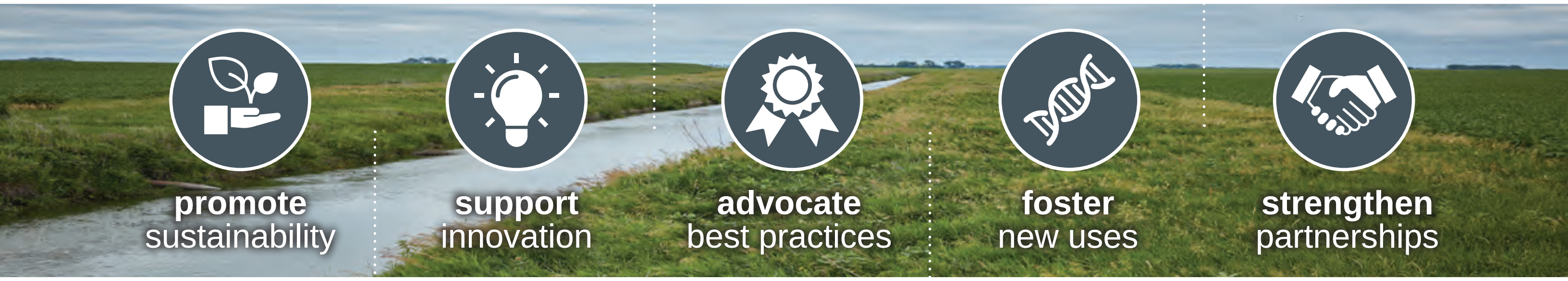
# RESEARCH SUMMARY 2017

Completed research projects funded by Minnesota corn farmers




MinnesotaCorn GROWERS ASSOCIATION

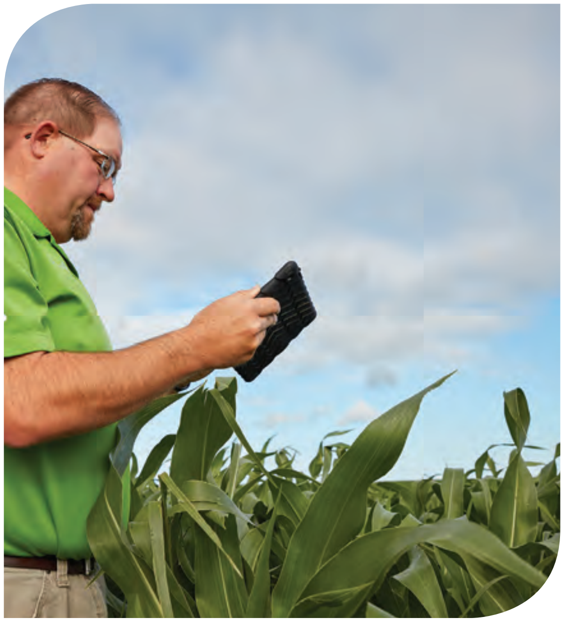
MinnesotaCorn RESEARCH & PROMOTION COUNCIL

RESEARCH SUMMARY 2017

# Farmers investing in their future.

The Minnesota Corn Growers Association and the Minnesota Corn Research & Promotion Council are committed to funding independent research that seeks to enhance the corn producing industry by improving agricultural practices and creating new opportunities for corn farmers.

Minnesota corn check-off dollars are funding a wide range of research projects that directly affect local businesses and families including the development of value-added products, the management of corn inputs, issues related to ethanol use, the evaluation of genetic traits, and the relationship between agricultural management practices and water quality.



This publication highlights completed research projects jointly funded by the Minnesota Corn Growers Association and the Minnesota Corn Research & Promotion Council that address each of these topic areas. Results of these studies are made available to growers in multiple formats, including this Minnesota Corn Research Summary. Growers are invited to apply this information to their own farm operations to help optimize best management practices and increase yield and returns.

For more information on projects funded by Minnesota's corn organizations, contact Paul Meints, Ph.D. at the MCGA office: pmeints@mncorn.org or 952-460-3601.

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# Committed to conservation.

Minnesota corn farmers are continuously working to improve and become better stewards of our state's natural resources while maintaining a thriving rural economy. That's why the Minnesota Corn Growers Association is committed to the following goal:

**Minnesota's corn farmers will become the most sustainable and environmentally responsible corn farmers in the United States.**

To help achieve that goal, Minnesota corn farmers invest millions of dollars each year through the corn check-off to fund third-party research related to the following initiatives:

**Promote sustainability**
We encourage Minnesota's corn farmers to research, evaluate and engage in a sustainability program that best fits the needs of their farm.

**Foster new uses**
We will identify and promote new opportunities for corn in the production of sustainable polymers, ethanol and bio-based chemicals. We will implement ethanol infrastructure, improve ethanol marketing efforts and increase utilization options.

**Strengthen partnerships**
We will commit to working collaboratively with a variety of partners to achieve success in fulfilling our vision.

**Support innovation**
We will significantly expand our efforts to increase innovative practices.

**Advocate best practices**
We will promote best practices for nitrogen management in Minnesota corn production.

## Risk and Management of Goss's Wilt of Corn (2013)

Dean Malvick

University of Minnesota

### Objectives

- Determine if there is pathogenic variability in the populations of the Goss's wilt pathogen that threatens durability of resistant hybrids. Based on field observations and preliminary research, we hypothesized that the Goss's wilt pathogen has different strain types with different aggressiveness that influence the level of effective resistant in hybrids.
- Determine which factors influence survival and spread of the Goss's wilt pathogen in a field and area. Our hypothesis was that burial of corn residue and tillage may reduce the risk of Goss's wilt in particular fields, and this will be influenced by environment.
- Determine if application of foliar fungicides can increase incidence and severity of Goss's wilt. Following scattered anecdotal observations, we hypothesize that application of foliar fungicides can potentially increase severity of Goss's wilt under some conditions.

### Introduction

Goss's wilt is a relatively new disease affecting corn production in fields scattered across Minnesota that can reduce yields over 40% on susceptible hybrids. First confirmed in Minnesota in 2009, this disease has since spread across the corn production region of Minnesota. As is the case for most crop diseases, it has a scattered presence across the landscape and inconsistent occurrence from year to year. Although we know that development of Goss's wilt is driven in part by weather, hybrid, and cropping history, the range of risk factors that favor Goss's are not understood and we cannot predict when, where, and how much damage this disease will cause.

Goss's wilt is the only significant corn disease in Minnesota caused by a bacterial pathogen *(Clavibacter michiganensis* subsp. *nebraskensis)*. There are no chemical sprays that have yet been shown to be consistently effective for management. The pathogen overwinters in infested corn residue. It infects plants that have been wounded by strong wind and thunderstorms and hail, and is favored by planting corn-on-corn. Much more research-based information is needed to reduce risk and to improve disease management.

Problem Statement: Although corn producers in Minnesota have historically had few significant problems with leaf diseases, this changed with the emergence of Goss's leaf blight and wilt. The pathogen is now widespread in corn fields across the state, and thus widely increasing the risk of disease. Management of Goss's wilt is based on genetic resistance, although crop rotation and tillage are also important. However, these practices have not prevented yield loss in all fields, and there is a paucity of information available upon which to improve and tailor management practices for Minnesota for the short and long term.

### Abstract

The overall goal of this project was to address key gaps in information needed to understand disease risk and to improve management. The first objective was to determine if there is pathogenic variability in populations of the Goss's wilt pathogen that threatens durability and efficacy of resistance in resistant hybrids. Results from our greenhouse and field studies clearly show that aggressiveness of the Goss's wilt pathogen (CMN) is highly variable, with strains existing in Minnesota that range from non-pathogenic to highly aggressive on hybrids susceptible to Goss's wilt. Thus, the population of the pathogen in a particular field can influence the level of disease severity and yield loss.

The presence of the non-pathogenic strains can reduce the severity of Goss's wilt. Corn hybrids and lines tested against a diversity of strains have demonstrated varying degrees of resistance and tolerance to infection and disease development. None of the hybrids were completely resistant to any strain and we did not identify races of the Goss's wilt pathogen that have the ability to overcome resistance on some hybrids and not others.

Another objective was to determine survival of the Goss's wilt pathogen in infected corn residue that was buried at different depths or left on the surface under different conditions. The results generally suggest that the Goss's wilt pathogen survives longer in residue on the soil surface than when it is buried.

The last objective was to determine in field studies if foliar fungicide applications to corn can influence the fungicide applications on disease development or yield under the conditions of these studies.

In conclusion, the results demonstrate that multiple factors influence development of Goss's wilt, including hybrid resistance, strain or strains of the pathogen present in a field, survival of the pathogen, and weather conditions in July. These results have direct applications to improving management of Goss's wilt in the short-term and long-term.

## Moving Corn North: Developing the Next Generation of Early Maturing Products (2014)

Marcelo Carena

North Dakota State University

### Objectives

The short-term goal was to develop, in cooperation with industry, unique corn products for commercial production. The long-term goal was to create a common and diverse short-season gene pool for the development of the next generation of northern U.S. hybrids with reduced risk and added value to farmers and ranchers.

### Introduction

Genetic diversity and sample sizes have declined for decades (Brown 1953, Goodman 1985, 1999b). However, corn producer options have been significantly minimized to genetically identical hybrids with different single-gene events (e.g., RR, BT) in the past decade.

Genetically uniform farmer fields have a high risk of disease epidemics and abiotic stresses. The seed industry has been reluctant to devote long-term efforts to prevent the genetic vulnerability of corn hybrids and emphasizes the use of similar genetics in current hybrids and in the development of the future narrow-based corn hybrids. Prediction models within companies have further reduced the chances to broaden their own germplasm pools.

Few corn breeding programs have had the long-term vision to incorporate exotic germplasm carrying unique alleles and the willingness to broaden the genetic basis of breeding programs (Hallauer and Sears, 1972; Goodman, 1985; Pollak, 2003; Carena, 2007; Carena *et al.*, 2009a; Sharma and Carena, 2012; Carena, 2013b; Carena and Sharma, 2016; Carena and Mitchell, 2016).

The use of genetically diverse germplasm was encouraged after the Southern Corn Leaf Blight epidemic *(Bipolaris maydis)* in the 1970s. Tropical genetic materials have not only been continuously exposed to major pests for improvement (Holley and Goodman, 1988) but also have shown useful genetic diversity for significant grain yield heterosis expression (Mungoma and Pollak, 1988; Crossa *et al.*, 1990; Echandi and Hallauer, 1996; Laude and Carena, 2013). However, long-term program efforts focused on the incorporation of tropical materials are still scarce.

Minimum industry efforts have been devoted to moving corn relative maturities north. The future relies on short-season lines and hybrids carrying genetic diversity with unique alleles not present in current genome sequences (Carena, 2013). Sampling in current genome sequences is not sufficient to obtain desirable trait combinations in corn hybrids. Only unique alleles can break environmental margins (Carena, 2011).

Annually, the upper Midwest consumes more than $1.4 billion of fossil fuels to dry $19.7 billion of corn grain (Bennett *et al.*, 2007). Northern MN corn often needs to be harvested at moisture levels too high for safe storage and must be artificially dried at high cost for storage and transport (e.g. 2013 fall).

MN corn farmers still continue to spend millions of dollars in corn grain drying due to the lack of short-season faster drying corn hybrids. Fast field dry down is one of the most important features for the stability of short-season corn hybrids especially in the northern U.S. Yang *et al.* (2010) were able to develop a new breeding methodology (AUDDC) to identify faster drier lines and hybrids in ND and MN. Still, there is a need to develop new corn breeding methodologies for the easier screening of genetically complex traits, difficult to measure, and largely influenced by the environment (Carena, 2013).

Molecular labs initially had the intention to work with these challenging and economically important traits but have targeted genetically simple traits instead, often not a challenge to breeders. Sharma and Carena (2016) recently invented BRACE, a high throughput phenotyping methodology to identify drought tolerant lines and hybrids with easier screening of root systems.

Genetically narrow-based corn hybrids have shown to be susceptible to climate changes. Growing genetically diverse and shorter-season vigorous corn varieties solves most of the agronomic problems facing farmers in early maturing environments. Still, in northern U.S. environments, the market offers hybrids that are not stable to short-season environmental conditions. Influencing industry to move corn north will be important to the future of

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## Moving Corn North: Developing the Next Generation of Early Maturing Products (2014)

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short-season corn producers. Millions of dollars are wasted annually to growing hybrids that have been bred under non-marginal conditions with hidden susceptibilities. Costs increase when hybrids with drought and cold susceptibility, later maturity, slow rate of dry down, low test weight, and low quality for ethanol and feedstock utilization are grown.

There is the need for new product development in marginal areas. Breeding programs have traditionally not been strategically located to work faster under the pressure of marginal environments. A long-term solution for improving profitability in the north is to develop the next generation of short-season stable and diverse products for a sustainable and profitable corn production. Breeding for adaptation is best done under target challenging, but uniform controlled environmental conditions where strengths and weaknesses are quickly identified and stable genotypes succeed.

Northern U.S. corn acres continue to significantly increase, making corn one of the top commodity crops and profitable alternatives for farmers and ranchers. However, the northern U.S. market has not yet taken advantage of value added products due to hybrids lacking high extractable starch and high quality protein for livestock. Premium payments for high quality short-season hybrids have been considered. Therefore, farmers and ranchers will only be able to increase their profitability if value-added products are available for their choice.

### Abstract

Minnesota (MN) corn farmers have few options as industry offers genetically identical hybrids with just different Genetically Modified Organism (GMO) events. In addition, northern MN farmers still do not have the same opportunities as southern MN farmers to enhance their quality of life. Billions of dollars are being lost annually to processing low test weight grain from cold and drought susceptible corn hybrids in central and northern MN.

There is a need to develop not only new corn products but also new breeding methodologies for the easier screening of quantitative traits that are largely influenced by the environment. Molecular labs initially had the intention to work with these challenging and economically important traits but have targeted genetically simple traits instead, often not a challenge to breeders.

The short-term goal of the project was to develop, in cooperation with industry, unique corn products and challenge the current intellectual property system. The long-term goal was to create a common and diverse short-season gene pool for the development of the next generation of northern U.S. hybrids with reduced risk and added value to farmers and ranchers.

Successful results were obtained and goals were achieved. During the time of the project, four Ph.D. students graduated, over 30 new corn products were released, one new breeding method was invented, 100% tropical varieties were (for the first time) adapted to short-season environments, and a new gene-pool has been created for the development of the next generation of early maturing products.

This project has generated unbiased knowledge and unique ideas and inventions behind making MN corn profitable and sustainable to MN corn producers and ranchers in the long-term. The development of unique products and methods has benefited corn farmers and ranchers with a reduction in production costs and an increase in their product values.

This particular project has increased the genetic diversity of MN hybrids incorporating unique tropical genes (e.g., agronomic and quality traits) that were not available in the northern U.S. industry. These genes have allowed unique traits (e.g., disease resistance) and unique trait combinations that were not available before for this region, for instance, top yields with faster drier non-GMO hybrids. Cold and drought tolerant hybrids are available for marginal MN regions as well.

The adaptation of unique tropical and temperate genes to short-season environments has positive implications for farmers and industry in the long run. It provides a unique combination of agronomic and quality traits not available in current industry hybrids and serves as the future sources of elite cultivars carrying diverse genetics. The current intellectual property system is being challenged, thanks in part of this project, to develop the ideal corn hybrid for MN farmers.

