help better time spray applications.
 - If conditions are favorable for tar spot development early in the season, an application at V4-V8 corn growth stage and/or the V10-VT growth stage with

- a registered product could reduce infection within fields confirmed with tar spot in prior years.
 - A second application may be warranted if conditions persist for infection around the VT-R3 growth stage.
 - If any of these exist, a second application could be needed: 1) susceptible hybrid was planted, 2) a conducive environment for infection continues, or 3) the field has a history of significant tar spot.
 - Fully registered Syngenta fungicide options include Trivapro® and Miravis® Neo to manage tar spot.
 - It is important to also consider other disease risks. Potential for other diseases like gray leaf spot, Northern corn leaf blight, Northern corn leaf spot and rust can help simplify decisions to treat fields with a broad-spectrum fungicide that can manage multiple diseases simultaneously.
- Other Considerations:** Observations of reduced tar spot severity in dryland corners of irrigated fields have highlighted the potential influence of irrigation on tar spot development. Current research is further investigating limiting irrigation to daytime hours to determine if that can help minimize disease development.

RM	GOLDEN HARVEST HYBRID SERIES	TAR SPOT (1-9)	RM	GOLDEN HARVEST HYBRID SERIES	TAR SPOT (1-9)
91	G91V51	3	106	G06Q68	4
92	G90Y04	4	107	G07F23	3
94	G94P48	7	107	E107C1	3
95	G95D32	4	107	G07G73	5
95	G95M41	6	108	G08D29	4
96	G96R61	3	108	G08M20	6
97	G97N86	3	109	G09T26	3
98	G98M44	5	109	G09A86	4
99	G99E68	4	109	G09Y24	4
100	G00H12	2	110	E110F4	2
102	G02K39	3	110	G10D21	3
102	G02W74	4	111	G11V76	3
103	G03C84	3	112	G12S75	2
103	G03R40	3	113	G13D55	3
103	G03B96	4	113	G13P84	4
104	G04G36	3	115	G15J91	2
104	G04S19	4	116	G16Q82	5
105	G05K08	5			

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

REGIONAL CORN ROOTWORM MONITORING NETWORK

ASHLEY N. DEAN AND ERIN W. HODGSON – Department of Entomology, Iowa State University

Western corn rootworm (WCR) and northern corn rootworm (NCR) larvae cause considerable yield loss in the corn-producing regions of North America, especially where continuous corn is prevalent. Lodging, severe root injury and high numbers of beetles in fields are usually the first indication of an economic issue. Adult beetles can further reduce yield by feeding on reproductive parts of corn and interfering with pollination.

Scouting and proper identification of these pests can help farmers make effective management decisions. There are several scouting techniques available for farmers and agronomists to use for estimating corn rootworm larval populations. However, many are labor intensive and time consuming. Using yellow sticky cards is an effective way to passively scout for corn rootworm adults and trap counts can assist in making management decisions the following year.¹

TRAPPING NETWORK GOALS

During the spring of 2021, university, industry and government personnel from 12 U.S. states and 5 Canadian provinces met to discuss goals for a regional corn rootworm trapping network and develop a shared protocol. The goals were to:

- Increase scouting efforts in corn
- Understand changes in populations between years
- Raise awareness about changes in western and northern corn rootworm activity and
- Use appropriate management strategies based on scouting information.

We provided free yellow sticky traps to volunteer cooperators (typically farmers or their advisors) in exchange for information about the fields where they placed the traps (e.g., cropping history, performance issues with rootworms, etc.) and weekly trap capture data.

The standard protocol was to place 4 traps along a single row of corn and check them for 4 weeks, exchanging traps for new ones each week, beginning in mid-July (near silking or after the first beetles were spotted in the field). Most cooperators chose to report data on the go with an online reporting system called *Survey123*;² the data entered in this system is summarized in this article.

LOCATIONS

In 2021, we had 619 unique locations entered in *Survey123* which represented 14 U.S. states and 5 Canadian provinces (Figure 1). Iowa had the most total sites, largely because Syngenta had an immense network of cooperators. Most sites were located in cornfields (560 sites), but 59 sites were in soybeans. Most soybean sites were in Illinois and Indiana where concern for the western corn rootworm variant (females laying eggs in soybeans) is higher. Very few beetles were captured from the soybean sites. The maximum beetles/trap/day was 1.63 compared to 339.57 for corn sites (Table 1).

The primary crop rotation reported was continuous corn (at least 2 years; 391 sites), followed by corn-soybean rotation (205 sites), and “other” (23 sites).

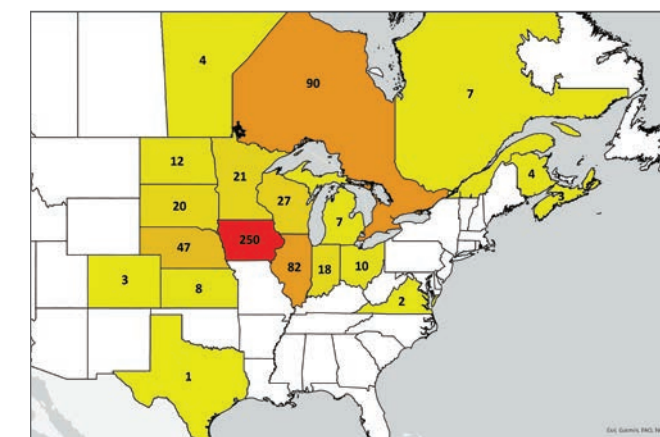


Figure 1. The number of corn rootworm trapping sites in each state that were entered in *Survey123* in 2021

TRAP SITE CROP	AVERAGE NCR*	AVERAGE WCR*	AVERAGE TOTAL*	MAXIMUM NCR	MAXIMUM WCR	MAXIMUM TOTAL
Corn-Corn	0.58	5.20	5.78	26.03	335.43	339.57
1st Year Corn	0.30	0.95	1.25	6.00	49.54	49.57
Soybean	0.04	0.10	0.15	1.38	0.57	1.63

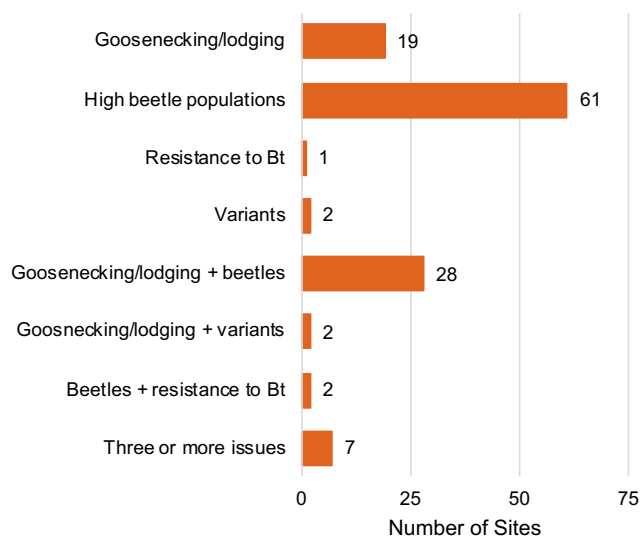
Table 1. Average and maximum beetles (each species and total) captured per trap per day at corn and soybean sites

*NCR = northern corn rootworm; WCR = western corn rootworm; total = northern and western corn rootworm.

CORN ROOTWORM ISSUES AND MANAGEMENT TACTICS

We asked cooperators to report any past or current corn rootworm issues in the field. Only 122 sites reported issues with corn rootworm (Graph 1). The most reported issue was high beetle populations (61 sites), followed by a combination of goosenecking/lodging and high beetle populations (28 sites), and goosenecking/lodging only (19 sites). Seven sites reported three or more issues, and very few sites reported expected resistance to Bt traits or crop rotation.

We also asked cooperators to report any corn rootworm management tactics that were used in the field during the current growing season. Out of the 115 sites that reported corn rootworm management tactics, 16 sites reported using no corn rootworm management, 50 sites reported using a single tactic to manage rootworms, and 49 sites reported using more than one corn rootworm management tactic (Graph 2).



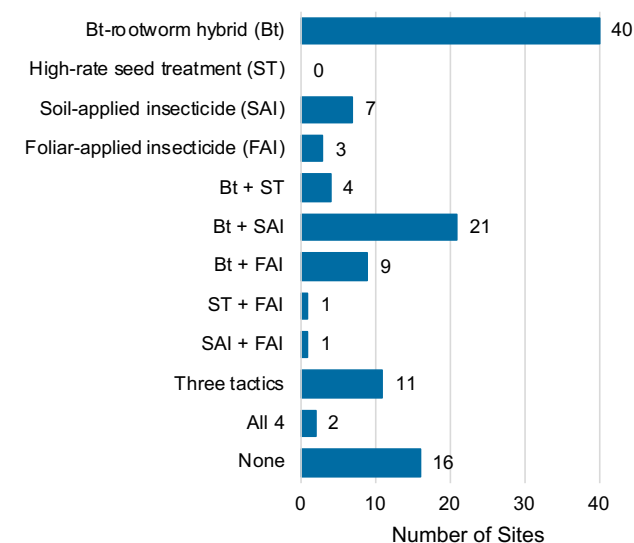
Graph 1. Reported corn rootworm issues in the fields where traps were placed

BEETLE COUNTS

A threshold exists for yellow sticky traps, regardless of species: 2 or more corn rootworm beetles/trap/day suggests that alternative management is needed the following year.¹ Approximately 29% of sites in 2021 met or exceeded the trapping threshold in their peak week (the week when the most total beetles were captured at each site; Figure 2). Of the sites that exceeded the threshold:

- WCR was the dominant species at 158 sites;
- NCR was dominant at 23 sites

Sites that exceeded the threshold would indicate regions where corn rootworm populations were particularly high in 2021. Most of these sites (80%) were in Nebraska, Iowa, Wisconsin and Ontario, which accounted for 67% of the total sites in the trapping network, and 90% were in continuous corn. Continuous corn is the most important factor for high corn rootworm populations. Of the continuous corn sites, 41.4% exceeded the trapping threshold, while only 8.8% of sites with a corn-soybean rotation exceeded the threshold.



Graph 2. Reported corn rootworm management tactics used in 2021 in the fields where traps were placed

For choosing whether to manage corn rootworms, it is not important to distinguish between the two species of rootworm beetles. However, knowing which species is most prevalent in the field could help determine which management decisions are best. Figure 3 shows where each species was the dominant species (species that comprised >50% of the total beetles) during the peak week at each site.

SUMMARY

Since corn rootworm populations are highly dependent on in-field management practices, it is difficult to extrapolate this data and make assumptions for fields not scouted. However, we plan to continue this network in 2022 (maybe beyond) to build a dataset that could uncover trends or changes in rootworm activity that may be useful to farmers, industry agronomists and Extension personnel. Some key management considerations:

- Every cornfield should be scouted every year to assess fresh root injury (mid to late July).³ Monitor for adult activity later in the season.⁴
- Continuous corn production is the biggest driver for high corn rootworm populations and development of resistance to Bt hybrids.⁵

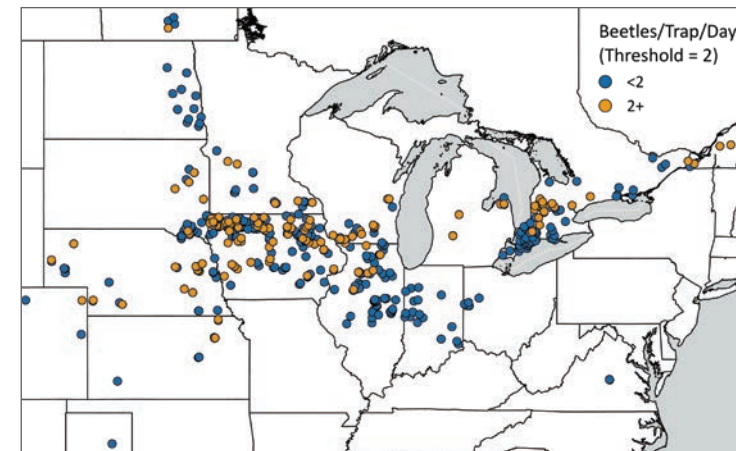


Figure 2. Relative trap captures during the peak week at each site. Blue dots indicate sites that did not reach the trapping threshold, while orange dots indicate sites that exceeded the threshold of 2 beetles/trap/day.

- Crop rotation is the most effective way to confuse corn rootworm. Rotating every 3-5 years will break up the life cycle and reduce resistance development in the field.
- Weedy fields and borders are attractive food sources after corn pollination is complete.
- Alternate management strategies are needed to prolong the efficacy of these tactics.
- Rescue treatments (foliar sprays for larvae or adults) have not shown consistent results.

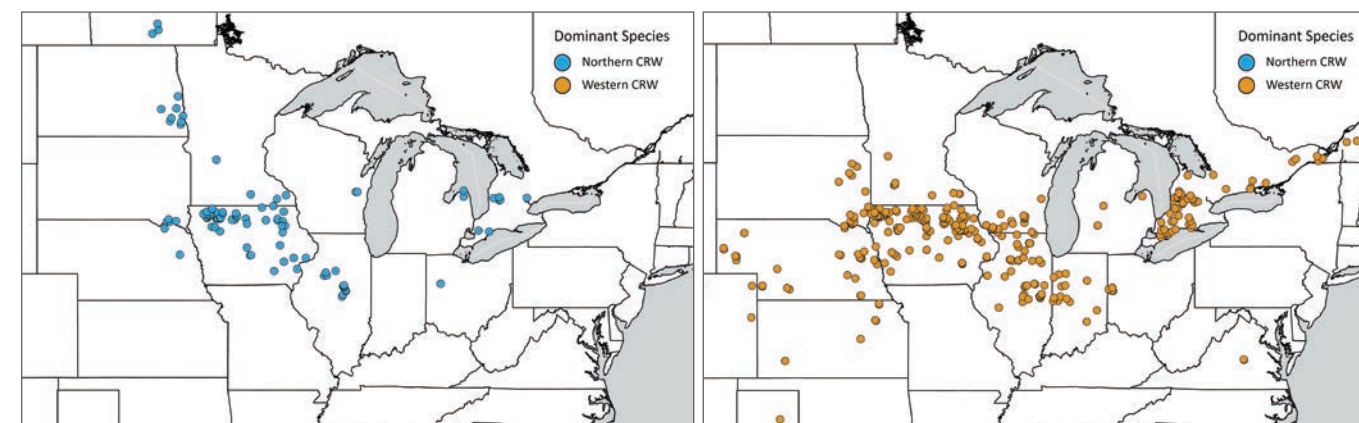


Figure 3. The dominant species during the peak week at each trap site. Left: sites where northern corn rootworm was dominant. Right: sites where western corn rootworm was dominant.

MANAGING CORN ROOTWORM

INSIGHTS

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

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

Corn rootworm is a difficult pest to manage, to the point that repeated use of the same single management practice will eventually end in disappointment. There is no silver bullet for corn rootworm, but smart planning and hybrid selection are key to building a sustainable, multi-year management plan. Developing a multi-year, field-by-field corn rootworm management plan utilizing different



Figure 1. Various levels of corn rootworm feeding

Geographic Distribution of Northern and Western Corn Rootworm and Variants

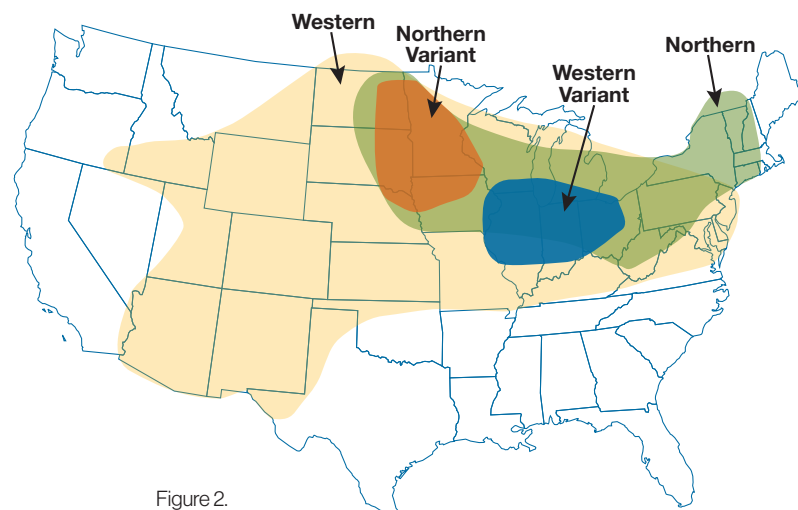


Figure 2.

control methods in different years is an important part of addressing one of the most damaging insect pests to corn and ensuring hybrids reach their full yield potential. Understanding if CRW is currently present in fields through scouting or beetle trapping is an important first step in developing management plans. Once the relative risk of CRW is understood, the following management options can be considered independently or in combination as part of a multi-year integrated management plan:

- Crop Rotation – rotate to non-host crops like soybeans to break up CRW's normal lifecycle. Adapted variants of CRW, known as western CRW variant or northern CRW with extended diapause, have changed their lifecycles to overcome single-year rotation (Figure 2). Be aware if present locally and its impact on rotation effectiveness.
- Dual mode of action CRW traits – use different CRW traits like Agrisure Duracade® and Agrisure® 3122 trait stacks that have more than one CRW trait.
- Soil-applied insecticides like Force® for larvae control.
- Foliar-applied insecticides like Warrior II with Zeon Technology® for adult beetles to minimize silk clipping and reduce egg laying.



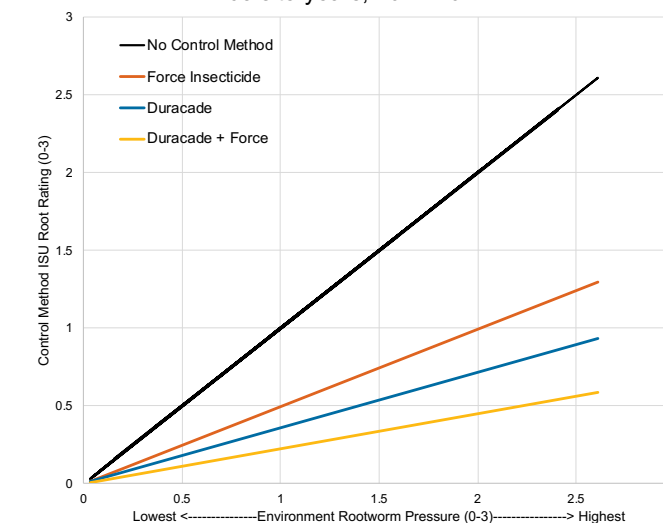
Figure 3. CRW damage shown with 2, 1 and 0 CRW modes of action (left to right; Agrisure Duracade, single CRW event, no insect trait)

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

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

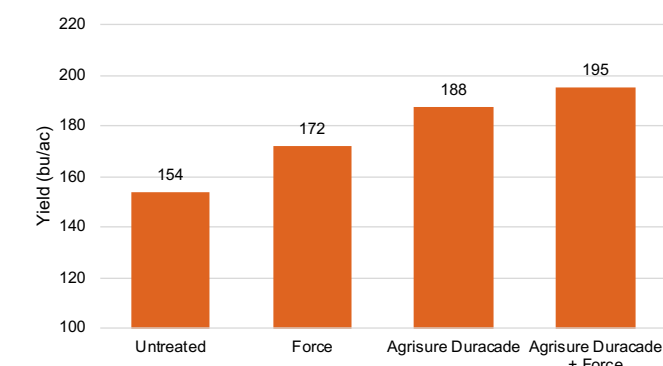
Select Golden Harvest Duracade hybrids are now available treated with Cruiser 1250 for additional root protection. Corn rootworm trials across 7 locations showed reduced feeding damage at most sites (Graph 3). Whether trying to protect yield or preserve effectiveness of current management practices,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

CRW Management Options - Performance Across Pest Levels 68 site-years, 2012-2021



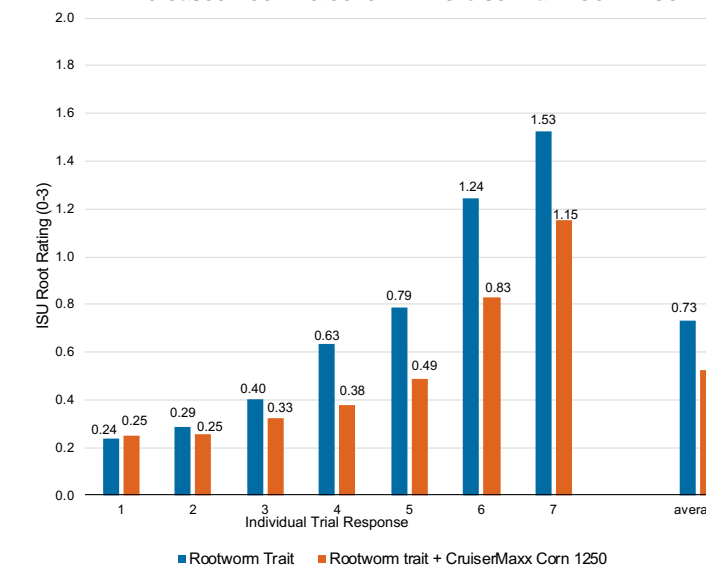
Graph 1. CRW root damage comparison of control methods

CRW Management Influence on Yield 9 site-years w/ UTC > 1.5 root rating 2013-2021



Graph 2. Yield comparison of CRW control method

Increased Root Protection with CruiserMaxx Corn 1250



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

MANAGING LOW PRESSURE CORN ROOTWORM

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

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

If planting first-year corn in areas where CRW has not yet been known to have adapted to corn rotation management, consider using a non-CRW traited hybrid, such as an Agrisure 3220 traited hybrid, that provides broad-spectrum control of above-ground pests. If other soil insects are present, consider adding Force soil insecticide.