## Converting Condensed Distillers Solubles (CDS) to Slow Release Fertilizers and Adsorbents for Phosphorous (2014)

Kenneth J. Valentas, S. Heilmann, M. Kessy, M. von Keitz, K. Spokas, Zac Pursell and B. Wood
University of Minnesota

### Objectives

- To perform HTC experiments to fully explore range of magnesium-oxide hydrochar products that will function as effective soil amendments to absorb phosphorous and possibly nitrogen from aqueous medium.
- Construct hydrochar-phosphorous slow release fertilizers utilizing various metal salts such as zirconium chloride, calcium chloride and the like.
- Confirm that Struvite fertilizer can be made from HTC/CDS filtrate and assess economics of such a process.
- The developed hydrochars will be characterized for the sorbed volatile contents both through headspace thermal desorption and solvent extraction techniques to evaluate the impact of production conditions on the resulting sorbed volatile components as well as %C, %N, surface area, moisture content, volatile content, and fixed carbon.
- Absorption isotherms for phosphorous and nitrogen will be determined for those hydrochars showing the most promise.
- Conduct elemental analysis to assess N/P binding properties (dissolution/plant availability/soil nutrient addition) as well as investigate potential N/P binding mechanisms.
- Assess biological effects (seed germination and seedling growth) for the "best" products resulting from the first two objectives.

### Introduction

The profitability of a corn ethanol plant is driven by the price of ethanol and DDGS balanced by the cost of corn. Corn prices can vary substantially from year to year and this can result in a "feast or famine" economic environment in corn ethanol plants. Generating new value-added products from the thin stillage stream offers an opportunity to add more positive cash flow to the equation independent of corn prices and is the purpose of this research.

Thin stillage is a potential source for several value-added bio-based products that includes fertilizers and adsorbents that are produced by a process called Hydrothermal Carbonization (HTC). Hydrochar porosity and structure can be modified by post chemical and thermal treatment for applications similar to activated carbons.

The HTC processing unit would be inserted in the process flow to receive the condensed distiller's solubles (CDS) from the oil recovery centrifuge as indicated in the schematic below. HTC will remove a portion of the solids present in the concentrated thin stillage in the form of a hydrochar to which some of the phosphorous that was dissolved in the thin stillage and the remaining corn oil (in form of fatty acids) are sorbed by the hydrochar. The hydrochar with sorbed components is recovered by conventional filtration. The filtrate from the HTC unit that still contains 70%+ of the original solids including N,P and K could be utilized as a liquid fertilizer for corn.

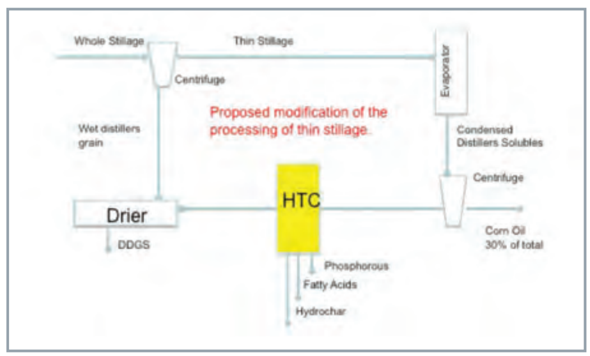


Figure 1. How HTS works: Aqueous biomass is heated to about 400$^0$F at pressure of 260 psia in a confined vessel. Biomass solids are dehydrated by elimination of oxygen and hydrogen in the form of water with no carbon dioxide generated. Fatty acids are sorbed by the char. Addition of a precipitant causes the phosphate to also be sorbed by the char. By cooling and simple filtration the carbon char and filtrate are easily recovered and separated.

In previous work sponsored by the Minnesota Corn Research Council and Agricultural Utilization Research Institute (AURI), it was shown that post thermally treated HTC hydrochars are effective as absorbents for hydroxymethyl furfural and furfural (AURI project AIC2101N, 6/30/2015). Subsequent unpublished results indicate application to a broader range of organic chemical sorption.

The incremental cash flow potential is highly dependent on the price that can be realized for the hydrochar itself. The AURI report referenced above

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## Converting Condensed Distillers Solubles (CDS) to Slow Release Fertilizers and Adsorbents for Phosphorous (2014)

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presents a detailed economic analysis for a 100MGPY ethanol plant. At the low end of $350/ton of hydrochar the PBT is about $500k with an after tax ROI in excess of 15%. This assumes a crude hydrochar with no augmentation or activation of the char by post processing with metal salts and thermal heating to increase porosity and surface area.

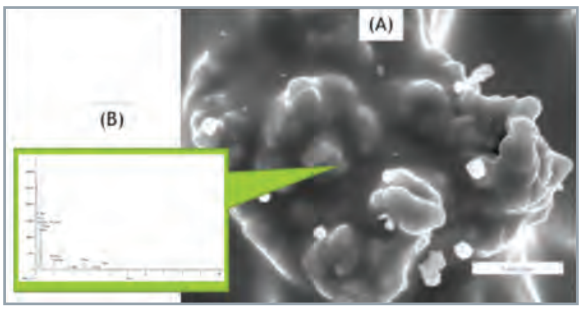


Figure 2. (A)Scanning electron micrograph of the ZnCl2 treated hydrochar after the post- treatment (BC-255) along with (B) the EDS (electron dispersion spectroscopy). The scale bar in Figure 1A shows a bar of 5 microns in length. Also note the present of the salts (white cubes and flat plate like crystals), potentially suggesting a source of soluble Zn salts (27% by weight or 7% by atom percent). These Zn cations could be the source of the increased sorption/precipitation by the hydrochar.

Activated chars are priced in the range of $500-$2300/ton from China and $4600-$9000/ton for products produced in the U.S.

This would suggest a two-tier market consisting of "crude" hydrochar at the low end and some form of "activated" char at the high end. A focused effort, beyond the scope of this work, would be required to develop the products and the economics.

### Abstract
HydroThermal Carbonization (HTC) provides an opportunity to convert condensed distillers solubles (CDS) to value-added products that can generate incremental cash flow to the operation of corn ethanol plant that is essentially independent of corn prices. CDS can be converted to hydrochars that are subsequently converted by metal salt doping and thermal post treatment to function as absorbents for phosphorous and a broad spectrum of organic chemicals.

Additionally the crude, unmodified hydrochar can serve as a soil amendment for improving soil fertility and corn productivity. The filtrate by-product of the HTC process has been shown to have potential as a liquid fertilizer for corn.

In a previous project funded by the Minnesota Corn Research council and AURI (AURI project AIC2101N, 6/30/2015), an economic assessment was made for a 100GPY corn ethanol plant to determine what impact an HTC addition could have on cash flow. The incremental cash flow potential is highly dependent on the price that can be realized for the hydrochar itself. At the low end of $350/ton of hydrochar the PBT is about $500k with an after tax ROI in excess of 5%. This assumes a crude hydrochar with no augmentation or activation of the char by post processing with metal salts and thermal heating to increase porosity and surface area.

Activated chars are priced in the range of $500-$2300/ton from China and $4600-$9000/ton for products produced in the U.S.

This would suggest a two-tier market consisting of "crude" hydrochar at the low end and some form of "activated" char at the high end.

CDS in the corn ethanol plant represents a clean and reliably consistent concentrated point source of biomass for conversion to hydrochar and subsequently high value-added activated carbons. Improved cash flow from ethanol production benefits both producers and farmers in the supply chain. This is also a unique opportunity to purposely design soil amendments for improving soil fertility, corn productivity, and increasing the sustainability of agricultural production.

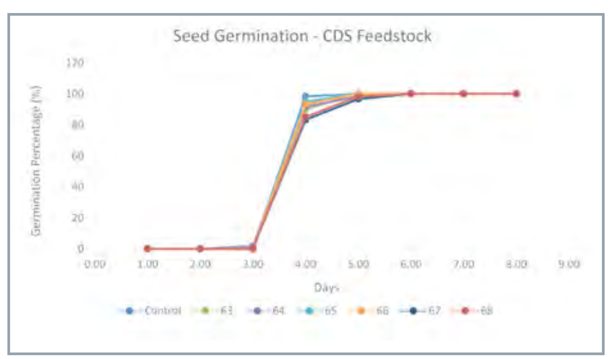


Figure 3. Seed germination rates observed with the addition of CDS hydrochar.

## Investigate the Impact of Hydrothermal Carbonization Filtrate as a Source of Fertilizer for Corn Production at Greenhouse Scale (2016)

Kenneth J. Valentas, Kurt Spokas, Gabriel Gerner, Zac Pursell and Scott Plewka

University of Minnesota

### Objectives

This research program is intended to experimentally answer the following questions through experiments on a greenhouse scale that need to be addressed to be able to use the hydrothermal carbonization (HTC) filtrate as a plant fertilizer.

- Does the addition of HTC filtrate to soil have any negative or positive effects on soil microorganisms?
- Does HTC filtrate have any phytotoxic effect on either seed germination or plant growth?
- What is the effect/benefit of aging the filtrate prior to application?
- What is effect of concentration of the filtrate on soil microorganisms and possible phytotoxicity?

### Introduction

HTC is a thermochemical process that provides an opportunity for nutrient reclamation, and more specifically, the recovery of phosphate (P), Nitrogen (N) and potassium (K) from condensed distillers solubles (CDS). The concept is illustrated below:

The basic principles of HTC processing are:

- Aqueous biomass is heated to about 400$^0$F at pressure of 260 psi in a confined vessel.
- Biomass solids are dehydrated by elimination of oxygen and hydrogen in the form of water with no carbon dioxide generated which effectively concentrates the carbon content.
- About 50% of the phosphate is sorbed by the char with the remainder staying in the liquid filtrate.
- By cooling and simple filtration the hydrochar and filtrate are easily recovered and separated.
- Filtrate contains enough N, P, and K to be a potential fertilizer.

Because HTC filtrates are enriched with abundant levels of ammonium, phosphate, and potassium, the filtrate has the potential to provide a renewable source of nutrients necessary for agricultural crop production. This presents an opportunity for a value-added product with more economic potential than offered by merely adding back the filtrate to DG's.

Several studies to date have analyzed the effect of the solid product from HTC (hydrochar) on plant growth (Cavellec *et al.*, 1997; Shanableh, 2000; George *et al.*, 2012; Bargmann *et al.*, 2013a; Bargmann *et al.*, 2013c; Jandl *et al.*, 2013). The use of HTC to generate value added solids from liquid biomass wastes has been known to provide the potential phosphorus fertilizer when municipal sludge or turkey manure waste streams are utilized (Svanström *et al.*, 2007).

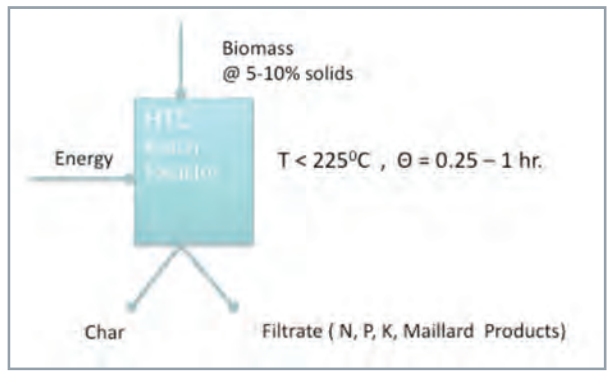


Figure 1. How HTS works: Aqueous biomass is heated to about 400$^0$F at pressure of 260 psia in a confined vessel. Biomass solids are dehydrated by elimination of oxygen and hydrogen in the form of water with no carbon dioxide generated. Fatty acids are sorbed by the char. Addition of a precipitant causes the phosphate to also be sorbed by the char. By cooling and simple filtration the carbon char and filtrate are easily recovered and separated.

This is largely attributed to the precipitation of phosphorus as a solid phase, which can encompass a variety of potential chemical forms (Cavellec *et al.*, 1997). On the other hand, very limited work has been conducted on the liquid phase, which is the dominant product from HTC processing of biomass. Typically, HTC filtrate has had negative impacts on barley growth (Bargmann *et al.*, 2013b; Bargmann *et al.*, 2013c). However, the exact mechanism for this suppression has not been completely elucidated.

Previous research (Valentas, *et al.*, Corn Growers project 1061-EU14) has demonstrated that this inhibition is linked to the dissolved organic

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## Investigate the Impact of Hydrothermal Carbonization Filtrate as a Source of Fertilizer for Corn Production at Greenhouse Scale (2016)

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compounds that are present in the filtrate. Upon aging the filtrate for 3 months (loss of these inhibitors through volatilization and microbial degradation), the germination suppression was reduced. Therefore, this data strongly supported the use of the filtrate as a fertilizer following simple pre-conditioning steps. Flashing the HTC reactor after the reaction is complete has been adopted as an effective alternative to aging the filtrate in that many volatile components linked to inhibition are eliminated through vaporization during flashing.


### Abstract

HydroThermal Carbonization (HTC) is a thermochemical process that was utilized to convert condensed distillers solubles (CDS) to hydrochar and filtrate: value-added products. HTC filtrate has been shown to contain high levels of ammonium and phosphorus and was subjected to greenhouse scale experiments to determine its efficacy as a fertilizer for corn. The CDS filtrate was tested with other agricultural by-product HTC filtrates (made from poultry and swine manures) as comparative control fertilizers. These were added to four different Minnesota soil types.

Soil Types:

- Waukegan silt loam (Rosemount, MN)
- Barnes silt loam (Morris, MN)
- Becker sand (Becker, MN)
- Fine silica sand

The treatments were compared both to a null control (no fertilizer or amendments) and assessed for their impact on corn growth and soil properties. Total above and below ground biomass, plant growth rates, C/N leaf contents, leaf-level measurements of transpiration, photosynthesis, and respiration were monitored within each treatment using a portable gas exchange system. We examined its effect on soil carbon dynamics (greenhouse gas production potentials), evapotranspiration rates, photosynthesis, water use efficiency, and carbon use efficiency at greenhouse level scale.


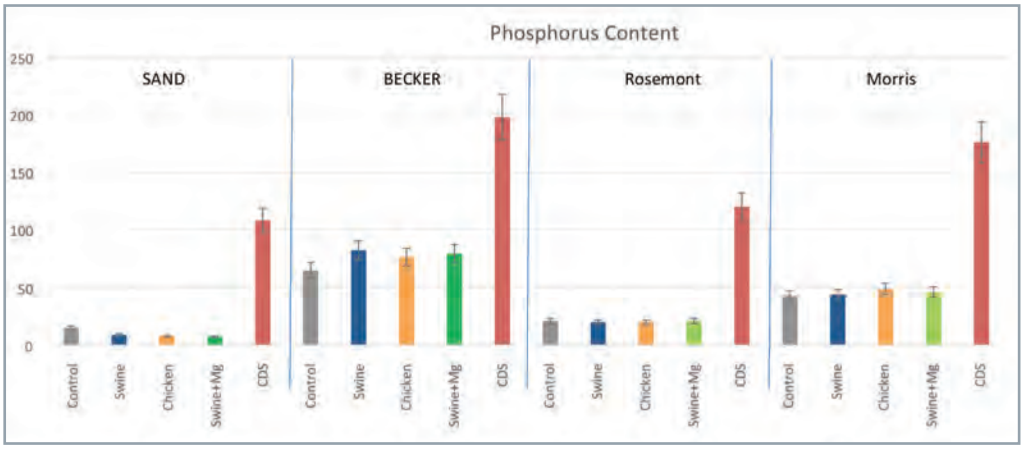


Figure 2. Available soil phosphorus (ppm = mg/g) following filtrate additions. Only the CDS filtrate addition improved the phosphorus content across all soil types evaluated.

Significant findings were:

- No apparent phytotoxic effects when filtrate addition < 0.5 ml/pot (1ml/100grams).
- No significant difference for Rosemont and Morris soils (expected).
- All filtrates show significant improvement for Becker soil (a sandy soil).
- Significant increase in plant height (1.66 times) across all filtrates and soils when applied at a low rate (0.25 mL/100 g soil).
- Site that experienced the largest improvement in plant performance across all filtrates was the Becker soil (sandy soil). This was nearly a doubling of the plant growth, which could amount to a substantial increase in yield. But this requires validation from field plot level research.
- CDS provides significant amount of phosphorous to all soils.
- CDS filtrate is effective means of providing sulfur

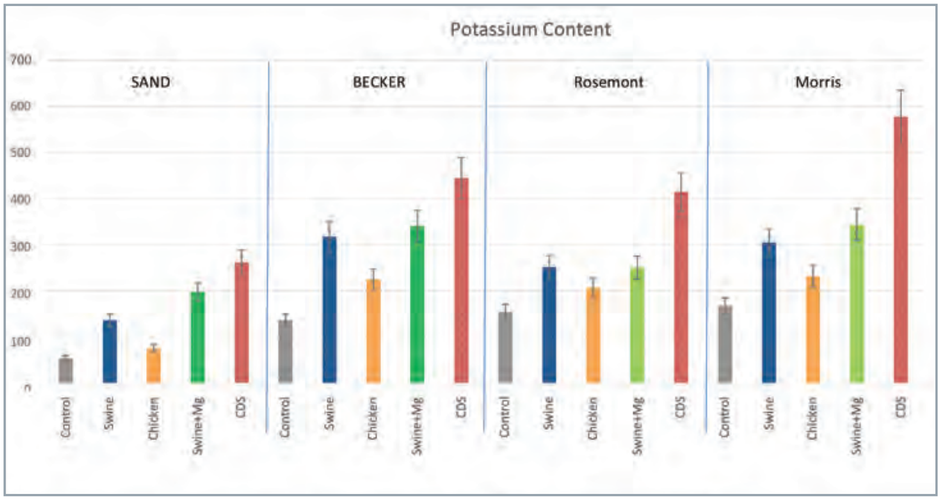


Figure 3. Soil potassium (ppm = mg/g) content following the filtrate additions. All filtrates increased available potassium after application.

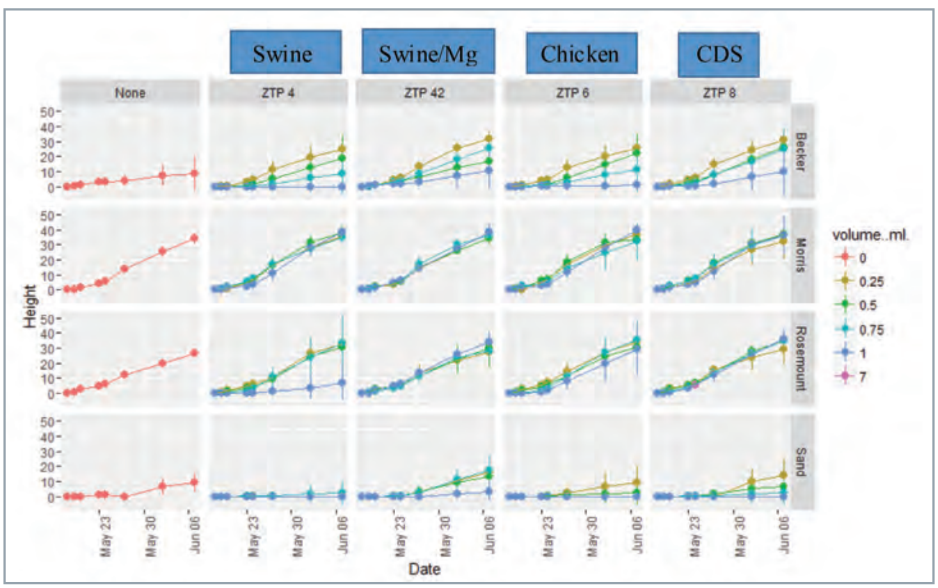


Figure 4. Illustration of the growth response (plant height – cm) of the various soils (divided into rows) and the filtrate type and amounts (colors).

## Evaluation of Costs of EPA's 2022-2025 GHG Standards with High Octane Fuels and Optimized High Efficiency Engines (2016)

Dean Drake, Gary Herwick and Tom Darlington
DeFour Group LLC

### Objectives

The objectives of this project were to:

- Upload and run Environmental Protection Agency's (EPA's) ALPHA and OMEGA models used by the agency in its upcoming mid-term review of the fuel economy standards.
- Modify the models to reflect high-octane mid-level blend fuels and high compression engine technology.
- Perform independent evaluation of the cost savings and emission reductions that can be achieved by substituting mid-level blend fuels and more efficient engines for more expensive fuel economy improving technology.
- Prepare reports and presentations summarizing these findings.
- Work with others to get this information considered by the appropriate regulatory agencies in the mid-term review.

### Introduction

In August of 2012, EPA released a final rule setting greenhouse gas (GHG) standards for cars, light trucks, and SUVs for model years 2017-2025. The final standards for model year 2025 were projected to result in a fleet wide CO2 tailpipe emissions of 163 g/mi, if achieved exclusively through fuel economy improvements.

The final standards were based on vehicle footprints, so that all vehicles would achieve GHG emission reductions, regardless of size. EPA expected that improvements would come from advances in engines and transmissions, weight reduction, improved aerodynamics, advances in internal combustion engines, along with increases in hybrid electric vehicles (HEVs) and battery electric vehicles (BEVs). New 2025 model year vehicles (cars and trucks combined) were estimated to cost $1,800 more than 2016 model year vehicles.

Since the standards were finalized with a long lead-time before they took effect, EPA committed to releasing a Technical Assessment Report (TAR), in 2016 to reassess the feasibility of the 2022-2025 model year standards. This report was released in July of 2016. The report generally reaffirmed the feasibility of the original GHG standards.

One key inexpensive technology that could improve vehicle fuel economy, which was not evaluated by the either the Final Rule or TAR, is an increase in engine compression ratio (CR) that is enabled by a high-octane fuel. Current production engine compression ratios are limited by the octane of gasoline in the U.S. If octane is increased, engine compression ratios can increase, increasing engine efficiency and reducing GHG emissions.

So called premium fuel with higher octane content does enable higher compression ratios, but the price difference between premium and regular fuel, along with the concern that vehicles designed for premium would most often be operated on regular because of the price difference in the fuels, effectively limits the amount that automakers can increase compression ratios in the U.S. A high-octane mid-level ethanol blend, however, is likely to be very price-competitive with current regular fuel.

If such a fuel were widely available at a competitive cost to regular fuel, auto manufacturers would be likely to employ increased compression ratios to reduce GHG emissions. There is much research going on in this area related to how much engine compression ratios could be increased with mid-level ethanol blends, such as E25 or E30. EPA has also indicated that high-octane fuels could be examined to improve GHG emissions post-2025.

The attractiveness of a high-octane mid-level ethanol blend goes beyond just meeting the GHG standards. The Renewable Fuel Standard (RFS) reduces up-stream GHG emissions reductions from future fuels by requiring increasing amounts of low-GHG fuels. The increase in these required low GHG fuels, however, has declined from the levels originally intended because development of cellulosic biofuel is taking somewhat longer than originally anticipated, and because gasoline marketers have not developed refueling infrastructure for E85 due to slow sales of E85.

The slow sales of E85, however, are a function of how E85 has been priced relative to its energy content. The availability of a high octane mid-level blend for vehicles purposely designed for this fuel, would spur additional advances in cellulosic biofuel, thereby increasing the benefits of the RFS.

To attempt to fill the gap in the Final Rule and TAR analysis on high-octane fuels, this study evaluates the possible implementation of higher compression ratio (HCR) engines using high-octane low carbon (HOLCF) fuel in the 2022-2025 model years, and the impacts on the costs of EPA's GHG standards. In this study, we assume the same tailpipe GHG standards as EPA's final rule, so the environmental benefits of this HCR/HOLCF strategy exceed the benefits of the current TAR, because under HCR/HOLCF, the tailpipe benefits are the same as the TAR, while the upstream benefits of the RFS are greater than currently estimated by EPA.

In this study, we evaluate the impacts of the widespread availability of a 98-Research Octane Number (RON) E25 fuel. We mainly focus on the impacts on the TAR-estimated costs, and for simplicity ignore the potential increases in RFS benefits. There are three general parts to the analysis. In the first part, we estimate how much of an increase in CR is possible with 98-RON E25 based on existing research, and the effects on tailpipe GHG emissions.

In the second part, we estimate the costs of compression ratio increases, and also 98-RON E25 fuel costs, relative to regular E10. In the third part, we implement high compression ratio engines and the total engine plus fuel costs into EPA's modeling system, and compare program costs and technology penetrations before and after this implementation.

### Abstract
This analysis has shown that if a high octane mid-level blend ethanol fuel such as 98-RON E25 were an option for model year 2022-2025 vehicles meeting EPA's GHG standards, overall program costs would be significantly reduced. There is no doubt that if this fuel were to be made widely available to the public, auto manufacturers would certify vehicles using it.

Major inputs to this conclusion are 1) the magnitude of GHG emission reduction due to increased octane, 2) the cost of higher compression ratio plus the incremental cost (or savings) from the fuel, and 3) how implementing high HCR would affect the benefits of other types of technologies.

We have estimated the tailpipe GHG emission reduction due to higher compression engines for the central case at 6%. This effectiveness is somewhat higher than most other technologies estimated by EPA, but it is not out of line, and in fact could perhaps be considerably higher.

There is a significant amount of research currently being done to refine this estimate, and the type of fuel needed to obtain as much engine efficiency improvement as practical. Our cost for the increased compression ratio of $50 also does not appear out of line, as some manufacturers have indicated it could be much less if done as a part of normal engine redesign cycles. Our analysis of fuel costs indicates that the fuel could be provided for slightly less than the current cost of regular. At this point, we are not sure how implementing HCR would affect the benefits of some of the other technologies, but more work will probably be performed on this as well.

Finally, another significant benefit of implementing a high-octane ethanol fuel with high compression ratio engines is that biofuel use would grow more significantly from today's levels, thereby reducing upstream GHG emissions from transportation fuels, growing the GHG benefits of the RFS, and reducing US petroleum consumption. Thus, the overall GHG benefits of EPA's 2022-2025 GHG standards with a high-octane low carbon fuel would be significantly greater than without a high-octane low carbon fuel.

# Evaluation of Strategies for Minimizing Metabolic Oxidative Stress in Nursery Pigs Fed Diets Containing High Concentrations of DDGS (2012)

Gerald Shurson

University of Minnesota

## Objectives

The objectives of this project were modified from the original proposal based on results from other related on-going research studies after the proposal was funded. As a result, the studies conducted in this project added much more information to our knowledge about the effects of feeding peroxidized lipids to pigs than originally proposed. Our objectives were to:

- Summarize the scientific literature to determine the growth performance and metabolic oxidation effects of feeding peroxidized lipids to pigs and broilers.
- Compare lipid peroxidation measures for corn oil subjected to varying thermal conditions.
- Determine the impact of antioxidants on lipid peroxidation of distillers dried grains with solubles and distillers corn oil stored in extreme temperature and humidity conditions.
- Determine the effects of dietary peroxidized corn growth performance and antioxidant status of nursery pigs.

## Introduction

Corn distillers dried grains with solubles (DDGS) has become a commonly used feed ingredient in swine diets in recent years due its abundant supply, high nutritional value, and favorable price relative to corn. In fact, the U.S. pork industry now consumes 15 to 20% of total DDGS production annually.

However, as ethanol plants are evolving into biorefineries, the composition of DDGS is changing and new co-products are being produced. Currently, about 85% of U.S. ethanol plants extract corn oil prior to manufacturing DDGS. This has resulted in increased variability in oil content of DDGS (5 to 12% oil) and a new opportunity for the feed industry to use distillers corn oil as an economical and high energy ingredient in animal feeds.

Extracted distillers corn oil, as well as corn oil present in DDGS, contains high amounts of polyunsaturated fatty acids, especially linoleic acid, and are highly susceptible to peroxidation. A recent University of Minnesota study from our group (Song and Shurson, 2013) showed that some sources of DDGS contain 25 times more peroxidized oil than corn. This is a potential concern because feeding peroxidized lipids to pigs and poultry has been shown to decrease growth performance and may lead to adverse health effects.

In fact, several years ago, some swine veterinarians reported an increased incidence of Mulberry Heart Disease (vitamin E and selenium nutritional deficiency) in nursery pigs, and suggested that feeding diets containing DDGS was a contributing factor. This perception was based on the fact that the heat processes used during DDGS production destroy most of the vitamin E content in corn oil, and that sulfur content in DDGS can sometimes exceed 1%, which may interfere with selenium utilization by the pig.

However, our research results (funded by MN Corn Research and Promotion Council, MN Pork Board, and Agricultural Utilization Research Institute in 2011) showed that adding high amounts of a highly peroxidized, high sulfur DDGS source to sow and nursery pig diets had no effect on the occurrence of Mulberry Heart Disease (Hanson *et al.*, 2015). However, we did observe a dramatic decline in the antioxidant status of nursery pigs in the immediate post-weaning period (Hanson *et al.*, 2015). These results led us to conducting the experiments described in this report because there is limited information regarding the effects of feeding peroxidized corn oil (extracted or in DDGS) to pigs, and the need for adding antioxidants to minimize corn oil peroxidation.

## Abstract

Energy is the most expensive nutritional component in animal feeds, and fats and oils contain 2.25 times more energy than carbohydrates. Corn oil contains the highest concentration of metabolizable energy

for swine and poultry compared to most feed grade vegetable oil and animal fats, and similar to soybean oil.

However, because of the high concentration of polyunsaturated fatty acids in corn oil, it is highly susceptible to damage from peroxidation during heat processing and storage. Although several peroxidation measures can be used to determine the extent of lipid damage, the numerous compounds produced and the complexity of the peroxidation process makes it difficult to determine the best measures to use.

Therefore, determining the most useful measures of lipid peroxidation, and understanding the effects of lipid quality (peroxidation) on metabolic oxidative stress is essential to optimize caloric efficiency of distillers corn oil and reduced oil DDGS. Feeding peroxidized lipids to pigs and poultry causes metabolic oxidative stress that can significantly reduce growth performance and health. Achieving optimal feed and caloric efficiency, as well as minimizing animal mortality and morbidity, are vital for maintaining profitability for Minnesota pork producers.

Because the pork industry is one of the predominant consumers of Minnesota corn, DDGS, and distillers corn oil, understanding the impact of lipid quality of these co-products, and approaches to mitigate these negative effects are essential for Minnesota corn producers to sustain current demand for DDGS, and increase future demand for distillers corn oil in swine diets.

Therefore, through funding support of the Minnesota Corn Research and Promotion Council, we have continued to develop a better understanding of potential connections between feeding diets containing DDGS and distillers corn oil on metabolic oxidative stress in pigs, and communicate these findings to national and international feed and pork industry audiences.

# Production of Low-Oil/Fat Distillers Dried Grain with Solubles (DDGS) to Replace Fish Meal in Aquaculture Diets (2013)

Timothy Bruce, Michael Brown, Bill Gibbons, Jason Bootsma, Dustin Schulz, Scott Sindelar and Michael Grey

Prairie Aquatech, LLC

## Objectives

To produce a first-generation high protein dried distillers grains with solubles (HP-DDGS) using microbial conversion, evaluate the replacement performance of HP-DDGS in yellow perch feed and determine preliminary mass/energy balance and costs.