OPTIONS FOR MANAGING HEAVY CORN ROOTWORM PRESSURE

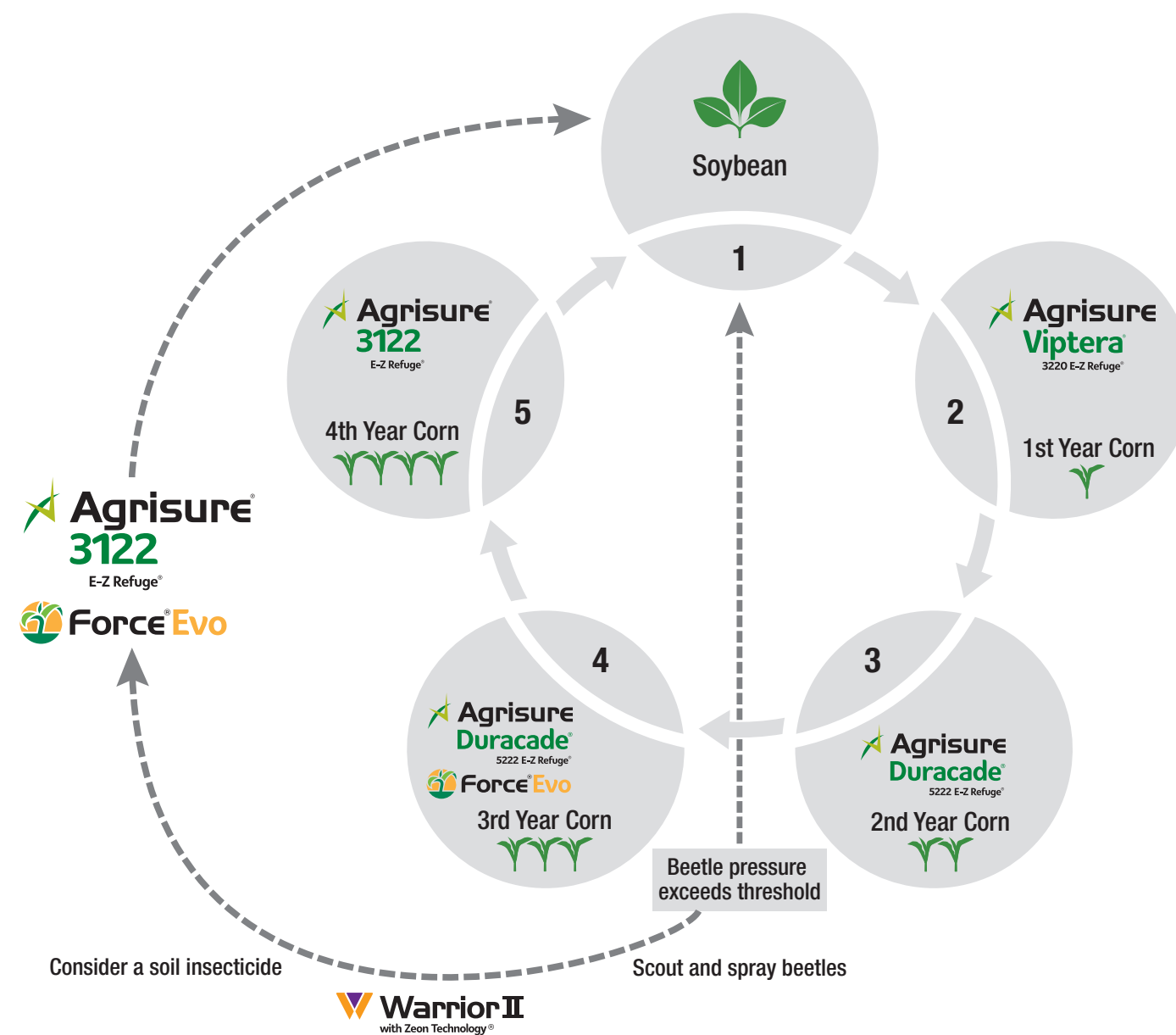
1. Crop rotation – breaking up CRW cycle by rotating to non-host crops, such as soybeans, in fields with a history of high CRW presence or injury should be considered.

2. Traitred corn hybrids:
 - a. If NO history of root injury on traitred hybrids:
 - i. Use hybrids with multiple CRW traits
 - ii. Scout and consider beetle control with a foliar insecticide to minimize silk clipping and reduce female egg laying
 - b. If there is a history of feeding damage to traitred hybrid and unable to rotate, use combination of:
 - i. Hybrids with multiple CRW traits
 - ii. Soil-applied insecticide with traits
 - iii. Scout and consider beetle control with a foliar insecticide.
 - iv. Seed treatment insecticides

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



Figure 4. Corn Rootworm Beetles feeding on silks



POTENTIAL FOR BIOLOGICAL SOURCES OF NITROGEN TO REDUCE SYNTHETIC NITROGEN FERTILIZER USE

INSIGHTS

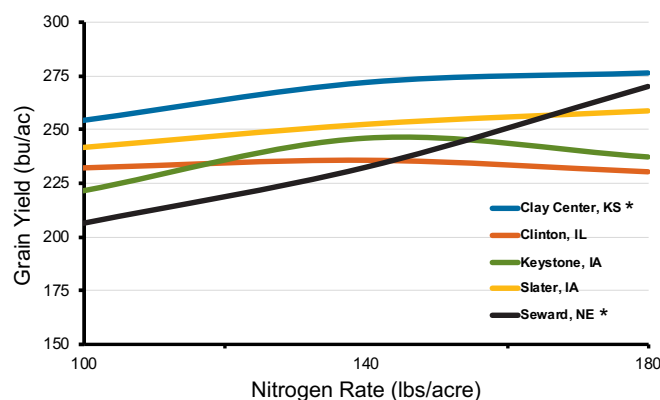
- Nitrogen-enhancing biological products provide a level of nitrogen to a corn crop.
- Positive yield responses to microbes become more consistent as nitrogen rates fall below plant requirements or environmental nitrogen loss occurs.

Biologicals are a hot topic in agriculture production. The U.S. Farm Bill defines biologicals, or biostimulants, as substances or microorganisms that, when applied to seeds, plants or the rhizosphere, stimulate processes to enhance or benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress or crop quality and yield. Biological products containing bacteria that can fix atmospheric nitrogen and provide plants with plant-available nitrogen are a big focus in the agriculture industry.

BIOLOGICALS FOR NITROGEN MANAGEMENT

Many companies have introduced separate biological products that utilize bacteria to form a mutualistic relationship with the plant, resulting in biological nitrogen fixation. The Agronomy In Action research team evaluated three of these products that are currently on the market at three nitrogen rates; 100, 140 and 180 lbs of N/acre. The products include:

1. **Envita™** - a naturally occurring, food grade bacteria (*Gluconacetobacter diazotrophicus*) from Azotic North America applied in-furrow
2. **Pivot Bio PROVEN®** - microbial (*Klebsiella variicola*) developed by Pivot Bio applied in-furrow
3. **BlueN™** – endophytic bacterium (*Methylobacterium symbioticum*) developed by Symborg foliar-applied at V4. Recently, Symborg reached a multi-year agreement providing an exclusive distribution license of the bacteria to Corteva Agriscience under the brand name Utrisha™ N.



Graph 1. Effect of nitrogen rate on grain yield averaged across three hybrids
* Effect of nitrogen rate on yield was significant at $\alpha = 0.10$.

Each nitrogen rate and product was implemented across three hybrids at five locations throughout the Midwest (Figure 1). There was no significant effect between the interaction of hybrid, nitrogen rate and product on grain yield, therefore, all results were averaged across hybrid.



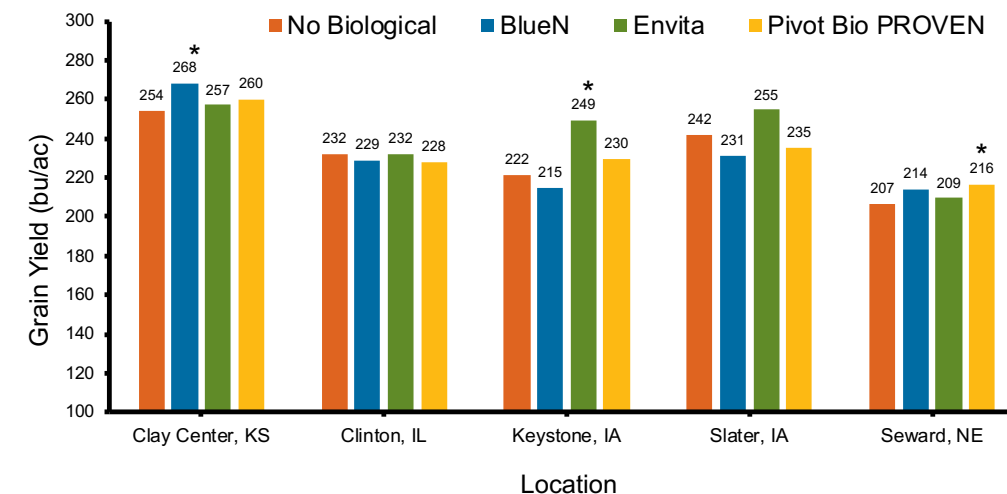
Figure 1. Trial design with nitrogen blocks stripped by biological product and hybrid randomized within those strips at Clinton, IL.

YIELD RESPONSE TO NITROGEN AND BIOLOGICALS

Clay Center, KS, and Seward, NE, were the only two locations where nitrogen rate had a significant effect on grain yield and are considered nitrogen responsive sites (Graph 1). At Seward, NE, each additional 40 lbs of N/acre applied resulted in an increase in yield. Statistically at Clay Center, KS, there was no yield advantage when increasing the nitrogen rate from 140 to 180 lbs of N/acre.

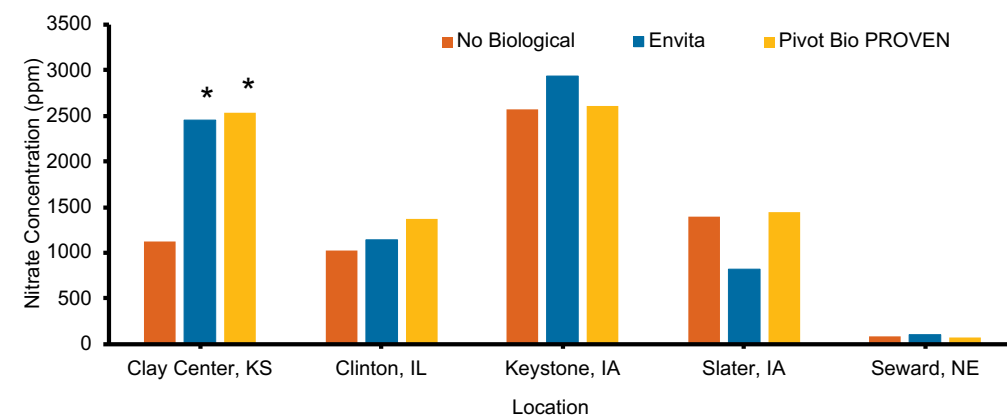
The addition of nitrogen enhancing biological products did not affect grain yield at the 140 or 180 lbs/acre nitrogen rate at any location. Except for Seward, NE, 140 lbs of N/acre were sufficient to maximize yield, therefore yield responses to biological products that supply plant-available nitrogen would not be expected.

The 100 lbs/acre nitrogen rate simulates an environment where nitrogen loss (leaching, denitrification, runoff, etc.) may have occurred, resulting in soil nitrogen levels below what is required by the plant. In the more nitrogen-stressed environment at Seward, NE, applying Pivot Bio PROVEN in-furrow significantly increased yield by 9 bu/acre (Graph 2). At Keystone, IA, Envita applied in-furrow resulted in a 27 bu/acre yield increase compared to when no biological was applied. There was a 12 bu/acre yield response to the foliar application of BlueN at Clay Center, KS. Clinton, IL, and Slater, IA, showed no biological product that significantly increased yield, although, numerically, plants responded positively to Envita at Slater, IA.



Graph 2. Yield response to nitrogen-enhancing biologicals at the 100 lbs/acre nitrogen rate averaged across three hybrids

* Significantly greater compared to no biological at $\alpha = 0.10$.



Graph 3. Basal stalk nitrate concentration response to nitrogen-enhancing biologicals averaged across three hybrids at the 100 lbs/acre N rate

* Significantly greater compared to no biological at $\alpha = 0.10$.

BASAL STALK NITRATE TEST

One to three weeks after black layer, lower stalk samples were collected and analyzed for nitrate levels. Foliar-applied BlueN treatments were excluded due to destructive sampling rows not receiving full application rates.

The basal stalk nitrate test is an end-of-season diagnostic tool that can indicate if nitrogen was overapplied. If corn plants have sufficient nitrogen available to attain maximum yield for the specific growing conditions, nitrate will accumulate in the lower stalk and increase stalk nitrate levels.

Iowa State University categorizes nitrate concentrations into three levels: < 250 ppm = nitrogen was likely deficient during the growing season; 250 – 2,000 ppm = yields were not likely limited by nitrogen; and > 2,000 ppm = nitrogen was likely overapplied.¹

Only at Seward, NE, was the stalk nitrate concentration considered low at the 100 lbs/acre N rate (Graph 3). Neither biological product increased the stalk nitrate concentration to be considered sufficient. Envita and Pivot Bio PROVEN applied at Clay Center, KS, more than doubled the nitrate concentration in the lower stalk compared to when no biological was applied. The increase in concentration did not have a significant impact on yield, suggesting nitrogen was not the limiting factor in that environment. Stalk nitrate concentrations tended to slightly increase when Envita and Pivot Bio PROVEN were applied at Clinton, IL, and when Envita was applied Keystone, IL.

Stalk nitrate levels of the untreated check being 1,000 ppm or greater at 4 of 5 locations indicate that other sources of nitrogen such as organic matter mineralization contributed significant amounts of nitrogen in addition to the 100 lb/

acre N rates. Increases in nitrate levels at Clay Center were negated by sufficient levels in absence of biologicals, resulting in minimal yield increases for both products. However, the increase in nitrates levels does confirm that both products have the ability to influence nitrogen availability within the plant.

CONCLUSION

Results from this study aligned with a similar study conducted by the Agronomy In Action team in 2019. Data from both years would suggest nitrogen-enhancing biological products are providing a level of nitrogen to the corn crop. However, positive yield responses are inconsistent. Biologicals applied with lower nitrogen rates at nitrogen responsive locations tend to increase yield potential more consistently. However, there is an inherent risk of yield loss when using microbials to lower synthetic nitrogen rates below plant requirements for the given environment.

Biological technology is continuing to advance rapidly. The role of microbials in nitrogen management is likely to increase.

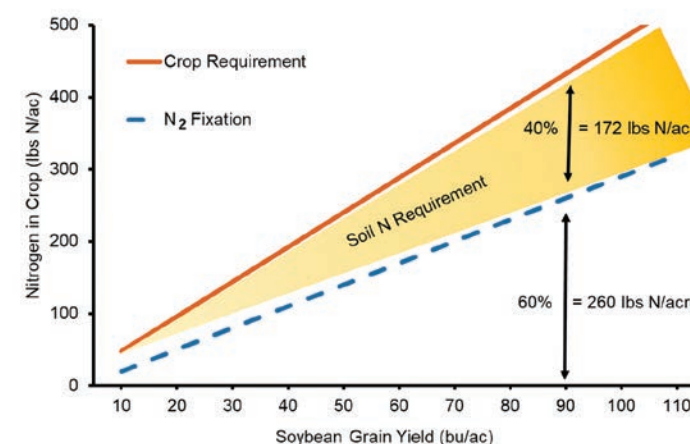
SOYBEANS NEED FOR SUPPLEMENTAL NITROGEN

INSIGHTS

- In high-yielding environments with conditions conducive to nitrogen loss, the potential for soybean yield response to nitrogen (N) is greatest.
- Biologicals could have potential to supplement nitrogen in soybeans without reducing nodulation and N fixation.

Soybeans have a high demand for nitrogen and must accumulate 4.8 lbs of N per bushel. It has been documented that biological nitrogen fixation from *Bradyrhizobium* can supply roughly 60% of the nitrogen requirement for soybeans.¹ The other 40% must come from the soil through mineralization or synthetic nitrogen fertilizers. At low yield levels, it is likely the soil can supply the remaining nitrogen requirement for soybeans. However, in high-yield environments the soil may not be able to mineralize enough incremental nitrogen above what is supplied by *Bradyrhizobium* to meet the total demand of soybeans.

The presence of plant-available nitrogen (nitrate or ammonium) has been shown to reduce nodule formation, growth and activity in soybeans.^{2,3,4} The reduction is directly proportional to the soil level of N supply so applications of synthetic nitrogen fertilizers may not be an effective



Graph 1. Influence of soybean yield on N in the crop, N supplied by fixation and required soil N

Adopted from: Salvagiotti et al., 2008⁴

method to fill the nitrogen requirement gap. A slow-release form of nitrogen through biological fixation from other bacteria could be a promising concept to meet this need. Alternatively, synthetic nitrogen fertilizer applied later in the season, after peak nodulation has occurred, may be a way to provide nitrogen without reducing nodulation.

AGRONOMY IN ACTION TRIALS

The Agronomy In Action research team implemented trials at 8 locations across the Midwest designed to supplement nitrogen to soybeans without reducing nodulation.

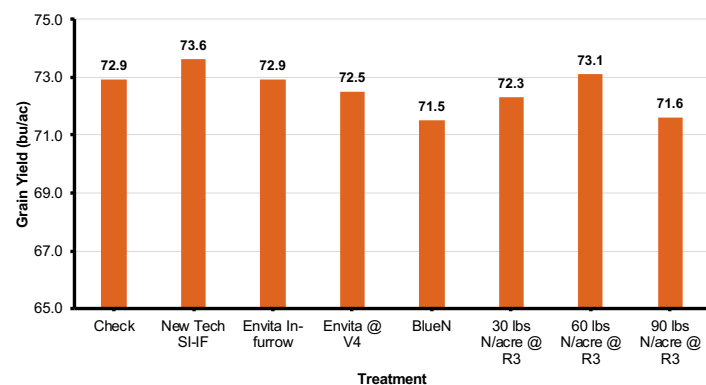


Two different varieties, either GH2102XF and GH2329X brands, or GH2788X and GH3088X brands, or GH3475X and GH3546X brands, were grown at each location.

Three biological products were evaluated including BlueN™, Envita™ and New Tech SI-IF™. BlueN is an endophytic bacterium (*Methylobacterium symbioticum*) developed by Symborg and foliar applied at the V4 growth stage. Recently, Symborg reached a multi-year agreement providing an exclusive distribution license of the bacteria to Corteva Agriscience under the brand name Utrisha™ N. A naturally occurring bacteria (*Gluconacetobacter diazotrophicus*) from Azotic North America, Envita, is applied in-furrow or foliar at the V4 growth stage. New Tech SI-IF is a soybean inoculant (*Bradyrhizobium japonicum*) combined with a bacteria known to fix N and enhance root hair growth and development (*Azospirillum brasilense*) introduced by TerraMax and applied in-furrow.

In addition, three synthetic nitrogen fertilizer treatments were included in the trial. Either 30, 60 or 90 lbs of N/acre was broadcasted as Agrotain®-coated urea at the R3 growth stage. The R3 growth stage is beyond peak nodulation, minimizing the negative effect of soil nitrate concentration on nodulation.





Graph 2. Effect of biological or synthetic nitrogen fertilizer on grain yield averaged across 8 locations and 2 varieties in 2021

LSD (0:10) = NS

NITROGEN MANAGEMENT EFFECT ON SOYBEAN YIELD

On average, across all locations and varieties, there was little yield difference between the biological or synthetic nitrogen treatments compared to the check (Graph 2). New Tech SI-IF was the highest yielding treatment averaging 73.6 bu/acre. Any potential yield responses to the different rates of synthetic nitrogen may have been mitigated by leaf burn from the broadcast Agrotain®-coated urea.

Clinton and Elwood, IL, experienced environmental conditions that were conducive for soybean nitrogen limitations. Both locations were high yielding with Clinton averaging 91 bu/acre and Elwood yielding 77 bu/acre. At those yield levels, the crop would require 437 and 370 lbs of N/acre, respectively. If nitrogen fixation supplies 60% of the plant nitrogen requirement, the remaining nitrogen gap that would need to be supplied from the soil would be 175 lbs of N/acre at Clinton and 148 lbs of N/acre at Elwood. Clinton received nearly 8 inches of precipitation in June and Elwood received 7 inches, which is close to double the 30-year average during June at both locations. Nitrogen loss through leaching was likely during this time.