## Introduction

Aquaculture is the fastest growing segment in U.S. food production and globally it is set to overtake capture fisheries as a source of food fish (Food and Agriculture Organization (FAO) 2012). The FAO recently reported that 61% of the world's wild fish stocks are now fully exploited and 29% are overexploited, depleted or recovering from depletion (FAO, 2014).

Furthermore, it was estimated by the National Oceanic and Atmospheric Administration (NOAA) that the U.S. aquaculture industry was worth $1.2 billion in 2011, but growth is hampered by feed cost. The growth of the aquaculture industry in the U.S. has sprouted both large-scale and small production operations that aim to fuel the economy and offer alternative seafood protein sources in a time where our wild-caught resources are diminishing.

Combined wild capture fisheries and aquaculture supplied 158 million tons of finfish and shellfish in 2012 (FAO, 2014). Farmed fish production accounted for about 42.2% of production in 2012 (FAO, 2014). Wild harvest peaked at 86 million tons in 1996 and has since stabilized at 80 million tons. Per capita consumption is currently about 19 kg and fish constitutes 17% of all animal protein consumed by humans (FAO, 2014). The rapid domestic development of this agriculture sector requires both government support and aquaculture research and education.

Similar trends of greater demand for and lower wild harvest of fish meal protein have led to a rapid escalation in price of this meal commodity. In the early 1980s about 10% of annual fish meal production was used in aquafeeds. By 2010 over 70% of annual production was used in the aquaculture industry with the remainder used in other livestock and companion animal feeds (IFFO, 2013).

In 2005, 2.7 mmt of fish meal was used in aquaculture feeds, while an estimated 6.7 mmt was used in 2012. Meanwhile, the harvest of species used to produce fish meal has dropped by >40% since 2000 (FAO, 2012). These trends are unsustainable, as aquaculture will soon consume the entire fish meal resource. This is reflected in current fish meal prices (e.g., Peruvian, 65% protein; 1,560-2,190 $US/mt, 2013; www.indexmundi.com), which are already hampering the economic production of finfish and shellfish products for human consumption.

Consequently, there is a significant market opportunity for a sustainable, economical, plant protein concentrate to replace fish meal in feeds manufactured for aquaculture and other feed markets.

Corn distillers dried grains with solubles (DDGS) has been tested as a partial replacement for fish meal, however the relatively low protein content, less than desirable amino acid profile, and high fiber level limit inclusion rates to ~20% for most species. Some ethanol plants are partially removing fiber or oil from DDGS, resulting in somewhat higher protein contents. However, inclusion rates of those products are still limited to 20-40% of dry diet for most species. The solution to this problem lies in developing an economically feasible process to convert DDGS into a more digestible, enhanced protein product. The development and provision of enhanced DDGS to the feed industry could reduce the strain on wild fish stocks exploited for fish meal (and marine food webs dependent on these prey) and support continued expansion of the domestic and global aquaculture industry but only if there is an economical and sustainable method to increase its nutritional qualities.

DDGS incorporation into aquaculture feeds has challenges, primarily due to its lower protein (28-32%), high fiber and phytic acid contents. Some ethanol facilities have incorporated technologies to remove part of the fiber and/or oil from DDGS, thereby increasing protein content. For example, Still Pro 50 is manufactured by removing some non-protein components from DDGS. However the amino acid balance and digestibility of this product is still lacking in comparison to the fish meal nutrient. Therefore even these modified DDGS products have been limited to inclusion rates <40% of fish meal, primarily in omnivorous fishes. Thus there is considerable market opportunity for an even higher protein DDGS that could be used for higher value carnivorous species (e.g., salmon, cobia, yellowtail, snappers). Such a product would be especially attractive if the protein component had higher levels of sulfur amino acids such as lysine, methionine, and cysteine that are critical to animal growth. Our microbially based system converts carbohydrates in the DDGS into cell mass resulting in a highly digestible protein concentrate at a lower cost, while also producing an exopolysaccharide with potential immuno-stimulative properties.

**Table 1. Comparison of DDG microbial pretreatments within a submerged process.**

| Feedstock | Pretreatment | Incubation pH | Final Protein (%, dmb) |
|---|---|---|---|
| DDGS | Non extruded | 5 | 45.75 |
| DDG | Non extruded | 5 | 38-42 |
| DDG | Dilute acid | 5 | 38.5 |
| DDG | Hot H20 cook | 5 | 48 |
| DDG | Hot H20 cook | 3 | 43 |
| DDG | Extrusion 1 | 5 | 38-41 |
| DDG | Extrusion 1 | 3 | 46.50 |
| DDG | Extrusion 2 | 3 | 49.90 |
| StillPro DDGS | Non extruded | 3 | 64.44 |

## Abstract

Aquaculture is the fastest growing segment of U.S. agriculture and is set to overtake wild capture fisheries. Farmed food fish accounted for 42.2% of the 158 million tons of global fish production in 2012 (FAO 2014). Fish meal, a major protein source in both aquaculture and livestock feeds, has been subject to elevated pricing due to demand and fixed supply. Plant-based protein sources, such as distillers dried grains with solubles (DDGS) have shown promise as fish meal replacements at an economically feasible pricing structure.

Use of traditional DDGS have been limited in aquaculture diets to approximately 20% inclusion, due to relatively low protein content, less than desirable amino acid profile, and high fiber level. Prairie AquaTech, an animal nutrition and health company has developed a novel microbial conversion process that creates a high protein DDGS (HP-DDGS), a protein-rich and more digestible product that may fully replace traditional fish meal-based diets. The initial objectives of the project included:

- 1) The development of a 1st generation HP-DDGS, 2) a performance evaluation in a feeding trial with yellow perch (Perca flavescens), and 3) an assessment of mass/energy balance and costs.
- The resultant HP-DDGS product was 43.43% crude protein with 84.4% protein digestibility, a marked increase from the starting values of 31.93% crude protein and 81.84% protein digestibility. Feeding trial results demonstrated that two initial HP-DDGS products achieved similar relative growth performance to a fish meal reference diet; these products also produced a similar feed conversion ratio (FCR).
- The continued innovation of this novel microbial conversion process allows for a high quality, cost-effective fish meal alternative for feed manufacturers and fish and livestock producers while creating a novel market for corn producers.

# Evaluation of Long-Term Reproductive and Lactation Performance of Dairy Heifers Fed Increasing Dietary Concentrations of Reduced Fat Distillers Dried Grains in Replacement of Forage During Pubertal Development (2014)

Jill Anderson and Angela Manthey

South Dakota State University

## Objectives

The objective of this study was to evaluate the effect of increasing the inclusion rate of DDGS in replacement of forage in limit-fed diets on the post-trial reproductive and first lactation performance of dairy heifers. Additionally this funding allowed for the expansion of the original project from 36 to 48 heifers, increasing our statistical power and strength of the experiment.

decreasing age at first calving has been shown to result in an earlier return on investment (Ettema and Santos, 2004). However, increasing the ADG of growing dairy heifers has been demonstrated to have a negative impact on mammary development and lactation performance (Van Amburgh *et al.*, 1998; Zanton and Heinrichs, 2005; Meyer *et al.*, 2006).

Feeding heifers high concentrate diets, but restricting ADG during the prepubertal has been demonstrated to maintain milk production when compared to high forage diets (Carson *et al.*, 2000; Zanton and Heinrichs, 2009). Manthey *et al.* (2016) limit-fed diets with increasing inclusion amounts of DDGS and found no differences in growth performance or ADG. Anderson *et al.* (2015) limit-fed heifers a corn and soybean product based control diet, low-fat DDGS, or high-fat DDGS and found that heifers fed the DDGS diets had similar or improved milk production.

**Table 1. Ingredient and nutrient composition of treatment diets with increasing inclusion amounts of distillers dried grains with solubles (DDGS) in replacement of forage fed to growing replacement dairy heifers during the prepubertal growth phase.**

| Item | 30DG[1] | 40DG[1] | 50DG[1] |
|---|---|---|---|
| Ingredient[2], % DM | | | |
| DDGS | 30.0 | 40.0 | 50.0 |
| Grass hay | 68.5 | 58.5 | 48.5 |
| Vitamin and mineral premix[3] | 0.75 | 0.75 | 0.75 |
| Limestone | 0.30 | 0.30 | 0.30 |
| Sodium bicarbonate | 0.30 | 0.30 | 0.30 |
| Salt | 0.15 | 0.15 | 0.15 |
| Nutrient, % of DM | | | |
| DM, % of diet | 86.7 | 86.7 | 86.8 |
| CP | 16.8 | 16.8 | 16.8 |
| Ether extract (diethyl) | 5.17 | 5.17 | 5.17 |
| Starch | 2.38 | 2.38 | 2.38 |
| ME, Mcal/kg | 2.38 | 2.38 | 2.38 |
| NEG, Mcal/kg | 2.89 | 2.89 | 2.89 |

[1]30% dietary inclusion rate of DDGS (30DG); 40% dietary inclusion rate of DDGS (40DG); 50% dietary inclusion rate of DDGS (50DG). [2]Formulated using NRC, 2001. [3]Contained: 2.2 g/kg of lasalocid, 14.5% Ca, 8.0% P, 21.0% NaCl, 2.5% Mg, 1.5% K, 2.0% S, [4]100 mg/kg Mn, 1,250 mg/kg Cu, 70 mg/kg Co, 70 mg/kg I, 53 mg/kg Se, 5,500 mg/kg Zn, 325 mg/kg Fe, 704,000 IU/kg Vitamin A, 140,800 IU/kg Vitamin D3, and 5,280 IU/kg Vitamin E (Future Cow Supreme Premix B2000, Land O' Lakes, Inc., St. Paul, MN).

There has been very limited research examining the effect of limit-feeding diets with DDGS as the primary concentrate ingredient during the prepubertal growth period of dairy heifers on subsequent reproductive and lactation performance. Therefore, the main objective of this research was to evaluate the effect of increasing the inclusion rate of DDGS in replacement of forage in limit-fed diets on the long-term reproductive and lactation performance of dairy heifers. It was hypothesized that increasing the inclusion rate of DDGS would result in a maintained or improved reproductive and lactation performance.

## Introduction

The optimal growth rate and feeding strategy of growing dairy heifers to maximize reproductive and lactation performance has been well researched. Increasing average daily gain (ADG) in order to shorten the length of the rearing period and

## Abstract

The objective of this study was to determine the effect of increasing the inclusion rate of distillers dried grains (DDGS) in replacement of forage in limit-fed diets fed during the prepubertal growth phase on the

**Table 2. Milk production performance based on Dairy Herd Improvement Association (DHIA) records for heifers fed increasing amounts of distillers dried grains with solubles (DDGS) in replacement of forage during the prebubertal growth period.**

| | Treatment[1] | | | | *P-value*[2] | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | 30DG | 40DG | 50DG | SEM | Trt | mo | Trt*mo | L | Q |
| Milk yield, kg | 27.4 | 28.8 | 29.4 | 1.85 | 0.74 | <0.01 | 0.30 | 0.46 | 0.84 |
| ECM[3], kg | 19.3 | 19.8 | 20.2 | 1.17 | 0.84 | 0.03 | 0.40 | 0.56 | 0.93 |
| Fat, % | 4.54 | 4.66 | 4.66 | 0.29 | 0.94 | <0.01 | 0.61 | 0.76 | 0.85 |
| Fat yield, kg/d | 0.59 | 0.59 | 0.60 | 0.040 | 0.99 | 0.96 | 0.40 | 0.90 | 0.93 |
| Protein, % | 2.88 | 2.92 | 2.96 | 0.08 | 0.80 | 0.07 | 0.92 | 0.51 | 0.96 |
| Protein yield, kg/d | 0.36 | 0.38 | 0.39 | 0.024 | 0.65 | <0.01 | 0.24 | 0.36 | 0.97 |
| Somatic cells, × $10^3$/mL | 451.0 | 132.6 | 113.4 | 84.0 | 0.01 | 0.06 | 0.02 | <0.01 | 0.12 |

[1]30% dietary inclusion rate of DDGS (30DG), 40% dietary inclusion rate of DDGS (40DG), 50% dietary inclusion rate of DDGS (50DG).
[2]Significance of effects for treatment (Trt), month (mo), treatment × month (Trt × mo), and linear (L) and quadratic (Q) orthogonal contrasts. [3]ECM = [(0.327 × kg of milk) + (12.95 × kg of fat) + (7.2 × kg of protein)] (Orth, 1992).

long-term reproductive and lactation performance of dairy heifers. Additionally this project funding allowed us to expand the original feeding project from 36 heifers to 48 heifers.

A 16-week randomized complete block design study was conducted using 48 Holstein heifers (199 ± 2 d of age) with three treatments. Treatments were 1) 30% DDGS (30DG), 2) 40% DDGS (40DG), and 3) 50% DDGS (50DG) with the remainder of the diet consisting of grass hay and 1.5% mineral mix. Heifers were individually limit-fed using Calan gates at 2.65, 2.50, and 2.35% of body weight (BW) on a dry matter (DM) basis for 30DG, 40DG, and 50DG, respectively.

After completing the feeding trial heifers were fed a common diet according to regular herd management. Data on reproductive performance and milk production for the first three months of lactation were collected for each heifer from dairy herd records. At 3 wk prepartum and at calving, BW, frame measurements, and body condition score (BCS) were recorded.

There was a linear tendency for age at first service to decrease with increasing amounts of DDGS; however, there were no differences in any other reproductive or frame measurements. There was a treatment by month effect for somatic cell count; however, there were no other differences for any of the lactation parameters measured during the first 90 days of first lactation. Results demonstrate that producers can feed DDGS at up to 50% of the diet to peripubertal heifers without negative consequences to long-term performance. This benefits corn growers by encouraging the use of DDGS for dairy heifer feeding.

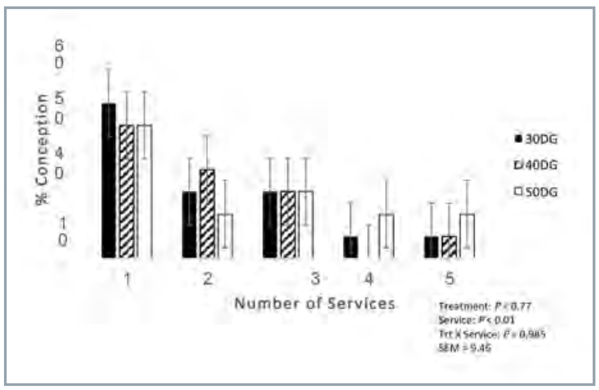


Figure 1. Percent conception based on service number for heifers fed increasing amounts of distillers dried grains with solubles (DDGS) in replacement of forage during the prepubertal growth period.

# Final Validation of Reduced-Oil DDGS Energy Prediction Equations for Swine and Widespread Industry Implementation (2014)

Gerald Shurson, Pedro E. Urriola, Bo Hu, Milena Saqui-Salces and Brian Kerr

University of Minnesota

## Objectives

We hypothesized that DDGS sources with oil content less than 6% will have less concentration of digestible energy (DE) and metabolizable energy (ME) than DDGS with > 10% oil. Therefore, the objective of this study was to determine if DE and ME content differs among pigs fed DDGS diets with increasing lipid content.