Tech SI-IF significantly increased yield by 5.1 bu/acre at Elwood and numerically by 2.0 bu/acre at Clinton compared to the check (Table 1). Soybeans tended to respond by 1.6 bu/acre when Envita was applied either in-furrow or foliar at V4 in Elwood. BlueN also tended to provide a 2.4 bu/acre yield increase at Elwood. The

60 lbs/acre nitrogen rate significantly increased yields at Clinton. At Elwood, all rates of synthetic nitrogen fertilizer tended to increase yield with the response being greatest at the 30 lbs/acre nitrogen rate. This rate likely supplemented nitrogen with minimum leaf burn compared to the higher rates.

In these high-yield environments that were subject to nitrogen loss, the slow-release form of nitrogen through biological fixation from bacteria likely supplemented the nitrogen requirement for soybeans and reduced the nitrogen demand gap.

EFFECT ON NODULATION

Roots from plants in the border rows of the check, Envita and New Tech SI-IF in-furrow treatments were evaluated for nodulation at the R2 growth stage. The degree of nodulation was rated on a scale from 0-3. A score of 0 would mean no nodules were present. Nodules present on only the taproot would be a score of 1. A score of 2 would have nodules present on the taproot and 1-3 lateral roots while a score of 3 would mean nodules were present on the taproot along with 4 or more lateral roots. Nodules were removed from the roots, split open and the percentage of nodules that were pink, or healthy and active, inside was recorded.

There was no effect of either biological application on nodulation or nodule activity at any location. These

TREATMENT	CLINTON, IL	ELWOOD, IL
	bu/acre	
Check	90.5	74.5
New Tech SI-IF	92.5	79.6
Envita In-furrow	90.7	76.1
Envita @ V4	90.6	76.1
BlueN	90.7	76.9
30 lbs N/acre @ R3	89.2	78.1
60 lbs N/acre @ R3	93.2	77.8
90 lbs N/acre @ R3	91.0	76.0
LSD (0:10)	2.4	4.3

Table 1. Effect of biological or synthetic nitrogen fertilizer on grain yield averaged across 2 varieties

results would indicate that nitrogen fixed from the bacteria in these products does not reduce nodulation. Also, any yield responses from New Tech SI-IF were likely driven by nitrogen fixed from the *Azospirillum brasilense* bacteria and potentially increased root hair development rather than the *Bradyrhizobium japonicum* increasing nodulation.

CONCLUSION

Results from this study show that soybean response to synthetic nitrogen fertilizer and nitrogen-enhancing biologicals are inconsistent and environment dependent. Many factors contribute to the potential of soybean yield to be limited by nitrogen. In high-yielding environments with conditions conducive to nitrogen loss, the potential for soybean yield response to nitrogen is greatest.



Photo 1. Soybean root with many nodules on the taproot and lateral roots in left image.; Right image illustrates the inside of nodule actively fixing nitrogen on the top and nodule no longer fixing nitrogen on the bottom.



SULFUR APPLICATION TIMING EFFECT ON CORN RESPONSE

INSIGHTS

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

INTRODUCTION

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

2021 CORN SULFUR TRIALS

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



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

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

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

CORN YIELD RESPONSE TO SULFUR

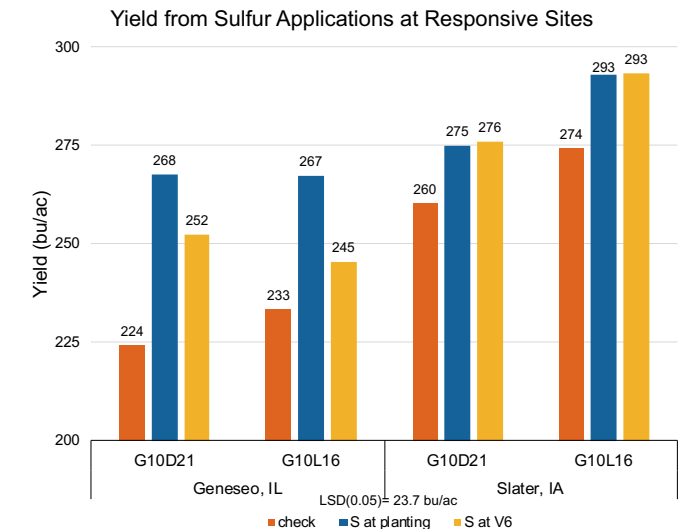
Yield response to sulfur ranged from 0-38 bu/ac across the 2021 trial locations. Of the 7 trials harvested, Geneseo, IL, and Slater, IA, responded significantly more than other locations (Table 1). Both at-planting and V6 application timings responded similarly at Slater with 16.6 and 17.2 bu/ac respectively,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

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

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

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

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



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

HYBRID RESPONSE TO SULFUR

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

DRIVERS FOR SITE RESPONSIVENESS

Soil and R1 tissue samples from plots not receiving sulfur applications were compared across locations to better understand the lack of responsiveness at sites other than Geneseo and Slater in 2021. Soil tests taken at planting provide a snapshot into plant available sulfur at that point in time but are unable to reflect sulfur that may become available later in the season from sources such as OM mineralization or irrigation water. Normally tissue testing would occur with small plants to allow time to take corrective measures, although in this trial they were taken at R1 to gauge if other sources of sulfur may have mitigated early soil deficiencies. Graph 2 illustrates the relationship of early soil test levels and the R1 tissue test results. Very low

soil sulfur levels (5 ppm) and lower soil organic matter content increased odds of seeing responsiveness at Geneseo. Soils with sulfur levels greater than 10 ppm have historically been considered nonresponsive, although Slater had soil levels of 15 ppm and resulted in a significant response. Both Seward, NE, and Clay Center, KS, also had lower soil sulfur levels but had higher leaf tissue test values later in the season and were non-responsive. This may have been in part due to in-season sulfur being partially supplemented through irrigation well water. University of Nebraska irrigation well water surveys found a median value of 35.1 pounds sulfur per acre foot of water sampled, which could have been enough to supplement soil deficiencies.¹ Bridgewater, SD, Keystone and Sac City, IA, locations all had initial soil sulfur levels greater than 20 ppm and soil OM levels greater than 3.5%, greatly reducing chances of responsiveness. In addition, the Sac City location has a long history of manure application, which can contribute to higher amounts of in-season sulfur mineralization. Like yield, sulfur R1 tissue test levels did not increase with either application timing at Clinton, IL. Potentially excessive sulfate leaching occurred at Clinton from multiple periods of excessive rain early in the season, reducing effectiveness of sulfur applications.

SUMMARY

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



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

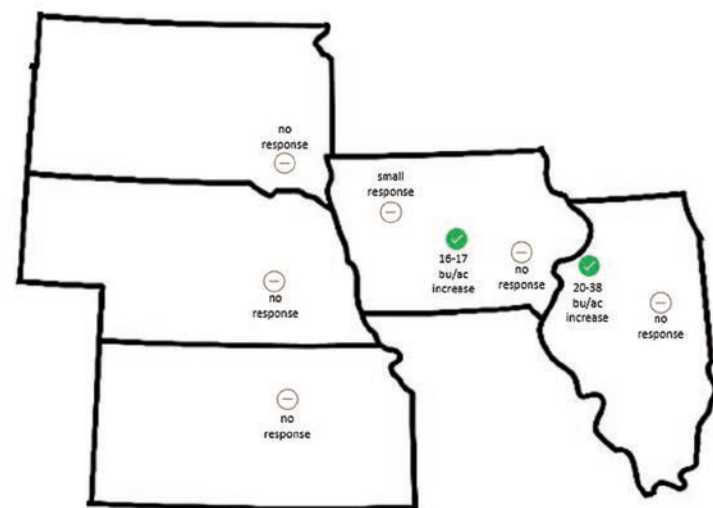
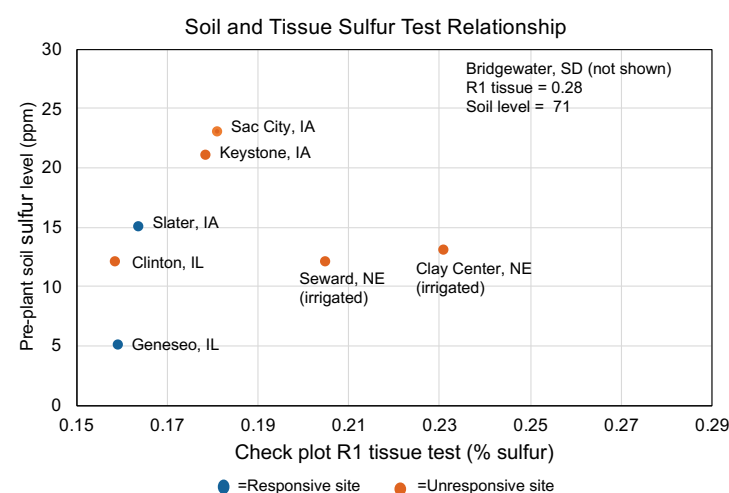


Figure 2. Trial sites in 2021 and average sulfur response



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

SULFUR INFLUENCE ON SOYBEAN YIELD AND GRAIN PROTEIN LEVEL

INSIGHTS

- Decreased atmospheric sulfate deposition is resulting in more frequent corn and soybean sulfur deficiencies.
- Soybean yields can significantly decline when the plant available form of sulfate-sulfur is limited.
- Correcting sulfur deficiencies can also improve soybean grain protein levels.

INTRODUCTION

Sulfur is one of the sixteen essential elements and one of three secondary macronutrients for crop production. Sulfur deficiency often appears more on young plants as yellowing of leaves and is more pronounced in new growth due to not being mobile within the plant. Sulfur has only recently 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 which makes it more subject to leaching, similarly 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.

Sulfur is also a component of cysteine and methionine (amino acids) and is essential for protein synthesis in plants. Grain protein levels are dependent on both nitrogen and sulfur availability to the plant. Soybeans are a high protein grain that is processed for oil and



Figure 1. Comparing soybeans with 20 lbs/ac of sulfur (right) to no sulfur (left) at Geneseo, IL 2021

commonly used in animal feed. The high level of protein and energy supplied from soybean meal is an essential feed component in livestock production. Increasing the nutritional feed value of soybeans could be useful in meeting rising demand for protein in livestock production.

Increased awareness of managing sulfur needs in corn has also created interest in better understanding soybean response to sulfur. In addition to yield improvement, many grain end use markets are interested in exploring new ways to increase soybean protein levels. Trials were planted in 2021 to determine if sulfur fertilizer could improve grain yield and protein content in soybeans.

MATERIALS AND METHODS

Trials were established at 9 locations across Illinois, Iowa, Kansas, Nebraska and South Dakota to understand if soybean yield and protein content could be influenced by applications of sulfur. Ammonium thiosulfate (ATS) 12-0-0-26S, a form of sulfur that is easily applied in a liquid form, was used to supply 20 lbs/acre of sulfate at the time of planting as a surface dribble 3 inches to each side of the row (Figure 1). Non-sulfur treated plots were treated

with 9 lbs/ac of nitrogen in the form of urea ammonium nitrate (UAN) using the same application method and timing to provide an equivalent amount of nitrogen as was applied to the ATS treated plots. Treatments were applied to 4 soybean varieties at each location to measure any potential response interactions. All treatments were replicated 4 times within each location. Research combines were used at harvest to collect grain analysis samples, grain moisture and determine yield.

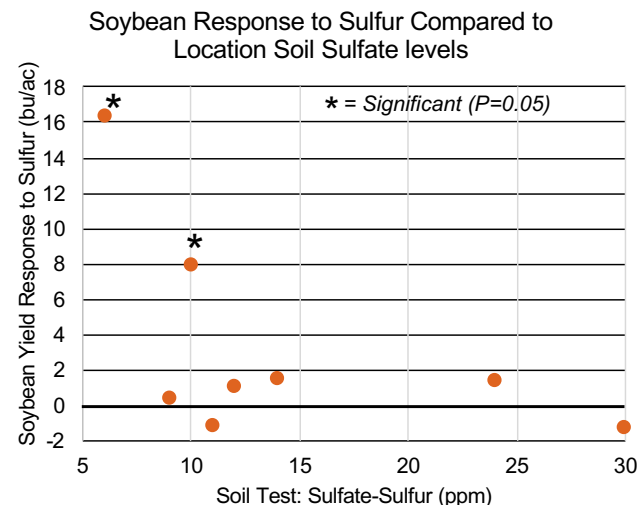
TRIAL YIELD RESPONSE TO SULFUR

Changes in soybean yield from ATS ranged from no response at several locations to as much as 16 bushels per acre depending on the location. Of the 9 locations, the Geneseo, IL and Clay Center, KS sites observed the largest yield increases of 16 and 8 bushels per acre respectively (Graph 1). Soil test sulfur results for both responsive sites fell in the low to very low sulfur category. Yield responses at other sites also testing in the low category (<14 ppm) were much less responsive (0-1.1 bu/ac), illustrating the challenges of predicting sulfur response based solely on soil test results.

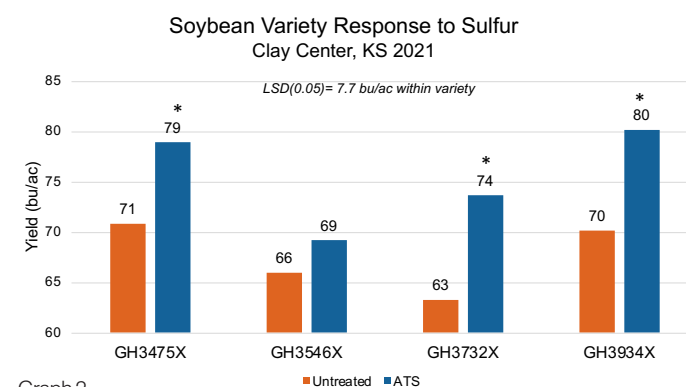
Yield response to sulfur also varied by variety planted within each location. GH3475X, GH3732X and GH3934X brands were all highly responsive to ATS applications at Clay Center, KS, averaging an additional 8 or more bu/ac than non-sulfur treatments (Graph 2). GH3546X was less responsive at Clay Center, but still yielded 3.2 bu/ac better with ATS applications. Averaged across six locations with relative maturity (RM) ranging from 2.7-3.0, GH2722XF, GH2788X and GH3088X brands yielded 2.2 to 5.5% better as result of ATS applications, whereas GH2872XF at the same locations was not responsive to sulfur (Graph 3). Early RM varieties, ranging from 2.1-2.5 planted at Sac City, IA, did not have a statistically significant response, although GH2102XF and GH2329X brands yielded 3-5% better with ATS applications (Graph 4). GH2230X and GH2552X brands were not responsive at the same location.

SULFUR EFFECT ON GRAIN PROTEIN

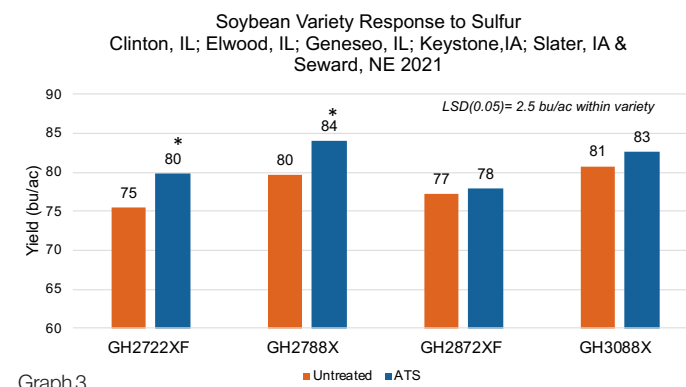
Due to the involvement of sulfur in protein synthesis, grain samples were also collected and analyzed using near-infrared (NIR) spectroscopy to understand if sulfur



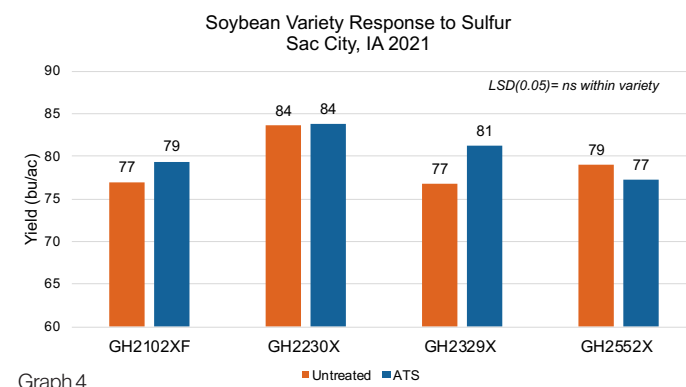
Graph 1. Individual trial location response to sulfur compared to site sulfate test results 2021



Graph 2.



Graph 3.



Graph 4.

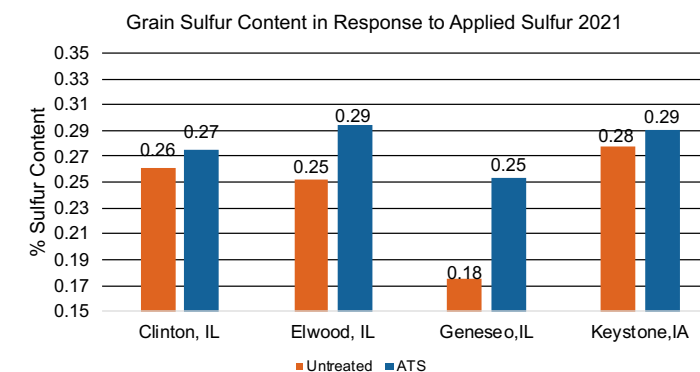
applications changed grain protein, oil and sulfur content. Adding sulfur increased grain sulfur content at 4 of the 9 trial sites (Graph 5). Of the 4 locations, Geneseo, IL, was the only site with a yield increase. Even though yields increased at Clay Center, KS, grain components were unchanged. Increases in sulfur uptake at 3 locations not observing a yield increase indicate sulfur availability was likely limited there, just not limiting enough to influence yield. In addition to sulfur, grain protein levels increased in all varieties planted at Geneseo, IL, Elwood, IL, and Keystone, IA (Graph 6) even though yield responses were not observed at all of these same locations. Grain oil levels consequently decreased at Elwood and Geneseo in response to large increases in protein level from ATS applications (Graph 7).

SUMMARY

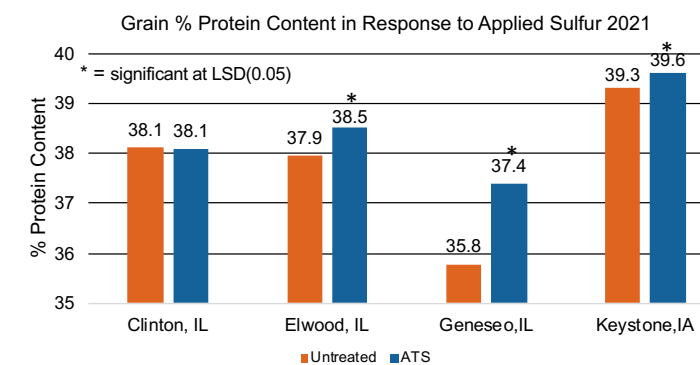
Soybean sulfur needs should be considered when plant-available sulfur is limiting. Sulfur deficiencies at 2 locations resulted in significant yield responses from ATS applications, proving that sulfur management is equally important in soybeans when limited. Non-responsive sites testing low in soil sulfur levels likely overcame deficiency through adequate in-season sulfate mineralization occurring as result of higher organic matter and warming soil temperatures. Both Geneseo, IL, and Clay Center, KS, the two most responsive sites, had much lower soil organic matter levels than all other sites.

Grain protein levels were positively influenced by applications of sulfur, where limited. Sulfur applications should be considered as a means of improving grain protein levels to improve feed value when sulfur deficiency is suspected.

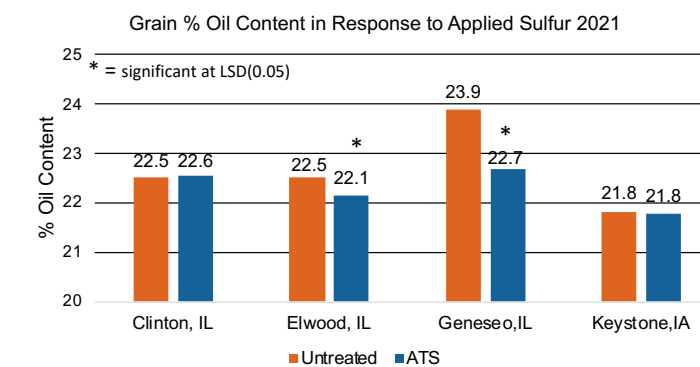
Sulfur deficiency has become more common in crop production today largely due to reduced atmospheric deposition as a result of the evolving environmental emission standards. As remaining soil sulfur levels continue to deplete, sulfur deficiencies are likely to become more common. Monitor fields closely with coarse, eroded or low organic matter soils for signs of sulfur deficiency and build nutrient plans around those suspected of being insufficient. Observations can be confirmed with leaf tissue samples to verify deficient fields.



Graph 5.



Graph 6.



Graph 7.

SOIL FERTILITY CONSIDERATIONS FOLLOWING A DROUGHT

INSIGHTS

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

INTRODUCTION

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

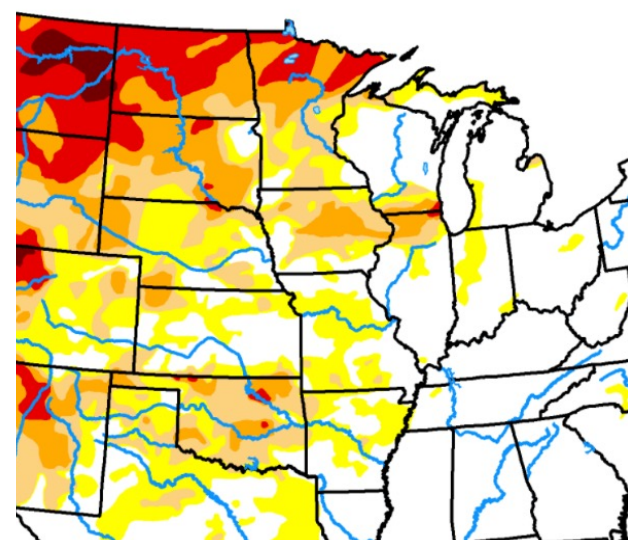


Figure 1. Drought-stressed areas on Sept. 28, 2021
Source: <https://droughtmonitor.unl.edu/>

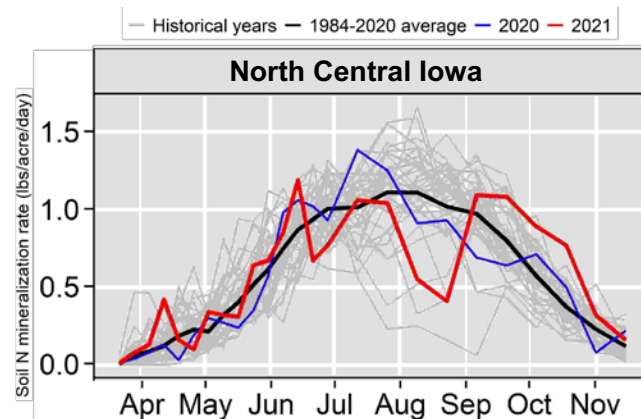


Figure 2. Nitrogen mineralization rates in north central Iowa
Source: Iowa State University FACTS,
<https://crops.extension.iastate.edu/facts/soil-n-mineralization>

DROUGHT IMPACT ON SOIL NUTRIENT INTERACTIONS

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

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

Immobile soil nutrients, such as phosphorus and potassium, do not leach under wet soil conditions, and are predominately removed from the soil through soil erosion and plant uptake. Both of these nutrient loss mechanisms are often reduced in drought conditions, potentially



Figure 3. Soil sampling with soil probe

resulting in above-average potassium and phosphorus available the following year. The exception to this can be soil availability from windblown sediment if there is not sufficient residue cover, such as from heavy tillage management. These water-nutrient interactions can be complex and unpredictable, but there are some management solutions.

CROP NUTRIENT REMOVAL CONSIDERATIONS

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

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



MORE INFORMATION ON HOW REMOVAL RATES IMPACT ROTATIONAL CROPS

SOIL TESTING FOLLOWING DROUGHT

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

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

DISCUSSION

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

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.

INTRODUCTION

Yellowing of leaves could be occurring in fields for many reasons such as disease presence, low fertility or management factors. In growing seasons with droughty conditions, potassium (K) deficiency in corn and soybeans may be causing these symptoms.

Even though symptoms of deficiency are present, actual soil tests may be in the normal range for potassium. Potassium moves to the roots by diffusion in the soil solution. This deficiency is because the plant is unable to access and uptake K from the soil due to limiting factors such as drought or compaction.

Potassium deficiency impacts are 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.

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



Figure 1. Yellowing symptoms in corn from K deficiency



Figure 2. Yellowing symptoms in soybeans impacted from K deficiency

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 pests 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 brown or necrotic symptoms

MISCONCEPTIONS OF MANURE NUTRIENT AVAILABILITY

INSIGHTS

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

INTRODUCTION

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

MANURE TYPE AND NUTRIENT LEVELS

Nutrient analysis of a manure source can vary depending on the animal source (Figure 1), how it is stored, water dilution and the bedding and diet of the animal. It is recommended to have the manure source regularly tested by a laboratory (typically offered through university agriculture programs)

Average nutrient content and standard deviations for various manure types

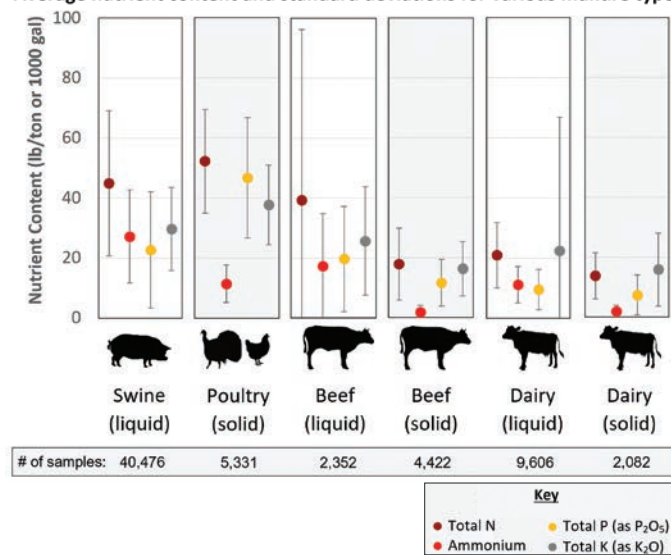


Figure 1. Nutrient ranges of different manure types from nutrient analysis
Source: Melissa Wilson, University of Minnesota Extension³

for more precise measurements of nutrient levels. There are some resources available online to help provide average ranges of manure nutrient percentages, as well as the percent moisture of various manure sources. Knowing the moisture percentage of a manure source is helpful to calculating the quantity of nutrients applied at a given rate because water has a diluting effect on the final nutrient concentration of manure.¹

MANURE NUTRIENT EFFICIENCY

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

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

MANAGEMENT CONSIDERATIONS

Soil Sampling

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

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

Manure Sample Testing

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

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

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

Source: Melissa Wilson, University of Minnesota Extension³

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

effective calcium carbonate (ECC) commercial fertilizer test to aid in determining optimal application rates.

Application Timing and Method

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

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

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

SUMMARY

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

SHOULD COLD GERMINATION AND VIGOR BE STANDARD FOR SOYBEANS?

INSIGHTS

- Warm germination seed testing is the industry standard for soybean seed quality reporting.
- There are currently no vigor testing standards for soybean seed.
- Vigor tests are difficult to replicate, and the results are challenging to implement due to variable environmental conditions.

INTRODUCTION

In recent years, the popularity for planting soybeans earlier has increased. With this there has been a fair amount of interest in seed and vigor testing for soybeans. Currently, there are standard protocols set following the Association of Official Seed Analysts (AOSA) rules for testing seeds for germination and purity, but not for seed vigor testing.

The quality of soybean seed is largely influenced by the growing conditions of the seed production field. Drought, rapid harvest dry-down, disease and insect damage all contribute to potential seed quality issues. Thin and fragile seed coats can lead to seed quality issues such as damaged seed coats, lower germination and poor seed appearance. The industry standard warm germination rate is 85%. However Golden Harvest strives for 90% germination rates for all soybeans.

CURRENT QUALITY STANDARDS

Golden Harvest utilizes a variety of quality control tests to evaluate soybean seed quality for conditioning and product release. The main tests utilized are the standard warm germination test, seed moisture and the hypochlorite (bleach) soak test. These tests are used to evaluate the physiological potential and mechanical damage potential for each seed lot. For certain later maturity varieties, the accelerated aging test is added to assess the potential stress of putting seed into storage conditions under less-than-ideal temperature and humidity.



Figure 1. Warm germination, paper towel test

There have been many attempts over the years to utilize a vigor test for assessing soybean quality. As with all vigor tests, the repeatability and correlation to field emergence have been the priority. There are currently no industry-wide standards for testing protocols and reporting for soybean vigor testing. Vigor testing results from third-party labs may be interpreted inconsistently and may not be representative of what will happen in the field. Many factors affect soybean seeds when planted into less-than-ideal conditions that cannot be mimicked in a laboratory test. Internal data from field trials indicate that the warm germination test continues to be the best predictor of seed quality and stand establishment.

MANAGEMENT CONSIDERATIONS

Planting soybeans early is beneficial only when soil and weather conditions are suitable. Planting into cool soils can delay germination and emergence. Cool, wet soils can expose soybeans to imbibitional chilling, which can cause seedling damage and decrease emergence. To avoid this type of risk, avoid planting soybean seed when soil temperatures are below 50°F and avoid planting when rain is imminent within 24 hours after planting.

Consider using a high-quality soybean seed treatment and store soybean seed in cooler temperatures with lower humidity before planting to maintain the quality of the seed. Environmental conditions are the primary factors in successful soybean emergence and should be mitigated for as much as possible. Soybean seed quality testing ensures high-quality seed for farmers.



Figure 2. Warm germination, paper towel test

ALIGNING SOYBEAN MATURITY TO PLANTING DATES

INSIGHTS

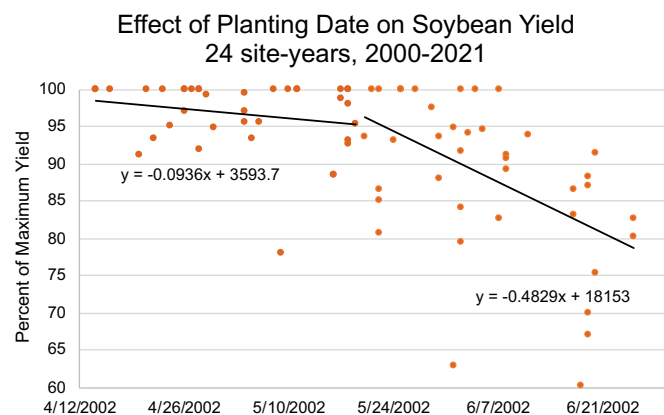
- Yield potential declines rapidly if planting after May 24 (1/2 % per day).
- Final stands greater than 100,000 plants per acre most often maximize yield potential.
- Switching to a 0.5 earlier relative maturity (RM) variety shortened the time to maturation by 4-6 days.
- Switching to 0.5 earlier RM produced less yield and revenue at all planting dates.

INTRODUCTION

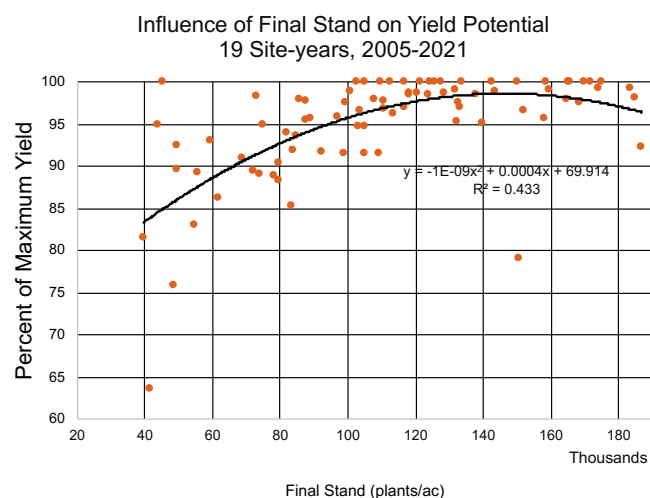
Early soybean planting can help maximize photoperiod and avoid heat and moisture stress during critical flowering stages. Early planting can also help optimize soybean growth between vegetative and reproductive stages, helping improve yield potential. Balancing the time spent accumulating nodes during vegetative growth and the length of time in reproductive stages to fill pods is crucial to ensuring high yield potential! Early planting can also allow farmers to plant fuller-season varieties to help maximize yield potential and economic returns.^{2,3} However, there can be risk of poor stand establishment if germination and emergence are slowed due to cool, wet soils. Insects and disease can also be a bigger concern with early planting dates and should be managed accordingly. Golden Harvest® Agronomy In Action research trials were conducted in 2021 to demonstrate how planting date, RM and seeding rate interact with each other.

MULTI-YEAR PLANTING DATE AND SEEDING RATE RESULTS

Results from historic Agronomy In Action planting date research conducted across Nebraska, Iowa and Illinois has shown that yield potential is generally maximized if planted before late May (Graph 1). If planting is delayed later, yield loss potential can average 0.5% per day delayed.



Graph 1. Multi-year planting date influence on soybean yield



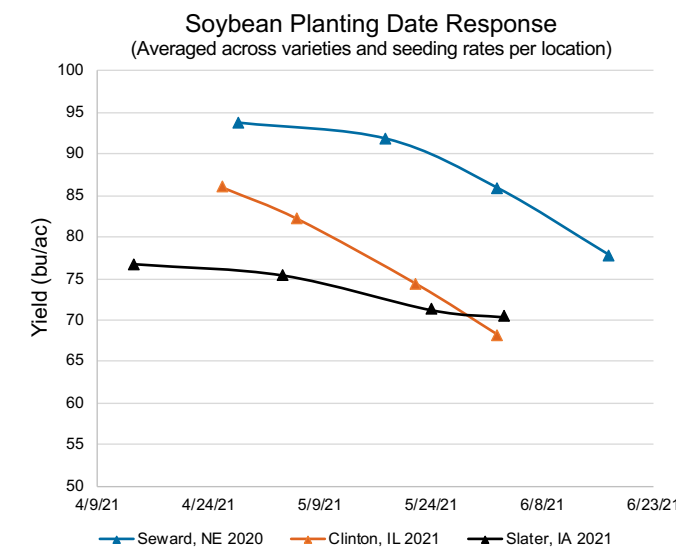
Graph 2. Influence of final stand on yield using 23 site-years of data

Soybeans have been less responsive to increasing seeding rates as other crops, such as corn. Due to the lack of responsiveness, most growers are more interested in understanding the minimum number of soybeans to plant to achieve a final stand that maximizes yields. Final plant stands are usually lower than actual seeding rates, and in many cases can be significantly less. Multi-year seeding rate trials have shown that final stands greater than 100,000 plants per acre typically maximized yields. Final stands greater than 100,000 plants per acre sometimes resulted in small yield gains (Graph 2). There was a 2% loss

in yield potential for every 10,000 fewer plants established when final stands were less than 100,000 plants/acre.

2021 PLANTING DATE TRIALS

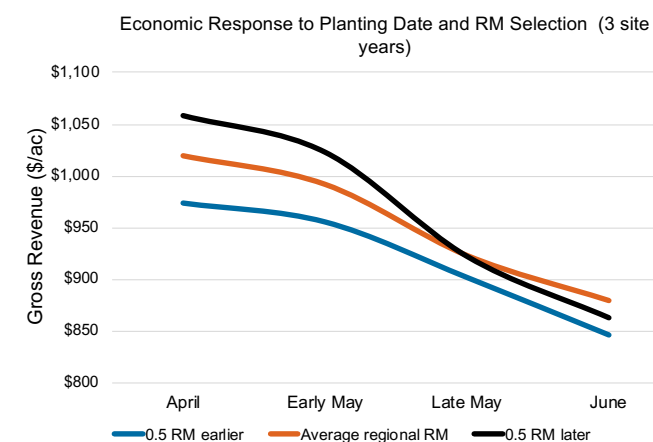
Planting date studies were conducted at Seward, NE, in 2020 as well as Slater, IA, and Clinton, IL, in 2021. Three soybean variety RM groups were selected to be planted at each location based on the average locally adapted RM as well as 0.5 RM earlier and later. Within each of the three RM groups, two varieties were selected. All 6 varieties were planted at 100,000, 140,000 and 180,000 seeds per acre. Maturity groups were stripped in each replicate to facilitate harvesting at appropriate timing based on maturity. Planting date responses behaved similarly across the three locations and followed general trends observed in multi-year planting date trials (Graph 3). Yields decreased with delayed planting in all locations and years, but at different rates.



Graph 3: Yield response by planting date

MAXIMIZING RM TO OPTIMIZE RETURNS

Farmers commonly select differing RM soybeans for a variety of reasons. Early RM soybeans are often chosen to begin harvesting prior to corn reaching maturity. In other situations, early RM varieties are used when planting is delayed to reduce the risk of fall frost injury. However, shortening RM too much can reduce yield potential. Clinton, IL, Seward, NE, and Slater, IA, planting date yields were used to model gross revenue of each RM across all planting dates. Gross revenue was calculated based on \$11.92 per bushel soybeans (the price at time of writing). Yield advantages observed with 0.5 RM later soybeans translated into higher revenues with April and early May planting dates (Graph 4). At all planting dates, mid- and full-RM varieties provided economic advantages over planting 0.5 RM earlier varieties (Graph 4).



Graph 4: Gross revenue by planting date and relative maturity

HOW SOYBEANS ADAPT TO PLANTING DATE

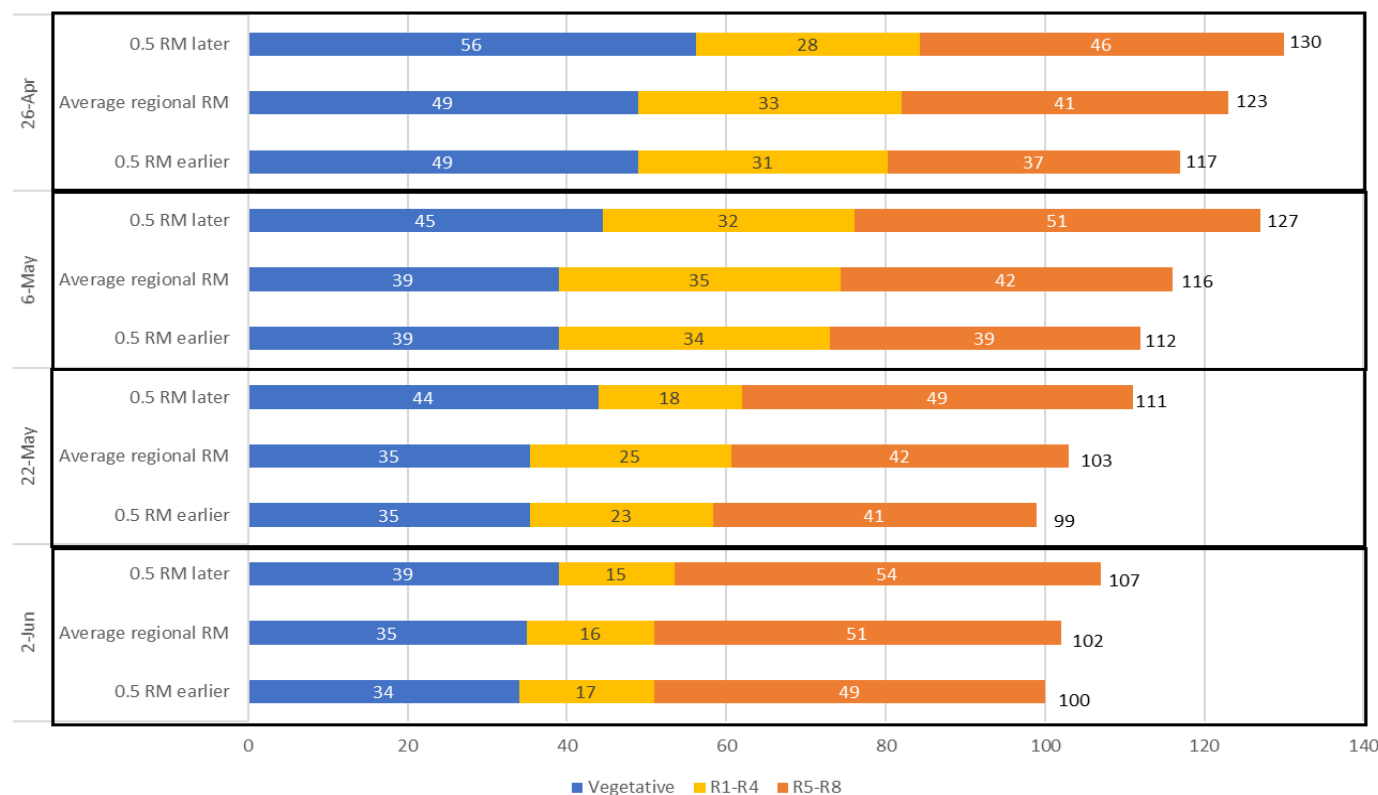
The number of days needed to reach maturity decreased with shorter season soybeans although not as much as previously anticipated. Planting early RM varieties to enable earlier harvest only provided 4-6 extra harvest days when compared to the average locally adapted RM (Graph 5). The fullest season soybeans matured nearly 2 weeks after the earliest RM varieties.

To reach maturity in fewer days with later planting dates, the soybean plant must adjust the amount of time spent in vegetative and reproductive stages. Later-planted soybeans accelerate through flowering stages (R1-R4) in fewer days and start filling pods sooner (Graph 5). A shortened vegetative period from delayed planting can also reduce the overall number of nodes per plant which is an important component of yield determination. Yield advantages of full-season RM varieties in these trials is likely partially due to an average of 6-8 additional days of vegetative growth in April and May planting dates when compared to earlier RM varieties (Graph 5).

SUMMARY

This study shows the importance of planting date and seeding rate on soybean management and the

Average days between growth stages by RM and planting date



Graph 5: Days to growth stage by RM and planting date. Number outside right of bars is mean total days to maturity.

implications of economics on those decisions. Data from this season and previous years reinforce the need to begin soybean planting in the latter half of April and finish by mid-May to avoid yield penalties in most Midwest geographies. Conditions for plant establishment within the first 1-2 weeks of planting are critical, otherwise emergence dates may not differ from later planting dates. Yield benefits from early planting are dependent upon date of emergence rather than actual planting date. Both April and mid-May planting dates can maximize crop canopy closure early in the season which helps improve photosynthesis efficiency.