## Introduction

Use of alternative feed ingredients decreases diet cost and improves nutritional efficiency of swine feeding programs (Woyengo *et al.*, 2014). However, issues with environmental impact of indigestible nutrients and variability in nutrient and energy content limit the inclusion levels of alternative feed ingredients.

Corn distillers dried grains with solubles (DDGS) has 3 times more neutral detergent fiber (NDF) content compared with corn (NRC, 2012) which has a negative impact on digestibility of other nutrients such as proteins and lipids (Kass *et al.*, 1980; Bach Knudsen and Hansen, 1991; Chen *et al.*, 2013). As a result, a large proportion of energy contained in DDGS is not utilized by the pig.

Ethanol plants also began extracting oil from thin stillage prior to manufacturing DDGS and consequently variability in nutrient and ME content among sources increased (Kerr *et al.*, 2013). This variable ME content limits utilization of DDGS in swine diets. Pigs fed corn soybean meal diets supplemented with 40% corn DDGS that have an oil content less than 6% (as measured by ether extract) have less G:F than pigs fed a control corn soybean meal diet (Wu *et al.*, 2016). This decrease of G:F appears to be the result of overestimating the ME content of DDGS with oil content less than 6%.

## Abstract

The widespread implementation of corn oil extraction in the U.S. ethanol industry has led to perceptions among DDGS marketers and nutritionists that the resulting reduced-oil DDGS has less metabolizable energy (ME) than traditional high-oil DDGS sources.

Our previous research showed a very poor association between oil content of DDGS and ME content for swine. As a result, ME prediction equations, based on chemical composition of DDGS, were developed and validated to accurately estimate ME content among DDGS sources with variable oil content for swine.

The objective of this study was to conduct a final validation that oil content of DDGS does not affect ME content for swine. Our results verified this when comparing 3 DDGS sources containing 14, 10, and 6% crude fat but similar predicted ME content. These results are invaluable for educating DDGS marketers and end-users that ME content can be accurately be predicted using our validated prediction equations even though oil and chemical composition varies among sources.

This benefits corn farmers because DDGS price should not be discounted because of reduced oil content, and provides convincing evidence to maintain existing diet inclusion rates for DDGS in swine. Ultimately, these results will help maintain demand in domestic and exports markets for using U.S. DDGS in swine diets.

**Table 1. Apparent total tract digestibility and energy content (DM basis) of corn distillers dried grains with solubles (DDGS) with different oil content.**

| | DDGS sources[1] | | | | |
|---|---|---|---|---|---|
| Item | Low oil | Medium oil | High oil | SEM | *P* |
| Apparent total tract digestibility, % | | | | | |
| DM | 72.1 | 73.0 | 72.0 | 1.4 | 0.75 |
| CP | 77.0[a] | 74.3[b] | 68.7[c] | 1.3 | < 0.01 |
| Acid hydrolyzed fat | -13.4[c] | 2.9[b] | 39.0[a] | 3.9 | < 0.01 |
| Neutral detergent fiber | 33.5 | 37.5 | 44.9 | 6.0 | 0.18 |
| Starch | 99.3 | 99.4 | 99.5 | 0.2 | 0.73 |
| Ash | 73.0 | 62.4 | 50.8 | 4.2 | 0.70 |
| Energy | | | | | |
| GE, kcal/kg | 5,142 | 5,248 | 5,468 | . | . |
| DE, kcal/kg | 3,314 | 3,270 | 3,477 | 106 | 0.42 |
| ME, kcal/kg | 3,076 | 3,085 | 3,223 | 173 | 0.65 |
| DE/GE, % | 70.4 | 70.4 | 70.0 | 1.4 | 0.95 |
| ME/DE, % | 92.7 | 94.2 | 92.6 | 1.4 | 0.46 |
| ME/GE, % | 59.8 | 58.8 | 58.9 | 3.3 | 0.94 |

[1]The same DDGS source were used in two studies abcValues within a row with different superscripts are different (P < 0.05).

## Assessment of Liquid Feeding Condensed Distillers Solubles and Distillers Whole Stillage from Ethanol Production on Growth Performance and Carcass Characteristics of Growing-Finishing Pigs (2015)

Sam Baidoo

University of Minnesota

### Objectives

The objectives of the project were to compare growth performance, carcass characteristics, and meat sensory quality of growing-finishing pigs fed diets containing high level of corn condensed distillers solubles (CCDS) and corn distillers whole stillage (CDWS) to those of pigs fed a corn-soybean meal control diet through liquid feeding.

### Introduction

In the dry milling process of ethanol production, the fermentation residue after distillation is called distillers whole stillage which can be further centrifuged or screened to produce wet distillers grains and thin stillage. Thin stillage may constitute up to 40% of the total residual dry matter (Stock *et al.*, 2000). Distillers whole stillage contains about 6-12 % dry matter.

Research in the 1940s suggested that feeding whole stillage alone to pigs caused soft carcass, yet the carcass quality was improved if dry corn was added to the diet (Lane, 1980). Koeln *et al*. (1984) indicated that corn distillers whole stillage (CDWS) might be used as a supplemental protein source for growing lambs and finishing steers. Corn condensed distillers solubles (CCDS) is obtained by evaporation of thin stillage to 30 to 40% dry matter and contains a significant amount of protein and fat.

Very limited data are available on including CCDS in swine diets. To our knowledge, very limited information is available regarding effects of inclusion of CCDS and CDWS on pork meat sensory characteristics and fat quality. Since the process of drying of wet cake and evaporation of thin stillage account for around 50% of total energy consumption of a bioethanol plant, it will be beneficial to both the ethanol industry and the livestock industry if whole stillage or syrup can be directly used for animal feeding via liquid feeding system.

### Abstract

This study was carried out to investigate effect of liquid feeding high level of corn distillers whole stillage (CDWS) and corn condensed distillers solubles (CCDS) on growth performance, carcass characteristics, belly firmness and meat sensory quality of growing-finishing pigs.

A total of 256 pigs (initial body weight 29.8±5.6 lb) were blocked by sex and body weight and assigned to 1 of 4 treatments: 1) corn-soybean meal based diet as control, 2) 25% CDWS (88 % dry matter basis) + 5% CCDS (88 % dry matter basis), 3) 19.5% CDWS (88 % dry matter basis) + 10.5% CCDS (88 % dry matter basis), and 4) 19.5%, 26%, and 32.5% CDWS (88 % dry matter basis) + 10.5.5, 14%, and 17.5% CCDS (88 % dry matter basis) in phases 1 (28 days), 2 (38 days), and 3 (60 days), respectively.

Our results indicated that the control group had greater ($P < 0.05$) average daily gain and feed efficiency than the other 3 treatments during the overall period. Compared with the control, the other 3 groups had lower ($P < 0.05$ or $0.05 < P < 0.10$) carcass weight and back fat depth due to lower ($P < 0.05$) slaughter body weight, but similar ($P > 0.05$) dressing percentage, muscle depth, and lean percentage were observed among the 4 treatments. Inclusion of CDWS and CCDS reduced ($P < 0.05$ or $0.05 < P < 0.10$) belly firmness but did not influence ($P > 0.05$) the overall like, flavor, tenderness and juiciness of loin chops when compared with the control group. A simple economic analysis indicated that 8 more dollars per pig could be earned for Treatment 4 relative to the control group.

In conclusion, our results suggest that inclusion of 30-50% whole stillage and condensed distillers solubles throughout the growing-finishing period may reduce growth performance, carcass weight and belly firmness, but does not affect carcass lean percentage and pork sensory quality.

## Reduced Fat DDGS Feeding: Investigating Impact on Milk Composition and Cheese Quality (2013)

Stephanie Clark and Donald Beitz

Iowa State University

### Objectives

To investigate impact of lactose, sulfate, and thiosulfate on quality of baby Swiss cheese. The resulting quality impacts on baby Swiss cheese made from milk of cows fed reduced-fat DDGS will be compared with cheese made from milk from cows fed a control diet containing no DDGS. Finally, the economic impacts of feeding reduced-fat DDGS on feed efficiency will be determined.

### Introduction

Late blowing in cheese is unacceptable to consumers and it reduces the economic value of cheese. Appearance of splits and cracks is due to unwanted gas production during the ripening of Swiss cheese. Dairy farmers suspect feeding DDGS might be a reason for such defects in cheese.

With ethanol production being a major industry in the Midwest, utilization of DDGS in animal feeding is inevitable and generally economical. Consequently, it is of high priority to farmers in the Midwest that we investigate the effects of DDGS inclusion in the diet of dairy cows on quality markers of milk as they relate to cheese production. The research was designed to investigate the impact of lactose, sulfate and thiosulfate on quality of baby Swiss cheese.

Additionally, because of the industrial shift from a “full-fat DDGS” to reduced-fat distillers dried grains with solubles (RF-DDGS), we will investigate the effect of feeding two types of RF-DDGS that contain two different concentrations of fat (3-4% and 8%) on feed efficiency and usability of milk for Swiss cheese production. It is expected that high concentrations of lactose, sulfate and thiosulfate in milk impair the growth and metabolism of the specific microorganisms responsible for high quality baby Swiss cheese.

**Table 1. Cheese by production day summary for significant interaction effects for flavor and body and texture attributes.**

| Cheese and production day[1] | Bitter | Curdy | Mealy/ grainy | Pasty | Weak | Amount | Distribution | Gas Formation |
|---|---|---|---|---|---|---|---|---|
| A1.day1 | $4.27^{abc}$ | **$11.05^{a}$** | **$10.52^{a}$** | 0.28b | 0.30b | **8.88a** | 3.16abc | 1.78a |
| C1.day1 | $3.52^{abc}$ | $8.63^{abc}$ | $5.90^{bcd}$ | 0.50b | 0.57b | **9.23a** | 3.20abc | 3.58a |
| A3.day2 | **$5.71^{c}$** | $7.40^{bc}$ | $4.64^{bcd}$ | 0.42b | 1.04b | **9.77a** | **1.93c** | 4.23a |
| C2.day2 | **$5.64^{c}$** | **$5.86^{cd}$** | **$2.13^{d}$** | 1.34b | 1.85ab | 7.65ab | 3.89abc | 6.44a |
| A2.day3 | $4.24^{abc}$ | $9.22^{ab}$ | $5.18^{bcd}$ | 0.33b | 0.40b | **8.98a** | **1.63c** | **7.86a** |
| C3.day3 | $3.13^{ab}$ | $8.48^{abc}$ | $5.89^{bcd}$ | 0.36b | 1.39b | **5.13b** | **6.73a** | 5.19a |
| A1.day4 | $3.85^{abc}$ | $7.30^{bc}$ | $6.85^{abc}$ | 0.29b | 0.39b | 7.02ab | 4.28abc | 6.74a |
| C1.day4 | $3.45^{abc}$ | $8.09^{abc}$ | $6.64^{abc}$ | 0.36b | 0.52b | 7.55ab | 2.33bc | 1.59a |
| A2.day5 | $3.22^{ab}$ | **$3.08^{d}$** | **$4.11^{cd}$** | **3.94a** | **3.36a** | **5.45b** | 6.62ab | **7.76a** |
| C2.day5 | $4.55^{b}$ | $8.92^{abc}$ | **$8.36^{ab}$** | 1.00b | 0.43b | **8.78a** | 3.89abc | 3.22a |
| A3.day6 | **$2.19^{a}$** | $6.43^{bcd}$ | $6.13^{bcd}$ | 1.03b | 1.70b | 6.58ab | 4.03abc | 3.58a |
| C3.day6 | **$2.32^{a}$** | $7.28^{bc}$ | $4.69^{bcd}$ | 0.41b | 0.58b | 8.10ab | 2.68abc | 2.88a |
| A1.day7 | **$2.36^{a}$** | $8.10^{abc}$ | $7.61^{abc}$ | 0.45b | 0.64b | 7.68ab | 2.87abc | 2.81a |
| A2.day7 | **$2.12^{a}$** | $7.08^{bc}$ | $6.50^{abc}$ | 0.57b | 1.21b | 8.26ab | **2.13c** | 2.78a |
| *P*-value | 0.01 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.001 | 0.005 | 0.03 |

[1]A = Control, C = Control, [a, b, c] Items in a row not sharing a common superscript differ, $P < 0.05$

### Abstract

In this investigation, the feeding of DDGS had little effect on cheese quality. Instead, cheese making procedures (temperature control, moisture removal, brine incorporation into curd, aging conditions) had more of an impact on cheese quality attributes. Significant cheese by production day interaction effects were noted for most sensory attributes, but very few trends stand out.

These findings, additionally, demonstrate that feeding RF-DDGS did cause a decrease in fat corrected milk (FCM) efficiency as a result of an increase in dry matter intake (DMI), however, when energy corrected milk (ECM) efficiency was calculated (accounting for fat, protein, and lactose concentration in milk) no difference in feed efficiency resulted.

These results indicate that RF-DDGS can be effectively fed at a 20% dry matter (DM) inclusion rate without having negative effects on milk components, blood glucose, or ECM milk efficiency and that protein utilization may be improved when cows are fed RF-DDGS.

## Utilization of Corn- and Soy Co-Products in Feedlot Diets, and Evaluation of Environmental Factors Contributing to the Prevalence of E.coli O157:H7 shedding (2012)

M. A. Nelson, J. Johnston, G. I. Crawford, R. B. Cox, and A. DiCostanzo

University of Minnesota

### Objectives

The research will investigate if site, not diet, impacts incidence of E. coli 0157:H7 shedding. It will also be investigated if under situations of high corn prices, reduced corn inclusion in diets high in inclusion of corn and soy co-products provide a viable, and profitable alternative to traditional corn diets with moderate inclusions of corn co-products.

### Introduction

Ethanol production in the U.S. increased from 3 billion gallons in 2003 to 13 billion gallons in 2013 (Renewable Fuels Association, 2014). Increasingly high amounts of corn co-products are being utilized in feedlot feeds due to the high level of protein availability and economics.

Modified distillers grains with solubles (MDGS) is one corn co-product producers can utilize in feeding systems. It contains roughly 28-30% crude protein, 50% water, and 126% total digestible nutrients (Lardy and Anderson). Feeding 50% MDGS to steers has been shown to increase their neutral detergent fiber digestibility ($p<0.01$) and decrease the cost of gain ($P<0.01$) (Schroeder *et al.*, 2014). When feeding MDGS, producers need to keep in mind that the shelf life is two to three weeks in cold seasons and less than one week in warmer seasons or climates (Lardy and Anderson).

Soybean co-products such as soybean hulls are high in energy, provided by the hemicellulose, and low in protein (Lardy and Anderson). The total digestible nutrients is 80% and 12.4% crude protein (Lardy and Anderson). Soy glycerin is another soybean co-product that results from the production of biodiesel that contains an energy value very similar to corn and a dry matter percent of 85 (Lardy and Anderson). Lardy and Anderson reported that 10% of the initial weight or oil or fat entering biodiesel production will end up as crude glycerol. The total digestible nutrient in glycerol is 89.0%.

While the impact of feeding MDGS, soybean hulls, and soy glycerin has been evaluated, the combined impact of corn and soy co-product has not. The objective of this study was to evaluate the effects of varying corn and soybean co-product inclusion feeding strategy on carcass characteristics and meat quality in feedlot heifers.

Also, in spite of some recent findings from our laboratory demonstrating no relationship between using distillers grains with solubles and incidence of E. coli O157:H7, feeding distillers grains with solubles continues to be implicated with greater incidence of E. coli O157:H7 shedding. Proposing the current study, presented an opportunity to add additional data on this relationship.