In years where planting is delayed, balancing between maximizing yield with a full-season RM and reaching maturity prior to frost with an earlier RM is important. These trials reinforced that when this happens, only small adjustments of earlier maturity soybeans are necessary to reach maturity faster and still maximize yield and revenue

potential. In these trials, there was only a 7-day spread in maturation between the earliest and fullest season RM varieties when planted in June (Graph 5).

Seeding rates from 2021 and prior years suggest that planting 140,000 seeds/acre will typically result in final stands greater than 100,000 plants/acre and maximize yield potential. There are years that increasing seeding rates higher than 140,000 have given slight yield benefits but most often didn't provide an economic return due to additional seed and seed treatment cost. If reducing seeding rates less than 140,000 seeds/acre, it will be increasingly difficult to achieve the minimum final stand of 100,000 plants per acre. Although yield penalties may not always be seen with reduced seeding rates, it will be more likely to occur as germination and stand establishment rates decrease.

ULTRA-LOW SOYBEAN SEEDING RATES AND BRANCHING

INSIGHTS

- Branching differences across soybean varieties at ultra-low seeding rates were not enough to justify managing seeding rates differently.
- Ultra-low seeding rates, less than 100K seeds per acre, did not provide any yield or economic benefits.
- Seeding rate decisions should be based on achieving a final stand equal to or greater than 100K plants per acre.

INTRODUCTION

Corn seeding rates are commonly adjusted for specific hybrids to maximize yield and returns. Soybeans, which flower and develop pods over a broader time frame than corn, are considered less responsive to increased seeding rates. However, they are known to respond to increased seeding rates when planting is delayed, largely due to a shortened growing season which limits the number of nodes a plant can produce. Seeding rate responses are also observed in lower yielding environments where soybean growth is limited, making more plants per acre advantageous.

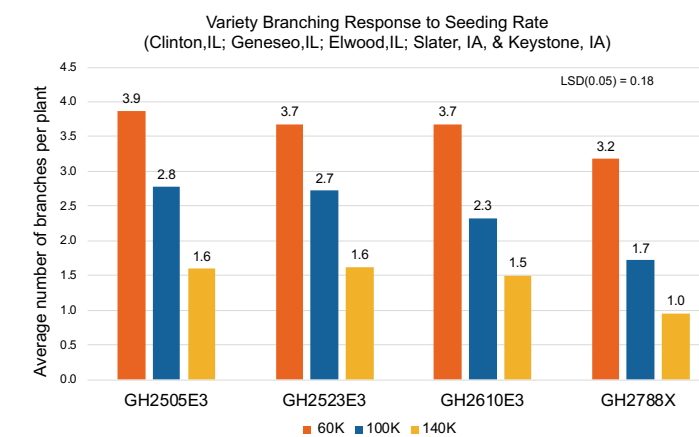
The primary reason increased soybean seeding rates is not usually considered is because of their ability to compensate by increasing the number of pods per plant at lower populations. This occurs partly through branching, or creating additional stems, to produce more nodes and pods. The ability of a soybean plant to increase seeds per plant with lower populations has piqued the curiosity of many farmers to wonder, "How low can you go with seeding rates?" When considering lower seeding rates, the frequently asked question is, "Do varieties respond differently?" To study these questions, ultra-low seeding rate trials were conducted in the 2021 growing season.



Figure 1. Branching and pod development differences when planted at 60K (left) and 140K (right) seeds per acre

ULTRA-LOW SEEDING RATE TRIALS

Ultra-low seeding rate trials were planted at 9 Midwestern locations to evaluate the response of 4 soybean varieties at 60K, 100K and 140K seeds per acre (Figure 1). Varieties were chosen based on having uniquely different branching



Graph 1. Changes in variety branching due to seeding rate

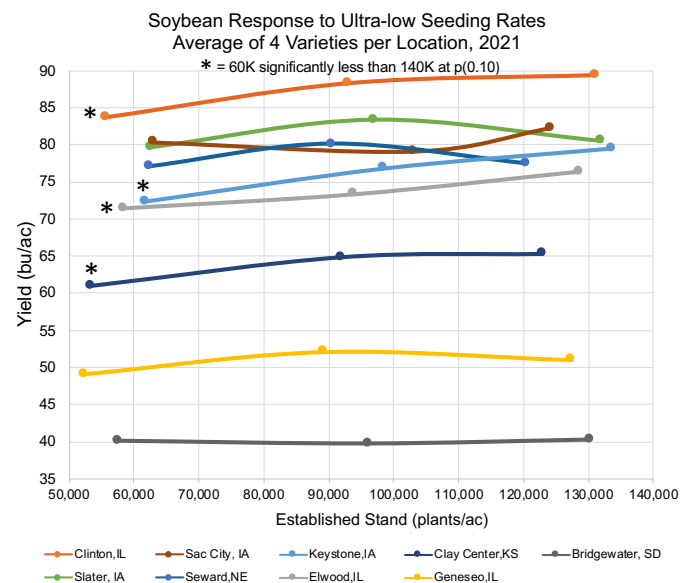
scores. GH2788X and GH2610E3 brands each have a branching score of 4, meaning they have a lower tendency to branch at normal populations. Whereas GH2523E3 and GH2505E3 brands have higher branching scores of 6 and 7 respectively, indicating they tend to produce more branches per plant. At each location, emergence, branching differences and yield were collected.

SEEDING RATE INFLUENCE ON BRANCHING

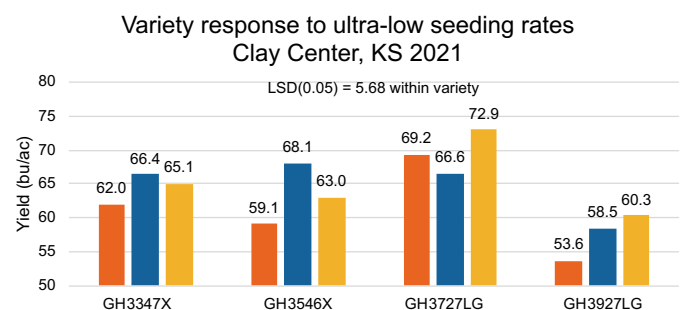
Reducing seeding rate consistently increased plant branching and number of pods per plant (Graph 1). There were differences in branching observed between varieties although differences were less distinct than anticipated. Prior branching ratings for GH2788X and GH2610E3 brands indicate they should branch similarly, however GH2788X branched less in trials. Likewise, GH2523E3 and GH2610E3 brands branched similarly, although prior ratings predicted GH2610E3 should branch less. The relatively small and inconsistent differences between varieties observed indicate branching ratings differences may not be substantial enough to justify modifying management strategies.

YIELD RESPONSE TO ULTRA-LOW SEEDING RATES

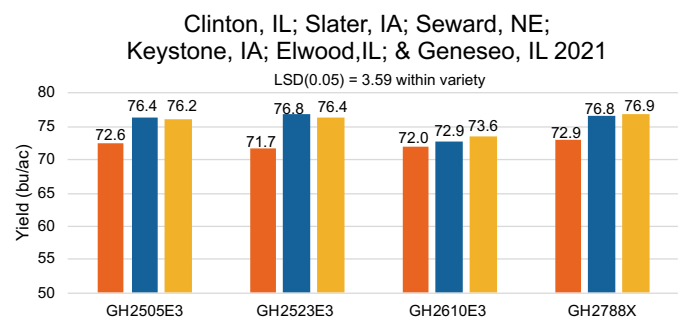
Of the 9 trial locations, yield potential was decreased at 4 locations when seeding rates were reduced to 60K seeds per acre and at 2 locations when reduced to 100K (Graph 2). Averaged across trials, there was only a 4.3% and 0.7% yield loss for 60K and 100K seeding rate respectively when compared to 140K seeding rates. Varieties generally responded similarly to 60K seeding rates and yield loss ranged from 1-6% across varieties. GH3927LG brand was more sensitive to planting ultra-low 60K seeding rates than all other varieties, reducing yield by 11% (Graph 3). The lower branching score of GH2610E3 brand suggests it would respond to higher seeding rates more than other varieties, but it maintained yield potential at lower populations better than all other varieties tested at the same locations (Graph 4). Almost no differences in variety or seeding rates were observed at early relative maturity (RM) locations (Graph 5).



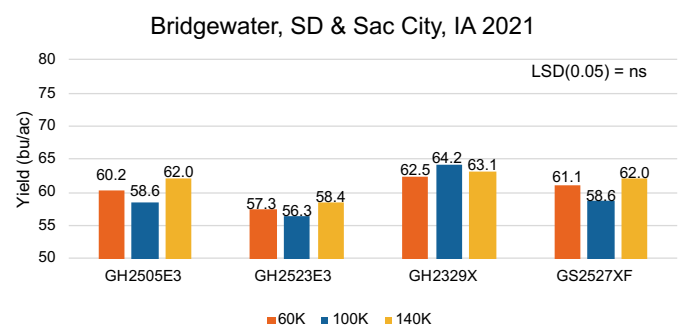
Graph 2. Individual location response to ultra-low seeding rates



Graph 3.



Graph 4.



Graph 5.

ECONOMICS OF REDUCED SEEDING RATES

Lowering overall seeding rates has the potential to decrease seed costs enough to offset lost yield potential. Assuming a seed cost of \$60 per unit (140K per unit), seeding costs would be \$25.71, \$42.86 and \$60.00 per acre for 60K, 100K and 140K seeding rates respectively. Using these assumptions, in combination with the average yield of each seeding rate across trial locations, an economic cost analysis indicates that the 100K seeding rate has the potential to be \$11 per acre more profitable than 140K (Table 1). Reducing seeding rates lower than 100K did not provide any yield or economic benefits in these trials.

Soybean response to reduced seeding rates is highly dependent on achieving a minimum stand establishment at or near 100K plants per acre. Trials conducted in 2021 had good emergence and seed spacing that was critical to achieving these results. It is interesting to note that under good planting conditions experienced in 2021, percent plant establishment rates improved from 91% at 140K to 97% at 60K respectively. Although establishment was good in these trials, there will be less of a safeguard when emergence challenges occur and seeding rates are significantly reduced. The best seeding rate will be the one that takes all the following factors into consideration to achieve a minimum final stand of 100K plants per acre.

CONSIDERATIONS OF ULTRA-LOW SEEDING RATES

- **Soil productivity:** Drought-prone or poorly drained soils that limit plant growth and development have limited ability to support soybeans to aggressively branch and compensate for lower populations. Maintain or increase seeding rates under these conditions.
- **Canopy closure:** Reduced seeding rates will be more prone to delayed canopy closure, resulting in less effective weed control and soil moisture loss. There is also a potentially negative aesthetic component to having fewer plants in a field.
- **Stand establishment:** Poor emergence caused by wet soils and soilborne disease may be more of a risk with reduced seeding rates and potentially result in more replanted fields. It is critical to protect seeds with a highly effective fungicide and insecticide seed treatment such as Golden Harvest Preferred Seed Treatment.
- **Late planting dates:** Delayed planting or double-crop fields have a reduced growth window and less ability to maximize branching and node development. Responses to increasing seeding rate are commonly observed in these types of situations.
- **Early planting dates:** Planting dates are being pushed earlier in many areas. Early planted soybeans are more prone to being in the soil for longer periods of time before emerging and have higher risk of injury due to cooler soil temperatures. Lower seeding rates will have less margin for lost seed before needing to replant. Ultra-low seeding rates are not well suited for these planting conditions.
- **Planter accuracy:** As seeding rates are lowered, seed singulation and proper planting depth become much more important to ensure as many seeds as possible can germinate and emerge evenly. Closing wheel adjustment will help ensure good seed-to-soil contact.
- **Seed quality:** Golden Harvest strives to deliver 90% soybean germination rates. However, seed quality can be challenging in hot and dry seed production years making it possible to see soybeans ranging from 80-85% germination occasionally. It is important to calculate "live" seed rates when planting at lower rates.
- **Plant phenotype:** Although branching scores had minimal impact on yield in our trials, it is important to select bushy plant type soybeans to help better close the canopy with lower seeding rates.

SEEDING RATE	FINAL STAND	% EMERGENCE	SEED COST \$/AC	INCOME	YIELD
60,000	58,625	97.7	\$25.71	\$760.51	68.4
100,000	94,819	94.8	\$42.86	\$772.26	70.9
140,000	127,867	91.3	\$60.00	\$761.19	71.4

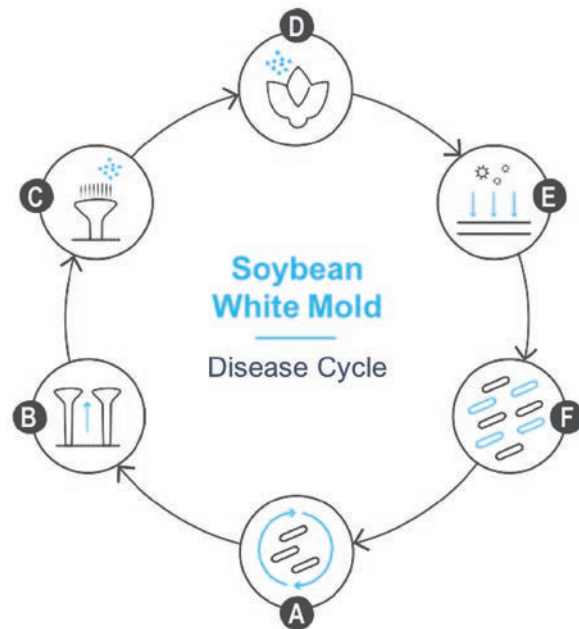
Table 1. Economic comparison of ultra-low seeding rates based on 2021 trial yields

WHITE MOLD MANAGEMENT

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 late in the season, it is important to know the factors that encourage growth so the disease can be managed.



- A** The fungus overwinters as sclerotia
- B** Sclerotia germinate to produce trumpet-shaped apothecia
- C** Apothecia contain numerous asci containing ascospores
- D** Ascospores are forcibly discharged and travel to young susceptible flowers
- E** Flower infections allow the fungus to enter the stem and kill plant tissues above
- F** More sclerotia develop (white are young sclerotia and black mature) to allow the fungus to survive over the winter

Figure 1.

WHITE MOLD DEVELOPMENT

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

Asci are filled with ascospores (C), which are forcibly released into the air. Some airborne spores land on susceptible soybean flowers, germinate and infect the plant (D). Flower infections extend into the stem and kill the tissues above the infections (E). 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 (F).

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).



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

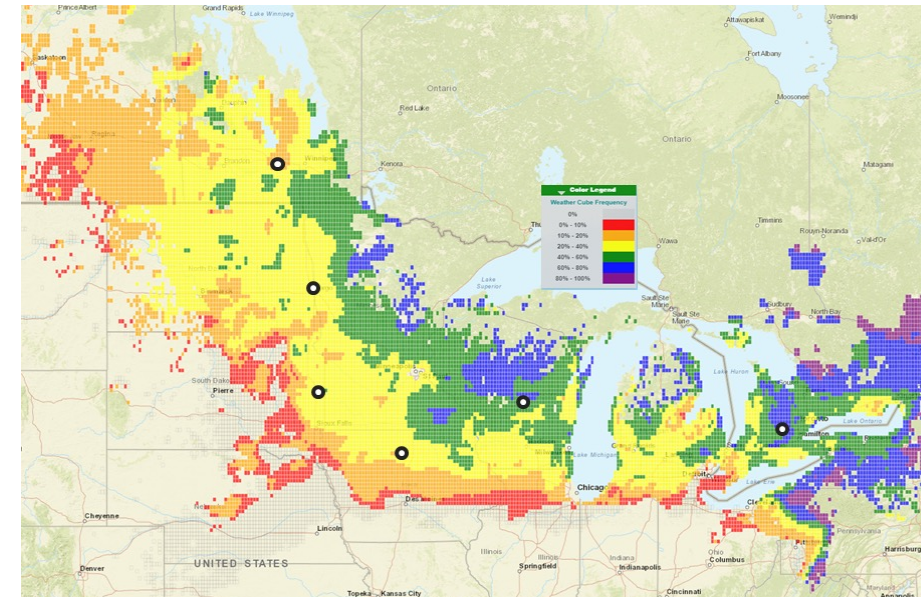


Figure 3. Areas with environments conducive to white mold (yellow, green, blue) due to frequency of cool, wet weather and corresponding trial locations

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.

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: 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.

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.

- 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.
 - 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.
 - Fungicides: Some can help suppress white mold with proper application timing.

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.

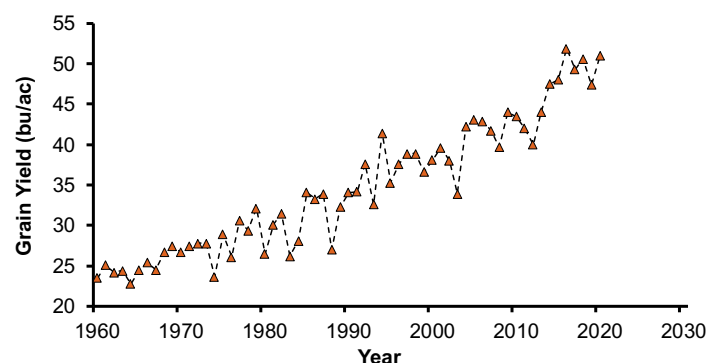
Effective white mold management begins with variety selection and detailed record keeping of fields for future planning. Other management considerations help keep the disease levels lower to protect yield potential.

SOYBEAN MANAGEMENT PRACTICE EFFECTS ON YIELD

INSIGHTS

- Yield response to management practice is location dependent.
- Crop monitoring is key to manage for potential yield-limiting factors.
- A foliar-applied fungicide at R3 was the management practice that provided the most consistent response across all locations.

The U.S. average soybean grain yield has continued to increase over the decades. In 1960, the average soybean grain yield was 24 bu/acre and in 2020, it was 51 bu/acre (Graph 1). Advancements in soybean genetics is the primary factor for the historical yield increases. However, improvements in crop management have also contributed to increasing soybean yields. Enhanced fertility, foliar protection, earlier planting, biologicals and precision agriculture are just some of the resources farmers have for managing soybeans.



Graph 1. Historical U.S. average soybean grain yield
Source: USDA-NASS¹

Justus von Liebig famously popularized the law of the minimum which states that plant growth and yield is dictated not by total resources available, but rather by the scarcest resource or limiting factor. The concept of adding more of one nutrient will not increase yield if another nutrient is deficient and impeding growth is often applied to agricultural crops. The law of the minimum applies to not

only soil nutrients, but also water availability, pest control, solar radiation and many other factors that contribute to crop growth and yield.

Increasing soybean yields requires a systems approach to management. Getting the plant off to a strong start sets up high yield potential early in the growing season and sustaining plant health through crop maturity helps maintain that yield potential.

MANAGEMENT APPROACH

Trials were implemented at 9 locations across the Midwest to evaluate the effect of different management practices on soybean grain yield. The trials were designed as an additive or “stair-step” approach starting with the farmer’s normal fertility program planted at 140,000 seeds/acre as the standard. Each management factor is an addition to the previous factor. The list and order of the management practices included:

- 1. Farmer Standard**
Farmer’s normal fertility program with no additional inputs planted at 140,000 seeds/acre
- 2. + Fertility**
Planter-applied 2x2x2 placement of 14 N, 44 P2O5, 57 K2O, and 3 S (lbs of nutrient/acre)
- 3. + Fungicide**
Foliar-applied Miravis® Neo (13.7 oz/acre) at R3
- 4. + Insecticide**
Foliar-applied Endigo® ZC (3.8 oz/acre) at R3
- 5. + Biological**
Foliar-applied YieldOn (1.5 pints/acre) at R3
- 6. + Nitrogen**
Broadcast Agrotain® coated urea (90 lbs of N/acre) at R3
- 7. + Foliar Micros**
Foliar-applied MAX-IN Ultra ZMB (2 quarts/acre) at R3
- 8. + Population**
180,000 seeds/acre

TREATMENT	BEAVER CROSSING, NE	BRIDGEWATER, SD	CLAY CENTER, KS	CLINTON, IL	ELWOOD, IL	GENESEO, IL	KEYSTONE, IA	SAC CITY, IA	SLATER, IA	AVERAGE
Grower Standard	83.8	34.5	72.8	90.8	77.7	68.2	84.8	84.3	85.7	76.3
+ Fertility	2.3	0.1	-3.6	0.5	-1.5	5.1	-2.2	-4.1	-4.3	-1.3
+ Fungicide	4.1	4.3	5.9	2.3	5.1	5	2.1	2	2.5	3.7
+ Insecticide	-0.8	2.7	-1.1	2.5	0.8	-3.2	0.3	-4	0.7	-0.3
+ Biological	-2.4	-3.9	-3.1	-0.1	0.6	2.2	-2.3	1.1	3.1	-0.6
+ Nitrogen	-0.6	-1.4	-3.6	-1.2	-4.3	-1	2.3	2.5	-0.1	-0.7
+ Foliar Micros	0.4	5.1	0.7	0.6	-0.1	4.1	0.1	-2.3	3.2	1.4
+ Population	0.4	-4.5	1.7	-1.3	1.2	-1.1	-1.8	1.8	-8.6	-1.7
Total Yield	87.1	36.8	69.9	94.2	79.6	79.3	83.2	81.3	82.2	76.9
LDS (0.05)	NS	NS	NS	3.9	NS	7.5	NS	NS	NS	2

Table 1. Change in yield with the addition of each factor to the previous management system. Orange highlights the management practice that provided the largest positive yield response for each given location.

Two varieties were grown at each location. Either GH2041X and GH2329X, GH2788X and GH3088X, or GH3475X and GH3546X varieties were planted depending on the geography. There was no interaction between management factor and variety at any location, so all results are averaged across locations.

YIELD RESPONSE TO MANAGEMENT PRACTICES

The average soybean yield at all locations was 70+ bu/acre except for Bridgewater, SD, which experienced drought conditions throughout most of the growing season. Not surprisingly, yield responses of each management practice varied across locations. The management factor providing the largest yield response at each location is highlighted in orange in Table 1. On average across all locations, there was a significant effect of management practices on grain yield (Table 1).

Foliar fungicide provided the most consistent yield response of all inputs, ranging from 2.0 to 5.9 bu/acre, depending on the location. Averaged across locations, foliar fungicide applications at R3 significantly increased yield by 3.7 bu/acre. Increases in yield from foliar fungicide applications appear to be due to an increased number of seeds produced (Table 2). None of the other management practices resulted in an increase in seed number as seen with fungicide applications. Although fungicide did not increase seed weight, it likely helped maintain it.

TREATMENT	SEED NUMBER SEEDS/FT² (Δ)	SEED WEIGHT SEEDS/LB (Δ)
Grower Standard	298	3236
+ Fertility	291 (-7)	3201 (-35)
+ Fungicide	306 (16)	3199 (-2)
+ Insecticide	307 (1)	3215 (16)
+ Biological	301 (-6)	3193 (-22)
+ Nitrogen	302 (0)	3219 (26)
+ Foliar Micros	305 (3)	3190 (-29)
+ Population	298 (-7)	3181 (-9)
LDS (0.05)	8	NS

Table 2. Seed number and seed weight
() = gain or loss each factor had over prior factor

Response to other management practices was much less consistent but significantly improved yields when specific yield-limiting factors such as insect pressure or soil nutrient deficiencies were present at a given location. Unique to other locations, a sandy loam soil with 1.7% organic matter and a CEC, cation exchange capacity, of 7.0 meq/100g at Geneseo, IL, likely made P2O5 and K2O applied through the planter more available to plants, resulting in a 5.1 bu/acre increase in yield over the farmer’s standard fertility program. Small amounts of sulfur applied likely also contributed to the fertilizer response, as Geneseo had lower soil sulfur levels. Japanese beetle and late-season bean leaf beetle feeding likely resulted in the 2.5 bu/acre R3 insecticide response at Clinton, IL (Figure 1).

Smaller and less consistent responses from foliar-applied micronutrients and biologicals were observed although not correlated with any specific yield-limiting factor. Increasing soybean seeding rates did not show a yield response when averaged across locations and was one of two management practices that never returned the largest yield improvement for a specific location. Broadcasting Agrotain® coated urea at R3 resulted in leaf burning at most locations and likely reduced yields in some cases (Figure 2).

MANAGE FOR THE LOCATION

The results from this study demonstrate that management practices need to be adjusted depending on the location. Locations with low soil fertility levels or soils that do not have the ability to hold available nutrients should benefit from fertilizer applied near the seed or from foliar-applied micronutrient. Insecticide should be applied when insect thresholds are met to reduce crop damage. A fungicide application was the management practice that provided the most consistent yield response across all locations. Continued crop monitoring is the key to identifying potential yield-limiting factors and to making management decisions to mitigate yield loss.



Figure 1. Bean leaf beetle feeding at Clinton, IL



Figure 2. Leaf burning from broadcast urea at the R3 growth stage at Clinton, IL

HERBICIDE CARRYOVER RISK FOLLOWING DRY CONDITIONS

INSIGHTS

- Herbicide carryover injury is not a large concern in most years but does have the potential to impact a field's next crop following certain environmental conditions.
- Potential risk is variable from field to field and even within each field.
- Nutrient deficiencies can sometimes be mistaken for herbicide carryover.

INTRODUCTION

Herbicide carryover occurs when an active ingredient or metabolites of a herbicide applied the previous crop year remain in the soil at high enough concentrations to cause damage to sensitive crops the following season. Under typical conditions, herbicide rotational planting intervals defined on pesticide labels provide a reasonable amount of time to reduce potential injury, if followed accordingly.

Herbicide labels often specify certain geographies, rates, application timing and soil type restrictions. Recommendations can change if specific restrictions are present at time of application. Under extreme conditions, some herbicides may be at risk of showing some crop response (Figure 1). Several factors can contribute to the risk of herbicide carryover:

- herbicide rate
- persistence of the herbicide
- soil characteristics
- annual precipitation and temperature
- interval time between herbicide application and planting the next crop
- susceptibility of the crop to the herbicide
- early-season crop growth rate¹



Figure 1. Herbicide carryover matching spray boom width from prior year where boom was charged

FATE OF HERBICIDES IN SOIL

What happens to a herbicide after reaching the soil is important in determining if it will persist and potentially carry over into the next crop. One of three things typically happen after herbicides are applied:

1. Herbicides are removed from the soil.

Herbicides can be carried away with surface water or leached through the soil profile. A portion of some herbicides may volatilize from the soil surface if not incorporated. Lastly, a portion of herbicides applied will be taken up by plant leaves and roots and metabolized.

2. Herbicides adsorb to the soil.

Herbicides can also bind to the surface of soil colloids (small particles) and organic matter.

3. Herbicides degrade.

Soil microbes, sunlight and chemical reactions will often begin to break herbicides down into an inactive form within the soil.

TYPES OF HERBICIDE DEGRADATION

Microbial degradation: Soil organisms known as microbes are largely responsible for naturally degrading herbicides in the soil over time. Specific forms of fungi, bacteria and algae commonly use herbicides as a source of food.

Environmental conditions that promote microbial development are less likely to experience herbicide carryover. Higher microbial activity often observed in high organic matter soils also helps promote faster breakdown of herbicides. Microbial activity tends to decrease with extended periods of dry conditions, making droughty soils more prone to herbicide carryover. Microbe activity also tends to decrease with colder soil conditions which can be a factor in herbicide degradation in cooler environments.

Chemical degradation is a process in which some very specific herbicides react with soil water in a process called hydrolysis. This form of degradation needs water present to occur. Dry soil conditions reduce degradation activity in general.² Chemical degradation can decrease in high pH and cooler soils.

Photodecomposition can occur with a very limited number of herbicides, such as Treflan™, when not incorporated into the soil. Sunlight will break down the molecules of these specific herbicides and make them inactive if left exposed on the soil surface for periods of time.

CONSIDERATIONS FOR CARRYOVER RISK

Several factors act together to influence carryover risk. Potential risk can even vary within fields.

1. Herbicide characteristics influence persistence:

- Herbicide interactions in the soil are complex. Characteristics of herbicide active ingredients along with how they interact with the soil and environment determine how much is left at the time of the next crop planting.
- The chemical structure of the herbicide impacts water solubility, vulnerability to degradation (microbial and chemical), soil binding and vapor pressure.

2. Application factors:

- *Timing:* Applying herbicides late in the season decreases the amount of time available for herbicide degradation.³ Rotational restrictions may not be met if applications are made late in the season.

- *Rate:* Higher rates than what is on the label for soil characteristics or the geographical area may lead to injury of rotational crops the following year.
- *Application uniformity:* Sprayer overlap can lead to areas receiving two times the herbicide rate, common on turn point rows or at the end of a sprayer pass. Sprayer malfunctions can also lead to application rates exceeding safe levels.

3. Weather Conditions:

- Temperature impacts chemical processes and microbial activity. Warm temperatures favor herbicide degradation by both mechanisms.
- Rainfall and moist soil conditions favor microbial activity, which increases degradation. Extended dry periods following application greatly reduce degradation, increasing persistence and risk of carryover.

4. Soil Characteristics:

- Soil pH plays a role in the persistence of herbicides in the soil since it can influence microbial activity, chemical degradation and herbicide solubility.
- Soil texture has an influence on herbicide persistence based on binding potential of the soil colloids. For example, clay and high organic matter soils bind herbicide molecules tightly to the surface, reducing the availability of the molecules to degradation.

5. Crop Rotation:

- Crops differ in sensitivity to different herbicides, making some more sensitive to specific herbicides if there is any risk of carryover.

REDUCING RISK OF HERBICIDE CARRYOVER

When planning for the next crop season, there are several things that can be done to reduce potential crop injury.

- 1. Review records and labels:** Understand which herbicides were applied the previous year and check each product's labels for any restrictions and rotational intervals to other crops. Labels may list specific conditions, such as seasonal precipitation totals, which may limit some crops from being planted.
- Herbicide carryover is rarely seen when pesticide labels are reviewed and followed.

- 2. Avoid early planting:** Herbicides taken up by plants in periods of cold stress can often cause higher levels of

injury due to a reduced ability to metabolize herbicides. Delaying planting until warmer conditions promotes rapid growth, helping better tolerate herbicide applications.

- 3. Switch crops:** Rotating to a less sensitive crop may need to be considered based on risk of carryover.

- 4. Consider tillage:** Tillage can distribute herbicides evenly throughout the soil often helping dilute herbicide concentrations and helping encourage microbial activity.

- 5. Soil Testing:** Soil testing can be done to measure residue, but it is generally quite expensive and requires a very representative soil sample to have any true value.

SYMPTOMS CONFUSED WITH HERBICIDE CARRYOVER

Herbicide carryover injury is generally difficult to diagnose. Often, carryover injury appears in uniform patterns where herbicide application overlap occurred. Soil type, high or low spots and weather conditions after herbicide application are key factors in potential crop injury symptoms.

Symptoms such as unnormal leaf or growing point development and chlorosis or necrosis of leaves can result from causes other than herbicide carryover injury. Many symptoms, such as disease, nutrient imbalance, frost, excessive moisture, heat stress or drought, can mimic herbicide carryover symptoms (Figure 2). Symptoms observed in early vegetative stages can often disappear quickly with new growth and have little, if any, effect on overall yield potential. A detailed analysis of all cropping information, as well as careful examination of the



Figure 2. Leaf striping from sulfur deficiency that appears similar to PPO carryover

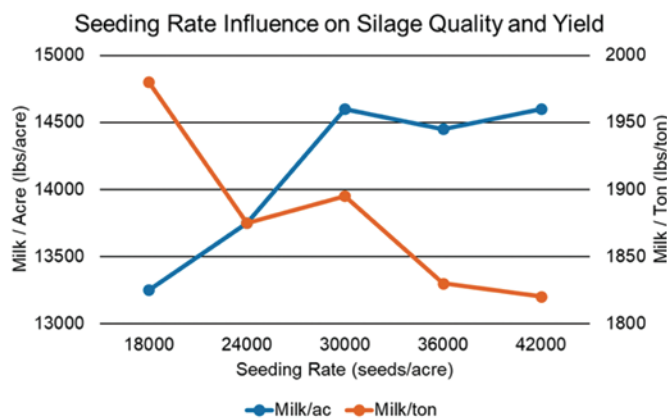
above- and below-ground symptoms, should be considered when determining the cause of an unhealthy crop.

There is little that can be done to change the amount of herbicide present in the soil at planting, but several options may help reduce injury risk. When herbicides are applied properly under typical growing conditions, there will be little concern of herbicide carryover risk. However, use caution following herbicide applications when conditions are conducive for herbicide persistence, such as a long-term drought.

IMPACT OF AGRONOMIC MANAGEMENT PRACTICES ON SILAGE

SEEDING RATE

Seeding rates are routinely adjusted for corn produced for grain to optimize yield potential. Increasing grain yield with higher seeding rates also increases overall silage tonnage up to a point, but simultaneously reduces quality. The increased plant biomass from additional plants tends to dilute starch contributed from grain, resulting in higher fiber levels. As a result, milk per acre of silage can be increased with higher seeding rates, but milk per ton will decrease (Graph 1). Increasing seeding rates 2,000 to 4,000 over normal corn grain seeding rates will typically maximize both yield and quality.



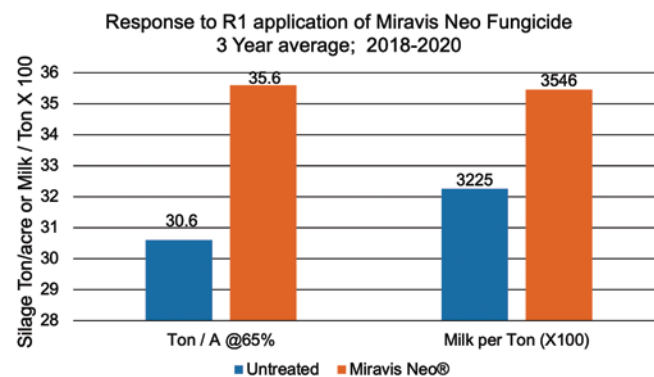
Graph 1.

PLANTING DATE

There is minimal impact on silage yield unless delayed into late May or June. It is common to see tonnage loss of 1 ton per week if planting after the last week in May, however reasonable yield can still be achieved with June plantings. Energy levels are likely to reduce in later planted silage as a result of lower starch levels from reduced grain fill.

TWO WAYS FUNGICIDES IMPROVE SILAGE

Managing disease in silage corn can be just as important as it is in grain. Previous research has illustrated how fungicides can improve silage yield potential and quality before harvest and during the ensiling process (Graph 2).



Graph 2.

1. Pre-Harvest Benefits

Fungicide applications can prevent fungal diseases in the field, which can preserve leaf area to improve tonnage and possibly reduce the number of fungal pathogens ensiled with corn. Fungal diseases have also been known to cause a plant defense mechanism in which cell walls increase lignin content after being infected by pathogens, resulting in lower silage quality. Fungicide applications have shown the ability to minimize this lignin increase and improve silage quality with NDF reductions and increased NDFd and starch content.

2. Ensiling Benefit

Previous research has shown increased levels of lactic acid during the ensiling process when corn received foliar fungicides. Lactic acid is important for lowering pH levels to preserve silage for feeding later. Reducing fungal pathogens with foliar fungicides likely increased the lactic acid content and the fermentative quality of corn silage.

HARVEST ADJUSTMENTS

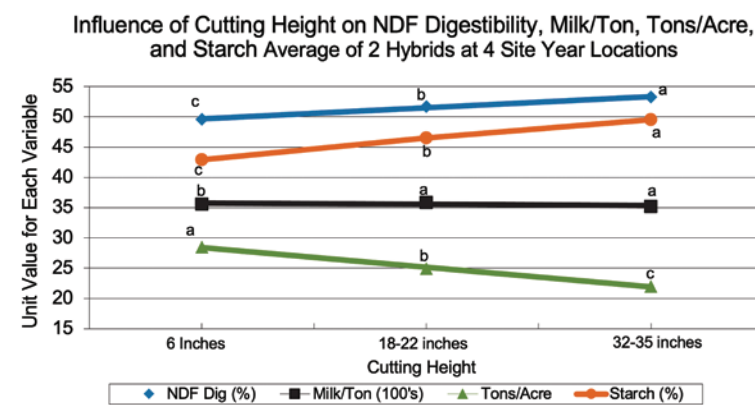
Harvest Timing and Moisture Content

One of the most important management factors is aligning harvest timing to maximize nutrient value and

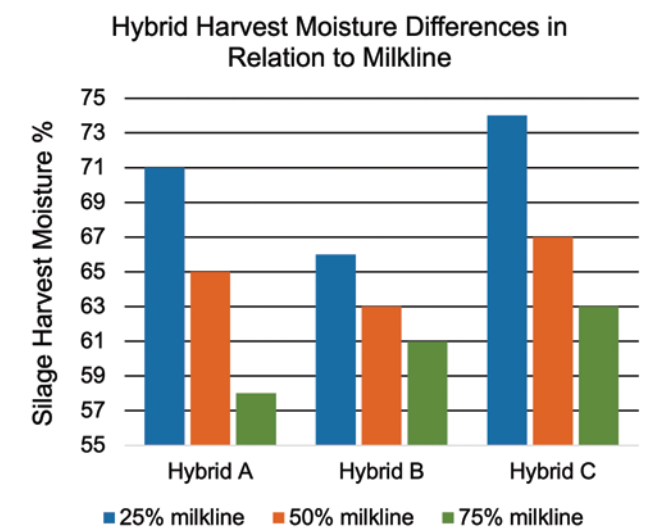
deliver silage moistures that best fit the storage type. Ensiling at moisture higher than the target will cause poor fermentation and nutrient loss, whereas too dry of silage will pack poorly, causing mold and spoilage. Recommended moisture contents are 65-70% for horizontal silos, 63-68% for conventional tower silos, 55-60% for limited-oxygen silos and 65% for silo bags. Milkline is often referenced for targeting correct harvest moisture. However, weather and hybrid variations make this a poor indicator, as illustrated in the graph comparing three hybrids with different kernel drying characteristics (Graph 3). Forage moisture testers or microwave ovens can be used to determine harvest moisture quickly. If testing shows moisture is above ideal, use the dry down rate of 0.5-0.75% moisture drop per day to estimate the best chopping dates.

Cutting Height

Cutting heights ranging from 2-3" in some areas to 8-10" in other regions are utilized for a variety of reasons, including changing the quality or simply to avoid equipment damage from stones. However, a 6-8" cutting height is most common. Increasing cutting height is a management practice that can increase energy content and NDFd by reducing total stover while maintaining grain content. Previous studies have shown adjusting 6" cutting heights to 18" can increase starch and NDFd levels by 2-3% points (Graph 4). Tonnage reductions are the trade-off for increasing quality. Increasing cutting height may be appealing if hay or haylage in storage is known to have lower fiber digestibility or if you have more acres dedicated to silage than needed.



Graph 4.



Graph 3.

Chop Length

Longer cut lengths will make it more difficult to achieve a good pack, allowing more space for air between forage particles during the ensiling process which affects the fermentation process. However, shortening the cut length will reduce physical fiber and its effectiveness. Finer chop will improve packing in all silo types and is especially important in upright silos where there is less opportunity to adjust pack methods. The recommendation for the theoretical cut length of unprocessed silage ranges from 3/8" to 3/4" in length and 3/4" for silage processed with 1-2 millimeter roller clearance.

Kernel Processor

As kernels begin to mature, a starch-protein matrix forms that make it harder to digest. Kernel processors installed on choppers smash kernels to increase starch digestibility. The value of processing kernels may not be observed with corn in early milkline stages, but typically provides nutritional advantages if harvested when milkline is halfway down the kernel or later stages.

AGRONOMIC SILAGE HYBRID SELECTION CHARACTERISTICS

Relative Maturity (RM)

Planting hybrid RM up to 10 days longer than an adapted full-season grain hybrid can offer yield advantages and typically still reach harvest before fall frost risk in most

areas. If fields may be utilized for grain harvest, you may not be able to increase RM as much. RM selection also needs to account for planting date spreads and the capability to harvest fields in a given time.

Root Strength

Hybrid root strength is important to ensure plants are standing well to chop at an efficient speed.

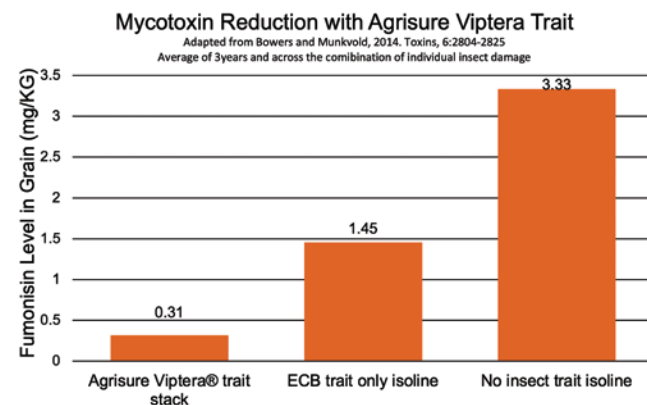
Disease Tolerance

Many silage acres will often be in a continuous corn rotation, resulting in a higher risk of potential disease presence. Hybrid selection and placement should consider tolerance to diseases such as Gray Leaf Spot, Northern Corn Leaf Blight and other regionalized diseases such as Tar Spot. In addition, foliar fungicide applications can also help reduce disease risk in fields.

Insect Trait Selection

Due to ground limitations and feed needs, silage acres often lack crop rotation. Consecutively planting multiple years of corn greatly increases the risk of insect populations and potential damage from insects. Trait selection should consider potential risk of damage from both below- and above-ground insects as well as disease that can supervene insect damage.

- Corn rootworm risk increases with each consecutive year of corn rotations. Agrisure Duracade® traitle hybrids and/or Force® brand insecticide may help mitigate risk.



Graph 5.

- Ear-feeding insects such as Western Bean Cutworm (WBC) and Corn Earworm can reduce grain and starch in feed rations. Selecting hybrids containing the Agrisure Viptera® trait, the only insect trait registered for WBC, can play an important role in mitigating ear feeding.
- Mycotoxins can occur for a variety of reasons but are often associated with pathogen infection of grain following insect feeding damage. Ear protection with insect traits can indirectly help reduce the potential risk of silage mycotoxin contamination, as shown in Graph 5.