### Abstract

The impact of using corn or soybean co-product in high or low corn grain finishing diets of feedlot heifers was evaluated using forty-four purebred Limousin heifers. Heifers were randomly assigned to one of four dietary treatments (11 per treatment) resulting from a nested design with factors being dry rolled corn grain inclusion, main plot: 25% or 65% of diet dry matter, where nested treatments were soy (15% of diet dry matter derived from soy glycerin and soybean high-fiber co-product) or corn co-product (20% to 60% modified distillers grains with solubles) inclusion.

Heifers were fed finishing diets for 129 d and were humanely harvested at a commercial facility. Soy co-product inclusion in high-corn grain ($P < 0.05$) but not in low-corn grain ($P > 0.10$) diets led to lower ($P < 0.05$) DMI, ADG and feed efficiency. Inclusion of modified distillers grains at concentrations equal to or greater than 40% of diet DM led to greater ($P < 0.05$) DMI but numerically lower ADG which resulted in poorer ($P < 0.05$) feed conversion efficiency. There was no treatment effect for HCW ($P = 0.37$), BF ($P = 0.10$), REA ($P = 0.50$), KPH ($P = 0.67$), or marbling score ($P = 0.18$). Drip loss did not differ among treatments ($P = 0.44$).

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## Utilization of Corn- and Soy Co-Products in Feedlot Diets, and Evaluation of Environmental Factors Contributing to the Prevalence of E.coli O157:H7 shedding (2012)

continued from previous page

At high corn grain inclusion, utilizing soy co-products resulted in lower (($P < 0.05$; more desirable) Warner–Bratzler shear force values of steaks. Treatment did not affect subjective scores for lean color ($P = 0.06$), surface discoloration ($P = 0.19$), and overall appearance ($P = 0.52$) or objective scores for L* ($P = 0.32$), a* ($P = 0.49$), and b* ($P = 0.30$) of steaks. Treatment did not affect overall liking ($P = 0.59$), flavor liking ($P = 0.78$), texture liking ($P = 0.38$), juiciness ($P = 0.56$), or off flavor ($P = 0.89$) of steaks. Subjective toughness ratings of steaks from heifers fed MDGS in high-corn grain diets were higher ($P < 0.05$) than those from heifers fed MDGS in low-corn grain diets.

Ground beef L* values from heifers fed 25% low-corn grain diets were higher than those from heifers fed high-corn grain diets ($P < 0.01$). Treatment had no effect on a* ($P = 0.44$) or b* ($P = 0.63$) in ground beef. Ground beef from heifers fed soy co-products in a high-grain diet had the greatest ($P < 0.05$) surface discoloration and last ($P < 0.05$) desirable appearance. Treatment did not affect lean color ($P = 1.00$) or overall appearance ($P = 1.00$) subjective mean values or a* ($P = 0.88$) or b* ($P = 0.82$) in bologna.

LO+MDGS had a higher mean subjective surface discoloration value (9.38) and L* (55.22) compared to all other dietary treatments ($P < 0.01$ and $< 0.01$, respectively) in bologna. Treatment did not affect TBARS but did effect C15:0 ($P = 0.05$) and 9c,12c,15c-C18:3 ($P = 0.04$) fatty acid levels. All other fatty acids and calculated iodine value were not influenced by treatment.

Results indicate feeding 40% MDGS had no effect on carcass traits and fresh meat quality. However, feeding 60% MDGS detrimentally affected processed meat quality, but 15.2% soy co-product inclusion decreased these negative effects.

# Effects of Reduced-Fat Distillers Grains Inclusion in Feedlot Diets on Cattle Growth Performance, Carcass Characteristics and Beef Quality (2016)

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## Objectives

To determine effects of partially replacing dry rolled corn with full- or reduced-fat distillers grains with solubles in feedlot diets on cattle growth performance and carcass characteristics.


## Abstract

Nineteen Jersey (initial BW 455 ± 49 kg) and 29 Jersey-Limousin cross steers (initial BW 518 ± 40 kg) were utilized in a generalized randomized complete block design. Steers were individually fed using Calan gates with 4 dietary treatments (dry rolled corn control, C; reduced-fat distillers grains inclusion at 20% of dietary DM with corn oil, FF; reduced-fat distillers grains inclusion at 20% of dietary DM, RFL; or reduced- fat distillers grains inclusion at 47% of dietary DM, RFH). The latter was intended to provide similar dietary fat content as the FF treatment.

Cattle were harvested on d 93 at a commercial abattoir and objective carcass measurements as well as USDA Yield and Quality Grades were collected. Strip loins (IMPS #180) and shoulder clods (IMPS #114) were removed from the right side of each carcass 48 h postmortem. Strip loins were evaluated for purge and drip loss and ultimate pH. Strip steaks were used to determine objective (L*, a*, and b*) and subjective color for six consecutive days. Warner-Bratzler shear force (WBSF) was determined from two steaks from each loin. Fresh strip steaks were cooked for consumer sensory evaluation.

Ground shoulder clods were used in ground beef objective and subjective color evaluation. Thiobarbituic acid reactive substance assay was evaluated on ground clods day 0 and day 7. The ground beef was then used in further processed production of bologna. Bolonga was evaluated for objective and subjective color. A consumer sensory panel evaluated bologna samples.

No differences were observed in cattle consuming full-fat versus reduced-fat distillers grains. Cattle consuming distillers grains (DG) had improved ($P < 0.05$) BW, ADG, and BW gain relative to cattle not consuming DG. Cattle consuming DG also had improved ($P < 0.02$) HCW, USDA QG, and percentage of cattle grading USDA Choice and Select. Cattle consuming 20% DG had improved ($P < 0.05$) USDA YG and percentage of cattle grading USDA Prime.

Hot carcass weight (HCW) was greater ($P=0.02$) in RF-L compared to CON (388.7 vs. 334.7±12.65 kg). Back fat depth was unaffected ($P=0.81$) by dietary treatment but tended ($P=0.06$) to be less in Jersey steers (7.36 vs. 9.65±2.79 mm). Ribeye area (REA) was not impacted ($P=0.81$) by dietary treatment.

However, Jersey steers had smaller ($P=0.01$) REA (83.94 vs 102.26±7.94 cm2). USDA Yield Grade (YG) was not influenced ($P=0.73$) by dietary treatment, but Jersey steers had lower ($P=0.02$) YG (2.69 vs. 2.90±0.06). Steers fed CON tended ($P=0.09$) to have greater WBSF compared to steers fed RF-O (3.00 vs. 2.24±0.20 kg). Steak objective color (L*) was greater ($P=0.03$) in steers fed RF-Low than steers fed CON (31.23 vs. 27.04±0.95). Consumers rated the liking of the steak flavor higher for samples from the Crossbred cattle ($P=0.03$) but preferred the texture of Jersey ($P<0.001$) strip steaks.

On the other hand, consumers overall liking of the bologna samples from Crossbred steers as compared to Jerseys in overall liking, flavor liking, and texture liking ($P<0.001$, $P<0.001$, and $P=0.02$, respectively).

In conclusion, Jersey X Limousine Crossbred steers had greater REA and HCW but no differences in the carcass or meat quality attributes evaluated. Feeding reduced-fat distillers grains in replacement of dry-rolled corn did not substantially affect the carcass or meat quality attributes evaluated. Results from this experiment indicate that utilizing reduced-fat DG in place of full-fat DG does not impact animal growth performance or carcass characteristics. Moreover, partially replacing dry rolled corn with DG may lead to an improvement in ADG, HCW, and USDA QG, and a reduction in USDA Select-grading carcasses.

## Fertilizer Value of Manure (2015)

Alfredo DiCostanzo, N. M. Kenney Rambo and A. Nesseth
University of Minnesota

### Objectives

To test the hypothesis that the type of manure management system is a factor in determining the nutrient value of manure. We further propose that feedlot operators need a greater understanding of opportunities to capture greater manure nutrient value by learning and applying concepts in demonstration fields where they will experience manure sampling and testing, manure spreader calibrations, and by gaining a greater understanding of costs to remove, process, transport, and apply manure.

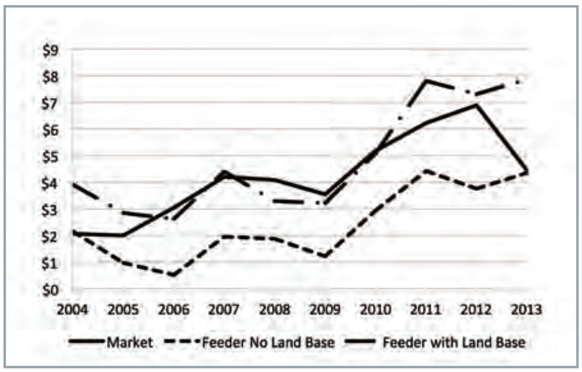


Figure 1. Average U.S. corn grain price (Market) or worth of corn grain realized after feeding cattle in operations with no land base to access bedding or roughage from crop residues or for manure application (Feed No Land Base) or those with land base to access bedding or roughage from crop residues or for manure application (Feeder With Land Base).

### Introduction

Design, construction and management of cattle feeding operations have evolved dramatically over the last 20 years. The quest for improved cattle comfort for consistent and predictable performance drove this process initially. Concurrently, changing regulatory climate towards greater environmental protection, particularly water quality protection by preventing or eliminating excessive nutrient or waste discharges to state or federal waters expedited development and adoption of new facility designs that would both provide cattle comfort for consistent performance and environmental protection.

Further, changing global economic conditions resulting from a biofuel-based economy and recent economic recession accelerated the need to make cattle feeding a more resource-efficient process.

Taken together, these factors have contributed to attributing greater economic value to manure derived from cattle feeding operations. This, in turn, promoted closer evaluation of cattle feedlot designs that would capture greater manure value; thereby, achieving a better matched nutrient cycle between soil, plants and animals while preventing contamination of state and federal water resources.

In spite of this, and because much of the recent developments in cattle feedlot design, construction and operation have arisen from the private sector, no public information exists where impact of feedlot design on measured nutrient value of manure produced. Therefore, one of the objectives of this manuscript is to provide an in-depth analysis of the impact of feedlot design on manure nutrient values to aid feedlot owners and managers in the decision to select a feedlot design consistent with their objectives for crop land and manure management.

A second objective is to demonstrate the impact of the value of manure as fertilizer on corn production destined as cattle feed and to determine how corn grain, fertilizer and cattle prices interact to determine sustainability of the land, cattle, crop and manure system.

### Abstract

Increased fertilizer prices and a more stringent regulatory climate have led to greater interest in capturing value of manure through from cattle feeding operations. As expected, feedlot designs that capture more manure either diluted with bedding materials such as bed pack designs or in a pit recover the greatest amount of nutrients per head space yearly. Guideline values utilized by engineers and other consultants are adequate estimates of manure nutrient yield per head space yearly.

Greater fertilizer prices starting in 2008 served as incentives to build feedlots with greater capacity to capture the value of manure as fertilizer. The value of manure as fertilizer has contributed to making cattle feeding operations competitive with corn farming only operations in the past decade. Corn grain, feeder and fed cattle prices, fertilizer prices and corn grain yield interact to determine profit from feeding corn grain to cattle vs. selling corn grain at market price.

High fed cattle prices relative to corn grain prices with greater than average corn grain yields at current high fertilizer prices favor feeding corn grain to cattle rather than selling in the market place.

# Carbon, Nitrogen, Phosphorus, and Sulfur Interactions Effects on Soil Biochemical Processes and Corn Grain Yield (2012)

Paulo Pagliari and Jeff Strock
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## Objectives

The overall objective of this research was to determine if corn grain yield could be increased beyond current averages by evaluating the interactions between carbon, nitrogen, phosphorus and sulfur (C, N, P, and S). This study looked at how the addition of these nutrients at several rates affects microbial activity in the soil and the rate of nutrient mineralization, by using enzymatic activity as surrogates. Understanding how the addition of C, N, P, and S affects these nutrients reactions, transformations, and availabilities during the growing season and understanding their interactions might help improve nutrient management, increase crop performance, and therefore, lead to potential increased grain yield and potentially reduced nutrient losses.

Carbon, N, P, and S were selected because they are the only macronutrients required for plant growth that are present in the organic and also inorganic forms in the soil. It was hypothesized that application of N, P, and S could potentially decrease biochemical mineralization by maintaining sufficient levels of available P and S for plant uptake. In addition, N immobilization by microbial activity was expected to be lower in plots where the previous crop residue was removed compared with plots where the previous crop residue was incorporated.

In this study soil enzyme activity was monitored in plots with and without plants to assess how the rhizosphere around the plant roots can change microbial activity, and as result, biological and biochemical mineralization rates. The hypothesis was that plants would exude enzymes that promote higher rates of N, P, and S mineralization compared to mineralization rates in plots without growing plants. In addition, the decrease in nutrient availability in soil due to crop uptake might also increase enzymatic activity in plots with growing plants compared with plots that are kept without growing plants.

Soil temperature and moisture content play a significant role in biological and biochemical mineralization, as microbes have ideal moisture content and temperature for maximum growth rates. Enzyme activity is also highly dependent on temperature. Therefore, it was hypothesized that rates of biological and biochemical mineralization would be different throughout the growing season.

## Introduction

Over the past few decades, increases in crop production, especially corn grain yields, have been mainly a result of genetic improvements. This can easily be observed in yields of control plots from long-term trials where yields have steadily increased over the time even though no fertilizer has been applied to those plots (personal communications).

Among the essential macronutrients required for plant growth, nitrogen (N) and phosphorus (P) are the most limiting nutrients for optimum grain yield in the Midwest. Grain yield response to N shows a rapid increase at lower application rates (e.g. 10 to 60 lbs N acre-1) when compared with a non-fertilized field; with greater N rates there is a decrease in the rate of grain yield gains per lb of N applied (e.g. 80 to 120 lbs N acre-1); and grain yield reaches a plateau (approximately 200 bu acre-1 at high yielding sites) with greater N rates (e.g. 160 to 200 lbs N acre-1).

Although this process is well understood, there has been no information in the literature that provides an explanation as to why grain yield levels off at a plateau at a given N rate, both which vary by location. This result could be interpreted as the crop has reached its maximum yield potential, and further increases in N rates will not improve yields. However, the fact that grain yield can be much greater at localized, apparently random locations within a field, suggests that possibly other factors including nutrient availability, soil moisture, temperature, microbial activity, among others could be limiting crop yields. It is apparent that nitrogen will only increase crop yield until it is not a limiting factor, or until another factor becomes limiting, and therefore prevents further yield increases (Liebig's Law of the Minimum).

Current research being conducted to provide information on how to increase yield beyond the current average reported (a given plateau) usually focuses on the interactions between tillage systems, crop rotation, and often a single nutrient. However, the number of interactions between multiple nutrients studied at the same time is limited. This is perhaps a reflection of the difficulty in interpreting higher-order interactions and logistic problems related to the number of plots required as the number of interactions increase.

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## Carbon, Nitrogen, Phosphorus, and Sulfur Interactions Effects on Soil Biochemical Processes and Corn Grain Yield (2012)

continued from previous page

For example, in a given study a researcher will test the effects of different tillage systems, in combination ith five or six increasing N rates,

**Table 1. 2013 Grain yield as affected by nitrogen rate and residue management.**

| Nitrogen Rate (lbs acre$^{-1}$) | 2013 Corn Grain Yield (bu acre$^{-1}$) | |
|---|---|---|
| | Removed | Incorporated |
| 0 | 114 f † | 124 ef |
| 40 | 130 de | 138 cd |
| 80 | 138 cd | 158 ab |
| 120 | 139 c | 156 b |
| 160 | 139 c | 165 a |
| 200 | 145 c | 159 ab |
| Average | 134 B | 150 A |
| LSD: 7 bushels acre$^{-1}$ | | |

† Means followed by different letters within a column are significantly different (P<0.05).

and also with or without sulfur (S). Although this is an important study to be conducted, it could be improved by adding a few increasing S rates instead of only two (with or without). Better results could be achieved if the researcher would add increasing rates of yet another limiting nutrient, for example P.