Staygreen

Hybrids with good late-season health or “staygreen” are known to better maintain green leaf area for a longer period of time. Staygreen can help widen harvest windows and ensure proper plant moisture to minimize poor silage pit packing and spoilage or mold damage associated with

it. Utilizing staygreen for expanding the harvest window should not be heavily relied on. Some hybrids will rapidly lose kernel moisture while leaves remain healthy, creating a starch-protein matrix that is harder to digest. Kernel processors can help improve starch digestibility once grain moisture starts to drop.

Test Weight

Test weight is a measure of corn grain bulk density that is sometimes associated with kernel texture. Test weight tends to increase as grain becomes drier. Test weight is loosely related to kernel hardness, which is also known to influence livestock feed to gain ratio in feeder cattle. However, as silage is harvested at a higher moisture content, it is not as great a predictor for silage quality.

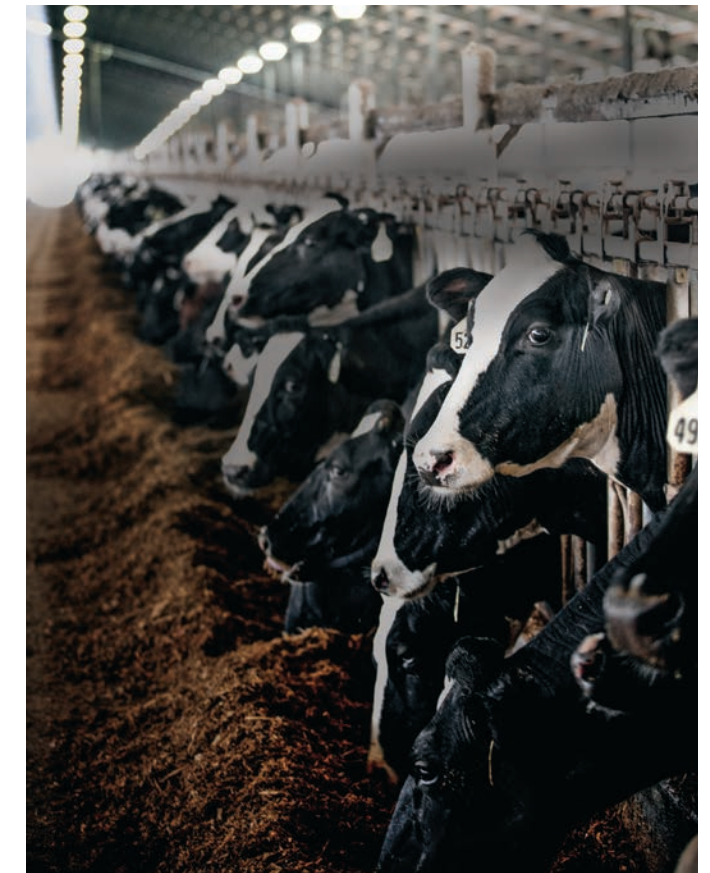
APPROACHES TO CHARACTERIZING HYBRID QUALITY

1. Fiber Digestibility

Due to the relatively large amount of silage being in the form of stover, understanding fiber digestibility is very important where corn silage is the largest portion of feed rations. The relative fiber digestibility of a hybrid is largely dependent on how much lignin is present in silage. Lignin is an indigestible fiber that has no energy value to animals and helps compose the total fiber content of forage, expressed as neutral detergent fiber (NDF). Corn silage with a low NDF is desirable. Neutral detergent fiber digestibility (NDFd) measures the amount of NDF that can be digested, and larger values are more desirable. Hybrids vary significantly in quality due to fiber content and digestibility.

2. Starch Digestibility

Increased starch digestibility is known to improve energy availability for dairy cows, thereby improving milk production and/or feed efficiency.^{1,2} Besides hybrid differences, multiple management practices such as



harvest timing, kernel processing and length of time in storage can greatly affect starch digestibility. Short-stature hybrids or raising chopping height can quickly reduce stover to grain ratio resulting in higher starch content as well.

3. Whole-Plant Digestibility

Total digestible nutrients (TDN) describe the energy content of feed as the sum of the digestibility of different nutrients. TDN is often based on calculations using acid detergent fiber (ADF), which is a low-cost and rapid turnaround method to predict energy content. Significant variations in digestibility of fiber often cause inaccuracies in ADF values and TDN values tend to underpredict forage feeding values.

ENERGIZE YOUR OPERATION WITH ENOGEN CORN SILAGE

Enogen corn hybrids contain a robust, efficient amylase enzyme that converts starch to useable sugars faster and more effectively than other corn. When Enogen corn silage is fed in beef or dairy operations, it provides more available energy per pound of feed than other corn silage, and also provides some real benefits during the ensiling process.

Starch in corn provides critical energy for dairy cows or beef cattle to grow and produce, but cattle do not digest and process starch from corn efficiently. The amylase enzyme in Enogen hybrids increases starch digestibility, increasing feed efficiency. That means decreased feed costs and increased profit potential for your livestock operation.

ENOGEN BENEFITS IN SILAGE PRODUCTION AND STORAGE

- High-yielding, elite genetics that require no additional management, unlike some other specialty silage hybrids⁴
- No adverse effects on yield potential – Enogen versions of Golden Harvest hybrids will yield as well as or better than their non-Enogen counterparts

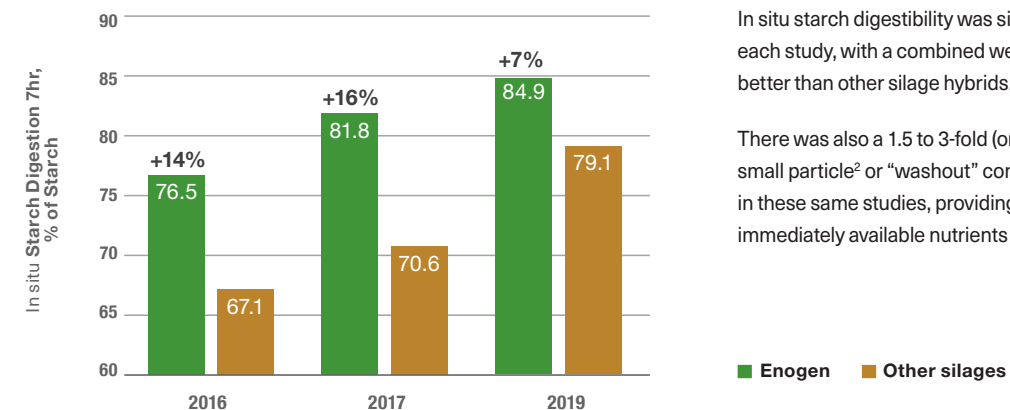
- Enogen's amylase enzyme begins converting starch to sugar as soon as it's chopped to increase the energy available to your cattle³
- Greater feed flexibility
 - Feed earlier with the confidence of greater starch digestibility in as little as one day
 - Store with confidence, knowing your Enogen silage maintains its digestibility advantage longer and may be less prone to spoilage and loss⁵

ENOGEN SILAGE BENEFITS IN LIVESTOCK PRODUCTION

- Increased available energy means increased feed efficiency of about 5%, according to recent feeding trials at leading universities⁶
- No adverse effects on ruminal digestion or pH, and no increase in the incidence of acidosis or bloat⁷
- Simple incorporation into rations – replace your current silage with Enogen silage to increase feed efficiency
- Helps to optimize DMI with production, lowering feed costs and increasing the efficiency of your operation



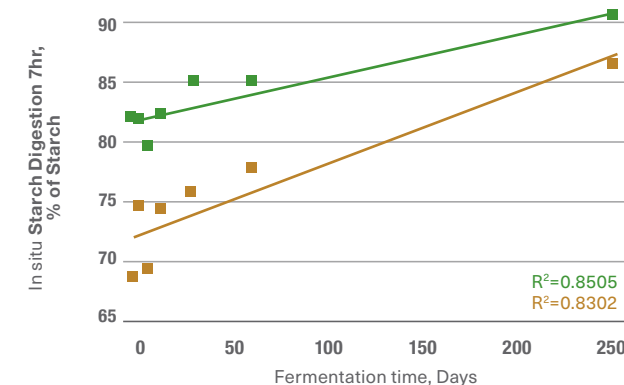
IN SITU RUMEN STARCH DIGESTIBILITY AFTER 60D FERMENTATION¹



In situ starch digestibility was significantly greater for Enogen silage in each study, with a combined weighted average of 9.1 percentage points better than other silage hybrids.

There was also a 1.5 to 3-fold (or >25 percentage points) increase in small particle² or "washout" content in Enogen silage vs. other silages in these same studies, providing significantly greater amounts of immediately available nutrients to rumen microbes.

IN SITU RUMEN STARCH DIGESTIBILITY VS FERMENTATION TIME³



In situ rumen starch digestion was significantly greater in Enogen silages as early as one day after harvest — about 20% greater — and this advantage continued through 240 days of fermentation time. Though digestibility improved over time in both silage types, the Enogen advantage was about 5% after 240 days of ensiling.

These differences in starch digestion and small particle content cannot be reliably detected with NIRS.

It would take about 157 days in the silo for other silage to match the starch digestibility exhibited by Enogen silage on day 1 after harvest.

■ Enogen; n=104 ■ Other silages; n=64



¹ Syngenta contract research: 2016 Sample Survey: n = 165 Enogen, 160 GH/NK non-Enogen, and 105 competitor hybrid samples; 2017 Replicated Plots: 5 locations with 2-5 Enogen/isoline pairs and 1-3 BMR hybrids/location, 4 replicates/hybrid; and 2019 Multi-location Project: time series with non-Enogen hybrids (8 locations), Enogen hybrids (10 locations). All samples fermented about 60 days in vacuum-sealed mini-silos before analysis by Rock River Laboratories, Inc. using rumen cannulated cows.

² Particles <50 microns in size.

³ 2019 Multi-location Project samples, as described above, average of day 1, 3, 7, 14, 30, 60, and 240 fermentation time.

⁴ Enogen is subject to specific yet simple stewardship requirements.

⁵ Kansas State University Research Study, 2017.

⁶ University of Nebraska-Lincoln Research Studies, 2013-2017; Kansas State University Research Study, 2017; Pennsylvania State University Research Study, 2019.

⁷ Kansas State University Research Studies, 2017-2018; Pennsylvania State University Research Study, 2019; Ohio State University Research Study, 2020; University of Nebraska-Lincoln Research Studies, 2016-2018.

LIMITATIONS OF SILAGE STARCH DIGESTIBILITY TESTING FOR COMPARING ENOGEN TO NON-ENOGEN HYBRIDS

INSIGHTS

- Four different methods are commonly used to measure silage starch digestibility, each with strengths and weaknesses.
- Near Infrared Reflectance Spectroscopy (NIRS) is one of the more common methods used to analyze silage hybrid evaluation trials.
- NIRS has limited ability to accurately predict Enogen® hybrid performance.
- Enogen hybrid performance is better predicted using in-situ testing methods.

BACKGROUND

Corn silage starch content frequently ranges from 25-35% of the whole plant harvested, making it a significant contributor of energy to feed rations.¹ Increases in starch digestibility in whole plant corn silage is believed to improve dairy and beef cattle performance, often making it one of several valuable traits considered when evaluating and selecting corn silage hybrids.² Accurately measuring starch digestion in a way that best reflects cattle performance, along with being done fast and economically, is challenging compared to other nutritive assessments. Inaccurate starch values may have additional implications because they are commonly used in calculations with other forage analyses to create a single value to estimate overall silage quality.

There are four approaches to characterizing starch digestion, each with advantages and disadvantages. Historically, almost all methods have been good enough for comparing relative differences between hybrids, but with the recent introduction of Enogen corn hybrids, containing higher levels of alpha-amylase to improve

starch breakdown, starch digestion values could be biased by certain testing methods.

Methods for quantifying starch digestibility:

1. **In-vitro:** This lab-bench technique uses rumen fluid from donor cattle to simulate digestion while outside the intestine or rumen.
 - Weakness: Variable results can occur from different testing batches due to changes in donor cattle rumen fluid. Silage samples must be finely ground, reducing any natural differences in digestion due to particle size. Samples could potentially be only partially digested due to not being exposed to multiple digestive processes within a live cow.
 - Advantage: Samples can be processed quicker and at less cost than most other techniques.
2. **In-situ:** Feed sample inside a porous sachet is placed inside live cattle rumen and incubated for a set period before removing and measuring actual starch disappearance.
 - Weakness: Results may vary when repeating test due to differences in each cow's rumen fluid. Samples may only be partially digested due to only being placed in one specific area of cow rumen.
 - Advantage: Believed to better reflect how cattle respond to hybrid differences than in-vitro method.³ Partially improved by using larger feed samples and particle size and replicating in multiple sachets and/or cows for more true assessment of hybrids.
3. **In-vivo:** The most comprehensive of all approaches, in-vivo measures the total mixed rations fed and what is passed through the animal in feeding trials.

- Weakness: Slow and expensive process that requires looking at impact of the total mixed ration. Difficult to use for screening significant number of hybrids.
- Advantage: The most accurate of all testing procedures as it measures the exact intake and pass-through within a live animal.

4. Near Infrared Reflectance

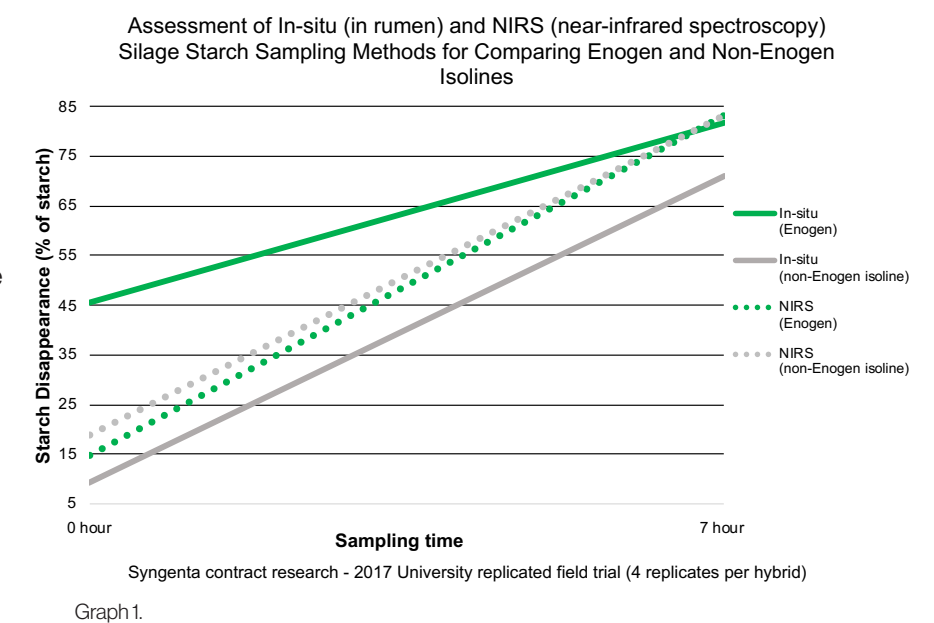
Spectroscopy (NIRS):

A lab process in which an apparatus measures reflectance and absorbance of specific light wavelengths of a silage sample and compares it to samples with known values previously quantified using in-situ analysis methods. NIRS uses multiple historic known values to calibrate against.

- Weakness: It is only a prediction based on previously known sample values. Lack of calibration for starch digestibility interactions with traits such as Enogen could result in predictions not accurately representing actual performance in live animals.
- Advantage: Quickest and least costly approach to testing many hybrids for relative differences.

COMPARING NIRS AND IN-SITU RESULTS

Hybrid silage evaluation trials commonly test multiple hybrids simultaneously for several quality trait characteristics. A mixture of Enogen and non-Enogen hybrids frequently are found within the same trial and are analyzed using NIRS methodology for quantifying starch and starch digestibility. A controlled study was set up to better understand the accuracy of results using NIRS as compared to in-situ testing methods. Silage samples



were collected from Enogen hybrids and respective non-Enogen isolines. Subsamples were pulled from each sample and starch disappearance was measured at 0- and 7-hour timings via in-situ assays and using NIRS calibrations specific for the two selected timings.

NIRS results for both Enogen and non-Enogen hybrids showed little difference between each other at both 0- and 7-hour intervals (dashed lines in Graph 1). When using in-situ methods, results of Enogen traited hybrids had a higher rate of starch disappearance at both 0- and 7-hour timings (solid green line in Graph 1). Although NIRS is quicker and a lower cost testing method, it cannot effectively detect starch digestion differences contributed by the alpha-amylase present in Enogen traited silage. NIRS has potential for screening large numbers of hybrids to understand genetic differences, although it may not be the most effective method for illustrating starch digestibility differences among hybrids with and without the Enogen trait.

MANAGEMENT CONSIDERATIONS FOR CORN SILAGE PRODUCTION

INSIGHTS

- It is important to understand corn hybrid properties when using them for silage.
- Silage quality and digestibility data are provided for many Golden Harvest® hybrids.

Golden Harvest is committed to sharing agronomic knowledge with livestock-producing customers to help them grow more corn silage and benefit their livestock operation. To help growers choose the best silage hybrids to meet the nutritional needs of dairy and beef operations, our Agronomy In Action Research team provides silage hybrid ratings. These ratings are supported by analysis of multiple company and third-party research trials and our understanding of each hybrid's silage characteristics.

HYBRID RATINGS EXPLANATION

Silage samples collected at harvest undergo analysis by independent labs to derive the silage quality and digestibility data results. This data is then reviewed, along with our agronomic field knowledge of each hybrid, to assign each a silage quality rating within four categories: BEST=best silage quality or yield content, relative to other hybrids; GOOD=good silage quality or yield content, relative to other hybrids; FAIR=fair silage quality or yield content, relative to other hybrids; and POOR=poor silage quality or yield content, relative to other hybrids.

SILAGE HYBRID MANAGEMENT CONSIDERATIONS

- Select hybrids well-adapted for the geographic region using local performance data whenever possible.
- Understand that hybrid characteristics such as increased starch digestibility are important for silage production.
- Select hybrids best fitting specific needs for yield and quality. When comparing hybrid ratings, it is recommended to compare ratings within a maturity group.
- Plant early to optimize crop utilization of water, nutrients and sunlight.
- Plant at populations equal to or up to 10% greater than corn for grain.
- Take high potassium and phosphorous removal rates from silage into consideration when fertilizing fields.
- Target a whole-plant moisture content of 60-70% at harvest, depending on ensiling method, with higher moistures best suited for storage in a bunker or pile.



Yield Calculated on a per acre basis and adjusted to standard moisture.

Crude Protein (CP) Indicates the percent content of this important feed component relative to other hybrids.

Neutral Detergent Fiber Digestibility 48 Hour Estimates the ruminant digestibility of the NDF fraction.

Fat Indicates the percent content of this important feed component relative to other hybrids.

Starch Indicates the percent content of this important feed component.

Total Digestible Nutrients (TDN) Describes the energy content of feeds as the sum of the digestibility of different nutrients.

Net Energy Lactation (NEL) Feed effect on net energy for lactating cows based on acid detergent fiber (ADF).

Milk/Ton An estimate of forage quality driven by starch content, starch digestibility and NDF; **Milk/A** Combines the estimate of forage quality (Milk/Ton) and yield (Tons/A) into a single term.**

Beef/Ton A proprietary estimate of forage quality driven by TDN; **Beef/A** Combines the estimate of forage quality (Beef/Ton) and yield(Tons/A) into a single term.