Carbon (C), N, P, and S have been reported to interact with each other in the soil, and as a result, affect mineralization and immobilization rates of nutrients under forest system (Vitousek *et al.*, 1988). Very few, if any, similar studies have been conducted for agronomic crops, where the interaction of all four nutrients is evaluated. Crop rotation can play a major role in nutrient cycling, availability and mobility and how subsequent crops will perform. Multi-cropping systems has been reported to provide better conditions for microbial growth in the soil than continuous cropping (Moore *et al.*, 2000), which will have an effect on nutrient mineralization and immobilization rates.

From a nutrient mineralization standpoint, the release of C and N from the soil organic matter is a process strictly driven to obtain energy, which is known as biological mineralization; whereas the release of P and S from soil organic matter might come from either biological mineralization, or from biochemical mineralization (McGill and Cole, 1981).

Biochemical mineralization is a process catalyzed by enzymes released by microorganisms and roots of higher plant in the soil solution, which promote the hydrolysis of organic P and S into their inorganic forms PO42- and SO42-. Biochemical mineralization of P and S is regulated by the concentration of inorganic P and S in the soil solution (Maynard *et al.*, 1985, Stevenson and Cole, 1999); therefore, fertilizer application can affect biochemical mineralization rates and as a result affect nutrient availability to plants and microbes. It is important to understand what the effects of nutrient application are on microbial activity because they are responsible for almost all of the biological mineralization that increases soil fertility.

To maintain soil sustainability, a dynamic equilibrium between nutrient mineralization and immobilization in the soil must be achieved so nutrient depletion can be avoided. Increasing grain yield beyond current yield potential might develop or aggravate the effects of nutrient deficiency on crop growth, unless a balance between nutrient inputs and export is implemented.

**Table 2. 2013 corn grain nutrient uptake as affected by nitrogen rate and residue management.**

| Nitrogen Rate (lbs acre$^{-1}$) | P | K | Ca | Mg | Fe | Mn | Zn |
|---|---|---|---|---|---|---|---|
| | | | | Residue Removed | | | |
| | | | | (lbs acre$^{-1}$) | | | |
| 0 | 58 a† | 83 ab | 49 ab | 64 abc | 0.61 ef | 0.18 cde | 0.33 abc |
| 40 | 61 a | 89 a | 51 ab | 69 abc | 0.72 de | 0.20 bcd | 0.36 a |
| 80 | 60 a | 89 a | 53 ab | 70 a | 0.82 bc | 0.21 ab | 0.35 ab |
| 120 | 54 ab | 84 ab | 52 ab | 66 abc | 0.83 bc | 0.21 bc | 0.32 abc |
| 160 | 54 ab | 84 ab | 51 ab | 69 abc | 0.89 ab | 0.21 bc | 0.32 abc |
| 200 | 54 ab | 83 ab | 52 ab | 70 ab | 0.96 a | 0.24 a | 0.33 ab |
| | | | | Residue Incorporated | | | |
| 0 | 34 d | 44 e | 32 c | 39 f | 0.36 g | 0.12 f | 0.21 e |
| 40 | 46 bc | 66 cd | 46 b | 52 de | 0.51 f | 0.15 e | 0.28 cd |
| 80 | 54 ab | 67 cd | 55 a | 58 cde | 0.64 e | 0.18 bcd | 0.31 abc |
| 120 | 52 ab | 71 bc | 51 ab | 59 bcd | 0.65 e | 0.18 bcd | 0.30 bc |
| 160 | 53 ab | 74 abc | 55 a | 64 abc | 0.76 cd | 0.20 bcd | 0.32 abc |
| 200 | 40 cd | 59 d | 45 b | 50 e | 0.61 e | 0.17 de | 0.25 de |

† Means followed by different letters within a column are significantly different (P<0.05).

The potential for environmental pollution (ground water contamination with N, S, and P) must also be evaluated to assure that new methodologies are not detrimental. For example, if S application in combination with P can increase yields at a given N rate, then there is a potential for the decrease in N leaching, as greater amounts of N will be taken up by the crop and assimilated into biomass.

On the other hand, if S and P increases N mineralization rates during a period of high soil moisture and low plant requirement, then greater amount of NO3- could leach out of the system. Because C, N, P, and S are in a dynamic interaction state within the soil matrix, it would be of interest to try and understand how the manipulation of any one the four elements would affect corn production.

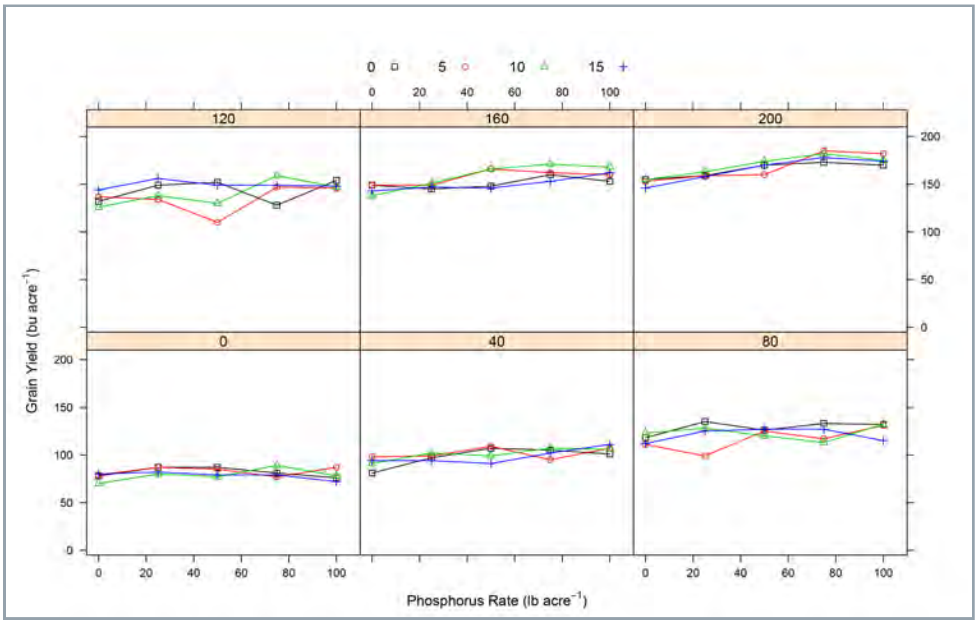



Figure 1. 2014 corn grain yield as a function of nitrogen, phosphorus, and sulfur application rates. Phosphorus application rate is shown in the x-axis, nitrogen application rate is shown in the box title, and sulfur rate is shown by the different symbols and colors within each box.

## Abstract

This research was designed to investigate how the addition of nutrients at different levels interacted with residue management and their impact on the parameters controlling corn grain yield. Our primary interest was to understand how different levels of N, P, and S affected nutrient availability during the growing season in addition to how those levels affected microbial activity.

Furthermore, we were also interested in investigating if residue management would interfere with nutrient availability and microbial activity. The study was set up in small plots located in a farmer's field that had initial test levels for P and K that were considered low. The area of the study was just over 13 acres, which should provide enough data to answer our research questions. The study was carried out from 2012, the initial year when a detail characterization of the site was done, until the end of the 2015 growing season. The cropping systems used was a continuous corn rotation.

The results of the study showed that corn grain was significantly affected in some level by all parameters being studied. The most dramatic effect, however, was residue management. It was determined that residue incorporation, in general, provided the best conditions for corn grain yield to be maximized when higher levels of P, N and S were applied. It was observed that plots were the residue was incorporated kept microbial activity higher than in the plots were the residue was removed, which in combination with higher moisture levels, led to a higher nutrient availability to the growing crop.

Although, the in-season measurements seem to indicate that nutrient uptake and biomass yield would be greater in plots where residue was removed, final grain yield and nutrient uptake showed a contradictory result. It was observed that a change in fertilizer and residue management will likely be need to maintain or improve corn grain yield in continuous corn cropping system in soils that are similar in properties to those used in this study.

## Paying Attention to the Details: Corn Nitrogen Recommendations in Uncertain Times (2013)

Jeff Coulter, Michael Russelle, Deborah Samac and Gary Feyereisen
University of Minnesota

### Objectives

- Compare standard and drought-tolerant and standard corn hybrids under 3 levels of water stress with sub-optimal, optimal, and supra-optimal N fertilizer rates on 3 fields with contrasting soil N supply.
- Determine the presence and severity of alfalfa diseases on several Minnesota farms, and determine whether these results are related to response to N fertilizer in the subsequent first-year corn crop.
- Quantify the response to N fertilizer in first-year corn after alfalfa on several Minnesota farms with fine-textured soils; compare yield and economic return for near-planting and sidedress N fertilizer applications at these sites; and use this information to validate the new field-specific N fertilizer recommendation system for first-year corn after alfalfa that we developed.

To accomplish these objectives, we conducted 2 years of field research. In 2013, we conducted an intensive drought stress experiment in each of 3 fields with contrasting levels of soil N supply potential at the University of Minnesota Sand Plain Research Farm near Becker, MN.

In 2013, we also evaluated 9 alfalfa fields across Minnesota for the presence and severity of alfalfa diseases. In some of these fields and in others, which all have fine-textured soils, on-farm experiments were established in the fall of 2013 in order to evaluate the response of first-year corn to N fertilizer rates in 2014. In total, 14 on-farm experiments were conducted in 2014.

### Introduction

<u>Drought:</u> Water stress can significantly reduce corn yield, especially if it occurs during tasseling and ear formation, but it can increase rooting depth if stress occurs early in corn growth. Water stress also reduces root proliferation. Shallower rooting that is caused by early water or N stress limits the use of subsoil moisture.

In a recent evaluation of corn yield in Illinois, researchers found that higher N fertilizer supply improved yield during a very dry August. They speculated that this occurred because the fertilized corn produced deeper roots and could better access subsoil moisture. More robust rooting was supported by greater leaf number and leaf area in fertilized than nonfertilized corn.

Although they conclude that more N is required during short-term drought on sites with subsoil water, they concede that lower N rates may be required on sites without subsoil moisture reserves. Under those conditions, excess leaf area and evapotranspiration during vegetative growth may utilize available soil water before the water-sensitive reproductive growth stages.

Do these conclusions hold for new drought-tolerant hybrids? This question is particularly important, because a recent analysis concluded that drought-tolerant hybrids were better than corn without drought tolerance only under moderate drought, but were worse in severe drought. How might this affect N fertilizer recommendation?

Dry conditions during the second half of the growing season in 2011 and 2012 reduced corn yield in some areas of Minnesota, but in general corn yields during these dry conditions were much higher than expected. Better understanding of interactions among hybrid type, water availability, and N supply on corn performance is needed.

<u>Previous Crop Nitrogen Credits:</u> In the Upper Midwest, alfalfa provides most or all of the N needed to maximize grain yield of the following corn crop on about 90% of fields (known as the N credit or N fertilizer replacement value). However, surveys show that some of the most extreme cases of excess N fertilization in corn occur when corn follows alfalfa. It is well known that excessive N applications cause disproportionately high N losses and can lead to water quality impairment.

Over-application of N in corn following alfalfa occurs because growers and crop advisors are unsure if N credit recommendations developed many years ago are still sufficient for the high corn yields of today. In addition, it is still difficult to identify fields that will not provide all of the N needed for first- year corn after alfalfa.

Current N credit recommendations for first-year corn after alfalfa in the Upper Midwest are based on the alfalfa plant density at the time of termination, but in a recent analysis of past research we found no evidence that alfalfa plant density can help predict N response or N uptake in first-year corn. This contradicts current N recommendations in several Corn Belt states, including Minnesota.

We hypothesize that numbers of living alfalfa plants are not as important as the numbers of vigorous living alfalfa plants. Alfalfa diseases such as *Aphanomyces* root rot and brown root rot reduce herbage yield, root production, and N fixation, thereby reducing the N added to soil by alfalfa growth.

Figure 1. Leaf rolling in the afternoons of the water-stressed treatments. The drought-tolerant hybrid tended to show leaf rolling first, perhaps as a water conservation mechanism. Water stress was managed with the drip irrigation system so that stressed plants exhibit leaf rolling in the afternoons, but not in the mornings.

In 31 recent on-farm N rate trials that we conducted in first-year corn following alfalfa that were funded by the Minnesota Corn Growers Association, the Minnesota Agricultural Fertilizer Research and Education Council, and the Minnesota Agricultural Water Resources Center, N fertilizer increased grain yield only on 3 farms. However, a substantial N rate (about 80 lb N/acre) was needed on these 3 farms to optimize grain yield. These 3 responsive farms all had fine-textured soil and above-average precipitation between planting and mid-June.

When the results from these trials were combined with results from 228 other N rate trials in first-year corn after alfalfa from the northern U.S. and southern Canada, there were a total of 19 trials conducted on fine-textured soils, and 53% of these trials had a response of grain yield to N fertilizer. Using simple predictors (alfalfa stand age and autumn precipitation and temperature prior to first-year corn), we developed a field-specific N recommendation system that: 1) can identify fields where first-year corn will respond to N fertilizer; and, 2) can predict the economically optimum N fertilizer rate prior to April of the corn year.

However, this field-specific N recommendation system for first-year corn after alfalfa needs validation in on-farm trials prior to farmer adoption.

## Abstract

Drought-tolerant hybrids have not been evaluated under controlled drought stress in Minnesota, leading to variable results influenced by location-specific weather conditions. In addition, nitrogen (N) response in first-year corn after alfalfa has been variable on fine-textured soils.

This project was conducted to help growers improve their decisions about hybrid selection and N fertilizer rate in years when water stress is anticipated, and have increased predictability of N response in first-year corn after alfalfa on fine-textured soils. Experiments were conducted in 3 fields on a coarse-textured soil at Becker, MN in 2013 to compare standard and drought-tolerant hybrids under 3 controlled drought stress treatments with multiple N fertilizer rates.

Grain yield did not differ between drought-tolerant and standard hybrids in the absence of drought stress or when sustained drought stress occurred from the R2 to R6 corn stages, but was 11% greater with the drought-tolerant hybrid when sustained drought stress occurred from the V14 to R6 corn stages. Response to N fertilizer did not differ between hybrids. Another set of trials evaluated N fertilizer rates applied near planting or as a sidedress in first-year corn after alfalfa on 14 farms with fine-textured soils in 2014.

On the 7 of 14 farms where grain yield was increased with N fertilizer, the range in the EONR for net return within $1.00/acre of maximum net return for N applied near planting ranged from 59–91 lb N/acre on 4 farms, was 90–111 lb N/acre on 1 farm, was 105–141 lb N/acre on 1 farm, and was 179 lb N/acre or more on 1 farm.

On the 7 of 14 farms where grain yield was increased with N fertilizer, the average EONR was 9–26 lb N/acre higher on 3 farms, 58–67 lb N/acre higher on 2 farms, and 6–29 lb N/acre lower on 2 farms for N that was applied near planting compared to as a sidedress. Results from these trials will help growers improve economic returns and environmental stewardship.