** Milk: Combining Yield and Quality into a Single Term, <https://fyi.uwex.edu/forage/files/2016/11/Milk-2016-Combining-Yield-and-Quality-into-a-Single-Term-2.pdf>

Golden Harvest Corn Silage Hybrid Ratings													
Golden Harvest Hybrid Series	Relative Maturity (RM)	Yield (tons/Acre)	Protein	NDF	NDFD	Starch	Fat	TDN	Feed Effect On				
									NEL	Milk/Ton	Milk/Acre	Beef/Ton	Beef/Acre
G78C29	78	Fair	Good	Good	Good	Best	-	Good	Good	Good	Good	Good	Fair
G80Q01	80	Fair	Best	Best	Good	Good	Good	Good	Good	Good	Good	Good	Good
G84J92	84	Fair	Fair	Fair	Good	Good	Good	Fair	Fair	Fair	Fair	Fair	Fair
G85Z56	85	Good	Best	Good	Good	Good	Good	Good	Good	Good	Best	Good	Best
G87A53	87	Poor	Fair	Good	Good	Good	Fair	Good	Good	Good	Fair	Good	Fair
G88F37	88	Good	Good	Good	Good	Best	-	Good	-	Good	Fair	Good	Fair
G90S99	90	Good	Best	Good	Fair	Good	Good	Fair	Fair	Fair	Good	Fair	Good
G90Y04	90	Good	Good	Fair	Good	Good	Fair	Good	Fair	Good	Best	Good	Best
G91V51	91	Good	Good	Best	Good	Best	Best	Good	Good	Good	Good	Good	Good
G92A51	92	Best	Good	Best	Good	Best	Good	Best	Best	Good	Good	Best	Good
G93A49	93	Good	Fair	Good	Good	Fair	Good	Good	Good	Good	Good	Good	Good
G94P48	94	Fair	Best	Best	Good	Best	Best	Best	Best	Good	Fair	Best	Fair
G95D32	95	Good	Good	Best	Good	Best	Best	Good	Good	Good	Good	Good	Good
G96R61	96	Best	Good	Good	Good	Good	Good	Good	Good	Good	Best	Good	Best
G97N86	97	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
G98L17	98	Best	Good	Fair	Fair	Good	Fair	Good	Good	Good	Best	Good	Best
G98M44	98	Good	Good	Good	Fair	Best	Good	Fair	Fair	Fair	Good	Good	Good
G99E68	99	Fair	Good	Good	Good	Good	Fair	Good	Good	Good	Fair	Good	Fair
G00A97	100	Fair	Good	Best	Good	Best	Best	Best	Good	Good	Good	Best	Best
G00H12	100	Good	Best	Fair	Good	Fair	Best	Good	Fair	Fair	Fair	Good	Fair
G02K39	102	Good	Good	Good	Good	Good	Best	Best	Best	Best	Good	Best	Good
G02W74	102	Fair	Good	Best	Best	Good	Good	Good	Good	Good	Fair	Good	Good
G03B96	103	Fair	Good	Good	Fair	Good	Good	Good	Good	Good	Fair	Good	Fair
G03R40	103	Good	Best	Poor	Good	Fair	Best	Fair	Fair	Fair	Good	Fair	Fair
G04G36	104	Fair	Good	Best	Best	Best	Best	Best	Best	Best	Fair	Best	Fair
G04S19	104	Good	Good	Fair	Good	Fair	Fair	Good	Good	Good	Good	Good	Good
G05K08	105	Good	Good	Good	Good	Best	Good	Fair	Fair	Fair	Fair	Good	Good
G06A27	106	Best	Best	Best	Good	Best	Good	Good	Good	Good	Best	Good	Best
G06K93	106	Good	Fair	Good	Good	Best	Best	Best	Good	Best	Good	Best	Good
G06Q68	106	Fair	Good	Best	Best	Good	Good	Good	Good	Good	Fair	Good	Fair
G07F23	107	Best	Good	Good	Good	Good	Fair	Good	Good	Good	Best	Good	Best
G07G73	107	Best	Good	Good	Fair	Fair	Good	Good	Good	Good	Best	Best	Best
G08D29	108	Good	Good	Fair	Fair	Fair	Fair	Good	Good	Good	Fair	Good	Fair
G08R52	108	Good	Good	Good	Good	Good	Fair	Fair	Fair	Fair	Good	Good	Good
G09A86	109	Best	Best	Good	Fair	Good	Good	Good	Good	Good	Good	Good	Best
G09Y24	109	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
G10C45	110	Good	Good	Good	Good	Best	Best	Best	Best	Good	Best	Good	Good
G10D21	110	Good	Good	Good	Fair	Good	Good	Good	Good	Good	Fair	Good	Good
G10L16	110	Good	Fair	Best	Good	Best	Best	Good	Good	Good	Good	Good	Good
G10S30	110	Fair	Good	Fair	Good	Good	Best	Good	Good	Good	Fair	Good	Fair
G11B63	111	Best	Good	Good	Good	Fair	Fair	Good	Good	Good	Best	Good	Best
G11V76	111	Good	Good	Good	Fair	Fair	Fair	Good	Good	Good	Good	Fair	Good
G12A22	112	Best	Good	Good	Good	Fair	Fair	Good	Good	Good	Good	Good	Good
G12S75	112	Best	Fair	Poor	Fair	Poor	Fair	Good	Good	Good	Good	Fair	Good
G12U17	112	Good	Good	Best	Best	Best	Fair	Good	Good	Good	Good	Good	Good
G13D55	113	Good	Good	Best	Good	Best	Best	Best	Good	Good	Good	Good	Good
G13E90	113	Good	Best	Good	Good	Fair	Good	Good	Good	Good	Best	Good	Good
G13H15	113	Best	Fair	Good	Good	Good	Poor	Good	Good	Good	Best	Good	Best
G13M88	113	Good	Fair	Good	Fair	Good	Good	Fair	Fair	Fair	Fair	Good	Fair
G13N18	113	Good	Good	Fair	Good	Good	Good	Best	Good	Best	Good	Best	Fair
G13P84	113	Good	Best	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
G13Z50	113	Good	Fair	Good	Good	Good	Poor	Good	Good	Good	Fair	Good	Fair
G14N11	114	Good	Good	Best	Good	Best	Fair	Good	Good	Good	Good	Good	Good
G14R38	114	Good	Fair	Best	Good	Best	Best	Best	Best	Best	Best	Best	Best
G15J91	115	Good	Good	Good	Good	Fair	Good	Best	Best	Good	Good	Good	Good
G15L32	115	Best	Good	Best	Good	Best	Good	Good	Good	Good	Good	Good	Good
G16K01	116	Good	Fair	Good	Good	Good	Good	Good	Best	Good	Good	Best	Good
G16Q82	116	Good	Fair	Good	Good	Best	Good	Good	Good	Good	Good	Good	Good
G17A74	117	Good	Best	Fair	Best	Fair	Good	Good	Good	Good	Best	Best	Best
G17A81	117	Fair	Good	Good	Good	Good	Good	Good	Good	Good	Fair	Good	Good
G17E95	117	Good	Good	Poor	Good	Poor	Good	Good	Good	Good	Best	Good	Best
G18D87	118	Good	Best	Fair	Good	Fair	Fair	Good	Good	Good	Best	Good	Best

Corn Silage Hybrid Ratings Chart Key: Best Good Fair Poor Insufficient Data

* NOTE: These ratings should not be used to estimate actual production per animal, but instead they should be used to determine relative overall silage quality and yield of each hybrid.

PHYSICAL CORN KERNEL ATTRIBUTES INFLUENCE ON BEEF CATTLE PERFORMANCE

INSIGHTS

- Specific physical corn kernel characteristics can be used to predict feed efficiency.
- High test weight was not a good indicator of beef feed-to-gain, although kernel size and softness were highly correlated.
- In a dry-rolled, corn-based diet, cattle fed corn with a higher proportion of soft endosperm gained more efficiently than cattle fed corn with a hard endosperm.

INTRODUCTION

Kernel characteristics such as test weight, density and hardness can vary significantly between corn hybrids. Test weight, expressed as pounds per bushel, can often become part of seed selection discussions even though grain market prices are typically not discounted until test weight falls below No. 2 yellow corn standards of 54 lbs/bu. There is a belief by many that high test weight grain is associated with high grain yields and feeding performance, however there is little evidence in research literature to support this. Golden Harvest®, in collaboration with the University of Nebraska-Lincoln (UNL), designed trials to evaluate the role that physical corn kernel characteristics have on influencing beef cattle feed performance.¹ Trials were designed in a way to address two main objectives:

1. Is cattle feed performance affected by physical attributes of corn hybrid grain utilized in feed rations?
2. What kernel characteristics of the hybrid most influence feed performance?



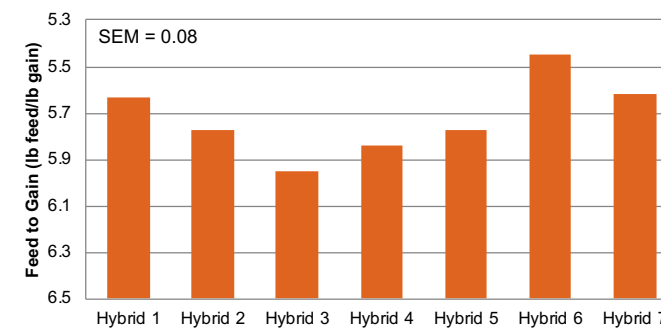
BEEF FEEDLOT STUDY DESIGN

- Eight crossbred steer calves were randomly assigned to pens.
- Seven hybrids with differing kernel characteristics were grown, characterized for kernel attributes and assigned to an individual pen as part of the feed ration.
- Rations consisted of 66% dry-rolled corn of each selected hybrid with 20% wet gluten, 10% corn silage and 4% supplement.
- Each hybrid was replicated in four pens.
- Cattle were fed for 167 days and processed at a commercial packing plant.
- Carcass data was collected to calculate multiple beef performance and quality variables.

KERNEL CHARACTERISTICS MEASURED

1. Test weight
2. 1,000 kernel weight
3. Kernel size and shape
4. Feed constituent content (% protein, oil, starch, etc.)
5. Starch type
6. In-vitro starch disappearance
7. In-situ rate and extent of disappearance
8. Kernel hardness – as determined by various methods

Effect of Corn Hybrid on Beef Feed to Gain (UNL Feedlot Study)



Graph 1. Feed-to-gain ratio of each hybrid

FEEDLOT STUDY RESULTS

Of all animal performance variables measured, “feed-to-gain ratio” was the only feed performance characteristic influenced by hybrid grain characteristics (Chart 1). Feed-to-gain is the average pounds of feed needed for each pound of animal gain. Low feed-to-gain values indicate that less feed is needed to produce similar weight gain. Other animal performance variables such as dry matter intake, average daily gain, hot carcass weight, marble score and 12th rib fat were not influenced by hybrid differences. In a dry-rolled, corn-based diet, cattle fed corn hybrids with a higher proportion of soft endosperm tended to gain more efficiently than cattle fed corn hybrids with a harder endosperm.

GRAIN CHARACTERISTICS RELATED TO LOW FEED-TO-GAIN RATIO

Of the 8 kernel characteristics measured across hybrids, 1,000 kernel weight, kernel hardness and in-situ rate of disappearance were strongly correlated with lower feed-to-gain ratios. More commonly recognized attributes such as high

test weight were not as correlated to feed efficiency gains. Due to the high correlations and relative ease of being able to characterize hybrids for 1,000 kernel weight and hardness characteristics, Golden Harvest utilizes these findings to characterize commercial hybrid physical grain characteristics for determining which are more likely to have better feed performance.

1. 1,000 kernel weight
 - Closely related to kernel size
 - Different measurement than test weight
 - Higher values correlated to better (lower) feed-to-gain ratios ($r^2 = -0.8135$; $P = 0.026$).
2. Kernel hardness
 - The “Stenvert Hardness Test” provided the best predictors of feed-to-gain response.
 - Softer kernels have better feed-to-gain ratios.
 - Hybrids that required less time to grind in a micro-hammer mill ($r^2 = 0.8275$; $P = 0.022$) and produced a larger percentage of soft particles ($r^2 = -0.83202$; $P = 0.021$) resulted in improved feed performance (lower feed-to-gain ratio).
3. In-situ rate of disappearance
 - Percent of grain digested within live animal rumen over designated time.

Kernel Test	Hybrid Used in Feedlot Trials							SEM	P
	1	2	3	4	5	6	7		
1,000 K wt.	318 ^c	317 ^c	315 ^{cd}	311 ^d	326 ^b	344 ^a	341 ^a	1.74	0.01
Stenvert Hardness									
% Soft	72 ^a	67 ^b	64 ^c	68 ^b	63 ^c	73 ^a	71 ^a	0.01	0.01
Time to grind (seconds)	7.6 ^d	7.8 ^{cd}	9.7 ^a	8.1 ^c	8.7 ^b	7.3 ^e	7.9 ^{cd}	0.12	0.01

Table 1. Hybrid 1,000 kernel weight and Stenvert Hardness test results

Golden Harvest® Corn Beef Feed-to-Gain Ratings (Based on UNL study correlating 1000 kernel weight and hardness to feed)*					
Golden Harvest Hybrid Series	Relative Maturity (RM)	Beef Feed-to-Gain Rating*	Golden Harvest Hybrid Series	Relative Maturity (RM)	Beef Feed-to-Gain Rating*
G78C29	78	Good	G07G73	107	Good
G80Q01	80	Poor	G08D29	108	Good
G84J92	84	Good	G08R52	108	Good
G85Z56	85	Best	G09A86	109	Best
G87A53	87	Fair	G09T26	109	Best
G88F37	88	Good	G09Y24	109	Fair
G90S99	90	Best	G10C45	110	Good
G90Y04	90	Good	G10D21	110	Good
G91V51	91	Good	G10L16	110	Good
G93A49	93	Good	G10S30	110	Good
G94P48	94	Good	G11B63	111	Best
G95D32	95	Good	G11V76	111	Good
G95M41	95	Good	G12A22	112	Best
G96R61	96	Fair	G12S75	112	Good
G97N86	97	Best	G12U17	112	Good
G98L17	98	Best	G13E90	113	Good
G98M44	98	Fair	G13H15	113	Good
G99A37	99	Good	G13M88	113	Good
G99E68	99	Fair	G13N18	113	Best
G00A97	100	Fair	G13P84	113	Fair
G00H12	100	Poor	G13T41	113	Good
G02K39	102	Best	G13Z50	113	Best
G02W74	102	Fair	G14N11	114	Best
G03B96	103	Poor	G14R38	114	Best
G03R40	103	Fair	G15J91	115	Fair
G04G36	104	Best	G15L32	115	Best
G04S19	104	Best	G16K01	116	Good
G05K08	105	Best	G16Q82	116	Fair
G06A27	106	Fair	G17A74	117	Good
G06K93	106	Good	G17A81	117	Fair
G06Q68	106	Good	G17E95	117	Fair
G07F23	107	Best	G18D87	118	Fair

Beef Feed-to-Gain Ratings Key: Best Good Fair Poor

* Ratings based on Jaeger, Stephanie L.; Macken, Casey N.; Erickson, Galen E.; Klopfenstein, Terry J.; Fithian, Wayne A.; and Jackson, David S., "The Influence of Corn Kernel Traits on Feedlot Cattle Performance" (2004). Nebraska Beef Cattle Reports. Paper 197.

Chart 1. Feed-to-gain ratings



G03B96



G12A22



G13P84



G16Q82

CORN HYBRID GRAIN END-USE CHARACTERISTICS

INSIGHTS

- Considering how harvested corn grain will be used may help in the hybrid selection process.
- Some hybrids will consistently produce higher levels of specific grain end-use characteristics.

Golden Harvest® is built on a commitment to sharing agronomic knowledge with customers to help them grow more corn. The Corn Hybrid Grain End-Use Ratings provide information that can help people produce corn for livestock, the ethanol industry or other grain end uses where grain quality is just as important as yield. These Corn Hybrid Grain End-Use Ratings are generated by collecting grain samples from internal company trials which are sent to an independent laboratory for protein, oil and starch analysis. The data from these analyses are then categorized for the end-use based on the level of each characteristic with four ratings: Best (highest level); Good (above-average level); Fair (average to below-average level); Poor (low level).

USES FOR HIGH QUALITY CORN GRAIN

- Greater feed value per unit of grain
- Can improve feed efficiency, reducing cost per pound of gain
- Reduces the need for feed supplements, and the storage and handling costs associated with those supplements
- Potential for premium on grain

UNDERSTANDING GRAIN QUALITY TRAITS

Protein: Represents the ability of a feed to supply the animal with amino acids and nitrogen, the basic building blocks needed for growth and maintenance of the body.

Oil and Starch: Both traits are an indication of the ability of a feed to meet the animal's energy, fat deposition and heat production needs.



Starch is the largest single component in corn grain and the primary source of most of the energy in corn. Oil is more energy dense than starch, thus a unit change in oil content affects the energy supplied by the feed more than a similar unit change in starch.

ETHANOL

- Specific hybrids can yield 2-5% more ethanol than bulk commodity corn.¹
- Ideal hybrids for dry-grind ethanol production have a larger portion of high total fermentables (HTF), which is starch plus small amounts of free glucose, fructose, maltose and sucrose within kernels.
- Grain starch content alone is not a good indicator of ethanol yield.

FACTORS INFLUENCING GRAIN END-USE CHARACTERISTIC CONTENT

- Environment – Corn grown in the northern U.S. tends to be higher in protein and corn grown in the central and southern U.S. tends to be higher in starch.
- Genetics – Some hybrids will consistently produce higher levels of specific grain end-use characteristics, regardless of growing conditions and crop management.
- Soils – High fertility soils tend to produce higher levels of protein.
- Management – Proper nitrogen fertility correlates to increased protein levels.

Golden Harvest® Corn Hybrid Grain End-Use Ratings											
Golden Harvest Hybrid Series	Relative Maturity (RM)	Protein	Oil	Starch	Ethanol	Golden Harvest Hybrid Series	Relative Maturity (RM)	Protein	Oil	Starch	Ethanol
G78C29	78	Fair	Good	Best	Good	G07G73	107	Fair	Best	Fair	Fair
G80Q01	80	Good	Fair	Good	Best	G08D29	108	Fair	Best	Good	Good
G84J92	84	Fair	Fair	Best	Best	G08R52	108	Good	Poor	Best	Best
G85Z56	85	Good	Fair	Good	Good	G09A86	109	Good	Good	Good	Good
G87A53	87	Good	Good	Good	Good	G09T26	109	Fair	Best	Good	Good
G88F37	88	Fair	Poor	Fair	Fair	G09Y24	109	Good	Best	Good	Good
G90S99	90	Best	Poor	Fair	Fair	G10C45	110	Good	Fair	Good	Good
G90Y04	90	Good	Fair	Best	Good	G10D21	110	Good	Good	Good	Best
G91V51	91	Poor	Fair	Good	Best	G10L16	110	Fair	Good	Good	Best
G92A51	92	Fair	Fair	Good	Fair	G10S30	110	Fair	Best	Fair	Best
G93A49	93	Fair	Fair	Good	Good	G11B63	111	Good	Fair	Best	Good
G94P48	94	Best	Best	Fair	Good	G11V76	111	Good	Poor	Good	Best
G95D32	95	Fair	Fair	Best	Best	G12A22	112	Fair	Poor	Good	Fair
G95M41	95	Fair	Fair	Best	Best	G12S75	112	Fair	Fair	Good	Best
G96R61	96	Best	Poor	Good	Good	G12U17	112	Fair	Good	Best	Best
G97N86	97	Best	Fair	Good	Good	G13D55	113	Fair	Good	Fair	Fair
G98L17	98	Good	Fair	Best	Best	G13E90	113	Fair	Fair	Good	Good
G98M44	98	Good	Best	Fair	Fair	G13H15	113	Good	Best	Good	Good
G99A37	99	Good	Fair	Good	Best	G13M88	113	Best	Best	Fair	Fair
G99E68	99	Good	Fair	Good	Best	G13N18	113	Good	Fair	Fair	Good
G00A97	100	Fair	Good	Good	Good	G13P84	113	Good	Fair	Good	Good
G00H12	100	Best	Best	Fair	Good	G13T41	113	Fair	Best	Good	Good
G02K39	102	Good	Best	Fair	Good	G13Z50	113	Fair	Poor	Best	Good
G02W74	102	Good	Fair	Good	Best	G14N11	114	Fair	Fair	Best	Best
G03B96	103	Good	Fair	Fair	Best	G14R38	114	Fair	Good	Good	Best
G03R40	103	Good	Best	Good	Good	G15J91	115	Good	Poor	Good	Best
G04G36	104	Fair	Best	Good	Good	G15L32	115	Fair	Good	Best	Good
G04S19	104	Fair	Fair	Best	Best	G16K01	116	Fair	Good	Good	Best
G05K08	105	Good	Best	Good	Good	G16Q82	116	Fair	Poor	Best	Good
G06A27	106	Poor	Poor	Best	Fair	G17A74	117	Good	Fair	Fair	Good
G06K93	106	Fair	Best	Best	Good	G17A81	117	Fair	Poor	Good	Fair
G06Q68	106	Fair	Fair	Best	Good	G17E95	117	Good	Best	Fair	Fair
G07F23	107	Fair	Best	Good	Best	G18D87	118	Best	Fair	Good	Good

Corn Hybrid Grain End-use Ratings Key:



Using this chart:

Protein – A source of nitrogen and amino acids needed for animal growth

Oil – A secondary source of energy in corn grain and more energy dense than starch

Starch – The largest single component in corn grain and the primary source of energy



ADDITIONAL RESOURCES

CORN MANAGEMENT



SOYBEAN MANAGEMENT



FERTILITY MANAGEMENT



GENERAL MANAGEMENT



HARVEST MANAGEMENT



REFERENCES

CORN MANAGEMENT

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LIVESTOCK FEED MANAGEMENT

Energize Your Operation with Enogen Corn Silage

¹ Syngenta contract research: 2016 Sample Survey: n = 165 Enogen, 160 GH/NK non-Enogen, and 105 competitor hybrid samples; 2017 Replicated Plots: 5 locations with 2-5 Enogen/isoline pairs and 1-3 BMR hybrids/location, 4 replicates/hybrid; and 2019 Multi-location Project: time series with non-Enogen hybrids (8 locations), Enogen hybrids (10 locations). All samples fermented about 60 days in vacuum-sealed mini-silos before analysis by Rock River Laboratories, Inc. using rumen cannulated cows.

² Particles <50 microns in size.

³ 2019 Multi-location Project samples, as described above, average of day 1,3,7,14,30,60, and 240 fermentation time.

⁴ Enogen is subject to specific yet simple stewardship requirements.

⁵ Kansas State University Research Study, 2017.

⁶ University of Nebraska-Lincoln Research Studies, 2013-2017; Kansas State University Research Study, 2017; Pennsylvania State University Research Study, 2019.

⁷ Kansas State University Research Studies, 2017-2018; Pennsylvania State University Research Study, 2019; Ohio State University Research Study, 2020; University of Nebraska – Lincoln Research Studies, 2016-2018.

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