## Corn Seeding Rate by Nitrogen Rate Study (2015)

Tom Hoverstad and Jeff Coulter
University of Minnesota

### Objectives

The objective of this research is to provide Minnesota corn growers with information about optimum N fertilizer rates for corn when production goals are for high corn yields utilizing high plant populations.

### Introduction

Current nitrogen (N) fertilizer recommendations for corn in Minnesota are based more on soil productivity and crop history than on yield goal. Minnesota corn growers are interested in whether these recommendations hold true for high yield environments where growers are using higher plant populations on highly productive soils and yields are expected to be much higher than state average yields.

Research conducted by university personnel at the Research and Outreach centers at both Waseca and Lamberton have identified areas where high corn yields can be expected. Additionally, several years research conducted on a site near Rochester by the same researchers identified an area in that area that historically produces corn yields higher than the state average.

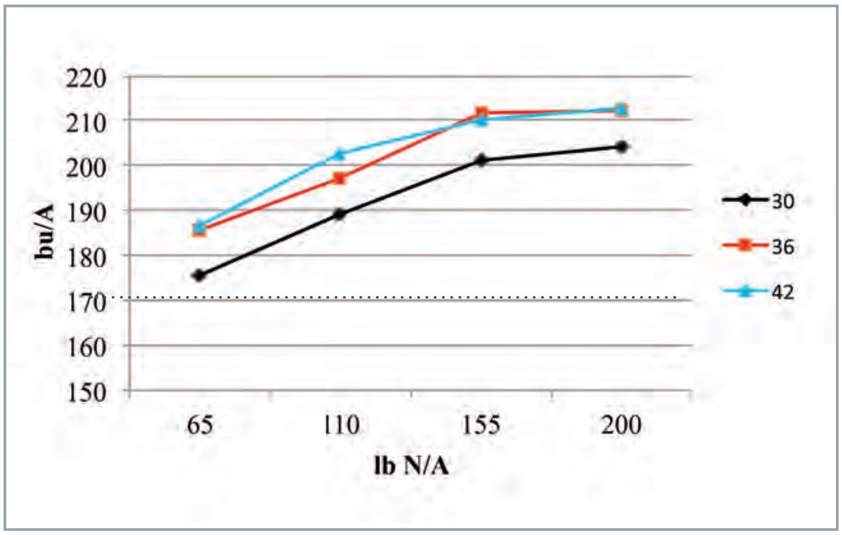
By establishing plot areas at all three of these sites, researchers set out to examine corn production on these sites where seeding populations were higher than current production practices under varying nitrogen rates.

### Abstract

Research was conducted from 2012 through 2014 to investigate nitrogen fertilizer and plant populations for corn where yield goals are higher than average corn yield. Trials were established at Lamberton, Waseca and Rochester utilizing Nitrogen rates of 65 to 200 lbs N/acre and populations ranging from 33,000 seeds per acre to 43,000 seeds per acre in 30-inch rows.

Response to nitrogen fertilizer was different in 2014 than in either 2012 or 2013. In either 2012 or 2013 maximum corn yields were achieved at all locations with nitrogen rates between 110 to 155 lb N/acre. In 2014 at the Waseca location corn yield increased with N rates of 200 lb N/acre. This was likely the result of N loss through denitrification and leaching because of an extremely wet spring in Waseca this year. The Waseca location received nearly 13 inches of rain in June of 2014. At Lamberton corn yields did not increase when using nitrogen rates above 155 lbs N/acre. At Rochester corn yield did not increase when using nitrogen rates above 110 lbs N/acre.

**Figure 1. Effect of Nitrogen Rate on Corn Yield at Three Seeding Rates**




Response to plant population in 2014 was similar to other years. At all locations there was no increase in yield for the 42,000 seeds/acre population compared to either 30,000 or 36,000 seeds/acre. At Lamberton corn yield increased as plant population was increased from 30,000 seeds/acre to 36,000 seeds/acre. At Waseca and Rochester no yield increases were measured at plant populations above 30,000 seeds/acre.

No location showed a significant nitrogen rate by population interaction indicating the optimum nitrogen fertilizer rate does not need to be changed as corn plant populations are increased to 42,000 seeds/acre.

# Identification of Erosion Mechanisms and Volume Loss for River Banks and Ravines (2012)

Satish Gupta and Andrew Kessler
University of Minnesota

## Objectives

- To test the use of terrestrial and airborne Lidar to detect river bank seepage and quantify bank erosion as a result of seepage.
- To compare Lidar technology with thermal infrared cameras technology for identifying seepage areas on river banks.
- To quantify seepage induced bank erosion in Blue Earth County using airborne Lidar scans from 2009 and 2012.

## Introduction

Seepage is an important mechanism of river bank erosion in the Minnesota River Basin. The basic mechanism involved in seepage induced bank erosion is that the shallow interflow exiting the face of river bank (i.e. seepage) reduces soil strength at the leading edge thus destabilizing the bank above which either detaches or slides down over time.

In spite of the recognition that seepage is an important process controlling bank erosion, there is a lack of research on techniques that can remotely identify seepage areas on river banks at a broader scale as well as quantify the extent of bank sloughing from seepage induced bank instability.

To date, ground based thermal imaging is the only technique that has been used to locate seeps along the face of river banks. However, ambient air temperature at different times of the day and year can mask the thermal detection of seepage on the face of river banks. Numerous remote sensing technologies have also been utilized to examine the relationship between reflectance and soil moisture.

However, many of these technologies are based on the use of radar from satellites such as synthetic aperture radar. Furthermore, watershed scale measurements of soil moisture using radar are unable to isolate seep locations on the face of river banks. Also, the spatial resolution of many satellite platforms are too coarse (i.e. ≥ 30 m) for detecting seepage on river banks or hillslopes.

Recently, studies have begun testing the relationship between soil moisture and return intensity from light detection and ranging (Lidar) at much finer (i.e. ≤ 1 m) spatial scale. The underlying principle of these studies is that near infra-red light is adsorbed by water thus decreasing the return intensity, an indication of increasing soil moisture content.

With increased availability and use of terrestrial and airborne Lidar to quantify bank erosion, the goal of this study was to test the suitability of terrestrial and airborne Lidar to detect river bank seepage as well as quantify bank erosion from seepage induced bank sloughing.

## Abstract

Seepage is an important mechanism of river bank failure in the Minnesota River basin. Yet, methods to quantify seepage induced river bank erosion across large scales are lacking. The objective of this study was to assess if laser return intensities from terrestrial and airborne light detection and ranging (Lidar) could be used to detect seepage locations on river banks and if these seepage locations relate to the extent of bank erosion calculated from multi-temporal Lidar change detection.

We tested the above concept 1) on a river bank along the Blue Earth River with terrestrial Lidar acquired in 2012 and 2013, 2) on a developing ravine along Carver Creek with terrestrial Lidar acquired in 2014 and 2015; and, 3) on a second bank along the Blue Earth River with airborne Lidar collected in 2009 and 2012.

The results indicate that both terrestrial and airborne Lidar return intensities provide a means to identify seep locations on river banks and this in combination with Lidar measured elevation change provides a means to evaluate seepage induced bank erosion. Since a majority of the sediments in the Minnesota River and Lake Pepin are from bank sloughing, the technique developed in this project helps to quantify bank erosion from seepage; an important bank sloughing mechanism. Information in this project helps corn farmers in making the case that sediments in the Minnesota River and its tributaries are to a large extent a result of natural processes.

## Cropland Runoff Management Using Riparian Tailored Design (2012)

Joe Magner and Lu Zhang
University of Minnesota

### Objectives

- Research and identify a suite of tailored landscape-specific drainage water treatment practices that can be implemented in riparian zones.
- Identify vegetative management systems that help restore ecological services of riparian corridors and provide agricultural income in some situations.
- Prepare a plan and funding proposal for implementing and monitoring the impact of riparian practices designed to treat agricultural drainage on Elm Creek in Martin Creek.

### Introduction

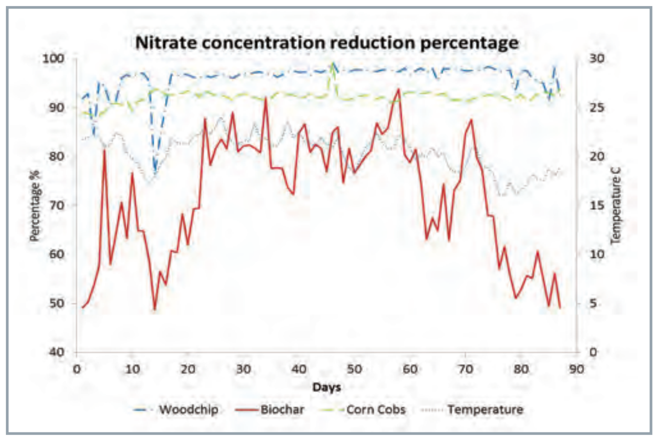
Nitrate export from agricultural fields has drawn a lot of environmental attention due to its significant health and environmental impact (Nitrates and Nitrites, EPA, 2007). Fertilizer application and the extensive drain tile system have contributed to the increase in nitrogen output from the Midwestern corn-belt. The tile drain system can increase the output nitrogen load by mineralization and left over nitrogen from previous years (Dinnes *et al.*, 2002).

Excess nitrate that ends up in groundwater, streams, lakes, and other surface water bodies substantially threaten the ecosystem health (Schipper *et al.*, 2010). Specifically for the Midwest region, the receiving water is the Mississippi River which delivers excess nutrients to the Gulf of Mexico resulting in hypoxic conditions more frequently (Bianchi *et al.*, 2010).

Common treatment strategies including cover crops, denitrifying bioreactors, treatment wetlands, drainage water management, two-stage ditches, and more recently, saturated buffer zones have been studied and implemented to reduce nitrate load leaving row-crop land. Among which, the bioreactor is simple and efficient but may be more costly than other practices depending on the sustainability of the carbon supply. Denitrification occurs under anaerobic conditions with nitrate and carbon supply and appropriate conditions for microbial activity. The bioreactor creates opportunity for the denitrification process by encouraging a biostimulation process.

A by-product from denitrification is nitrous oxide. It can be emitted during the denitrification process when there is not enough residence time to complete all total N reactions. Nitrous oxide contributes 300 times more to the global warming effect than carbon dioxide (Forster *et al.*, 2007).

The Intergovernmental Panel on Climate Change (IPCC) has been producing assessment reports and greenhouse gas inventory guidelines since 1990 to address the importance of nitrous oxide emission (Ravindranath, 2010). Studies also attempt to measure the nitrous oxide emission directly from the agricultural field. Nitrous oxide emission is potentially affected by soil management, environmental, and soil factors (Venterea *et al.*, 2012). However, compare to the crop fields, nitrous oxide emission from BMP's will be minor.




Besides nitrate, phosphorus is another limiting nutrient in the eutrophication process (USEPA). Some algae species responds to the addition of phosphate rather than nitrate (Maloney *et al.*, 1972). Phosphorus is an essential component of nucleic acids and intermediary metabolites process. Phosphorus enters the aquatic systems as a mixture of dissolved and particulate forms (Correll, D.L., 1998).

Orthophosphate is the most stable and common form of dissolved phosphorus. In the tile drain system, the drainage water contains both orthophosphate and particulate phosphorus depending on sediment size and transport into tile lines. The simulated ditch water in the lab contains only orthophosphate. However, not many studies have reported phosphorus removal via bioreactors. Zhang *et al.* (2011) compared phosphorus removal effects of two plant species as well as the presence of a submerged zone with a carbon addition and found that total phosphorus removal significantly increased in the treatment with the submerged zone regardless of plant presence. The average removal was more than

93% total phosphorus and more than 97% total dissolved phosphorus (Zhang *et al.*, 2011).

Different types of biochar also have different phosphorus sorption/desorption effect. Biochar formed at 600 ºC has a reduced capacity to sorb phosphorus than biochar formed at 400 ºC and 500 ºC (Morales *et al.*, 2013). Sarkhot *et al.* suggested that biochar can be used for recovering excess phosphorus. They measured 50% of the PO43- sorption; and during the desorption phase, biochar retained 60% of the sorbed PO43- at a reaction time less than 24 hours (Sarkhot *et al.*, 2014). However, another study suggested that certain types of biochar showed little or no ability to sorb nitrate or phosphate (Yao *et al.*, 2012), which suggests that it is important to know the type of biochar being used when conducting a study.

The efficiency of a bioreactor is affected by multiple factors. Schipper *et al.* (2010) indicated that residence time and alternative carbon source are two of the key factors controlling the effectiveness of a bioreactor. Over the years, researchers have tested a variety of solid carbon sources (Gibert *et al.*, 2008; Woli *et al.*, 2010) as well as non-carbon sources like pyrite (Postma and Boesen, 1991). Woodchips are economically used in field-scale bioreactors (Christianson *et al.*, 2013). More labile carbon sources, like corn stalks, may support higher removal rates than wood media; however, these need to be replenished more often due to the higher depletion rate (Schipper *et al.*, 2010).

In Minnesota, corn is the largest agricultural commodity product. Labile carbon sources such as corn cobs are readily available under certain management scenarios. Studies have shown that corn cobs are quite efficient in removing nitrate. Li *et al.* (2012) used corn cobs as the carbon source for denitrification and observed around 97% reduction at a 23-hour residence time, 88% at 16-hour, and 59% at 8-hour retention time.

They suggested that corn cobs, a feasible carbon source for denitrification, could be effectively used by denitrifying bacteria (Li *et al.*, 2012). Corn cobs can be effective quickly after installation; Wang *et al.* (2013) reported 58% nitrate reduction on the first day with an influent nitrate concentration around 50 mg/L. After an 8-day continuous running of the reactor, the nitrate removal rate became stable at 98% at a 10-hour retention time (Wang *et al.*, 2013). Xu *et al.* (2009) found that corn cobs lixivium has high concentration of Ca, K, Mg, Na, Si, and P, which are necessary for microorganism growth. Trace element like Ba and Zn were also detected. Heavy metal elements that negatively affect metabolism of microbes, such as Cu, Pb, Cr, Cd, were not detected (Xu *et al.*, 2009). The metal ions can be beneficial to denitrification because they are used as an activation center in the denitrification process (Tan and Luo, 2002).

Another carbon source that is drawing attention is biochar. It has a good potential of being used as a soil amendment to enhance crop production, but there is a lack of understanding of the mechanism. The chemical structure and elemental composition depends highly on the conditions of pyrolysis and the biomass parent material (Spokas, 2010). Thermal conversion of biomass in the absence of oxygen yields liquid, solid, and gas products. The solid residual, biochar, is more known as a soil amendment substrate to retain nitrogen and enhance production (Chan *et al.*, 2007).

Keeping low-cost and feasibility in mind, the procedure of making biochar in this particular study was made simple by caramelizing woodchips near the wood source. Cayuela *et al.* (2013) reported a decrease in N2O: (N2+N20) emission when biochar was incorporated in the soil. Singh *et al.* (2010) did a study on the influence of biochar on N2O emission and found an increase in N2O emission during the first two wetting/drying cycles of their study; during the third cycle, N2O emission decreased consistently from all biochar treatments (Singh *et al.*, 2010).

## Abstract

Several capture and treat practices we evaluated at strategically important locations. New approaches we examined for their ability to sequester nutrients before water entered surface waters. The approach included lab testing of corn cobs, woodchips and biochar to observe nutrient reduction.

Field testing included the placement of woodchips and biochar into a trench and beds of synthetic plastic to serve as bacteria hosts. Wetland plants where used in seepage cells to pull nutrients from tile-inflow. Results showed varying degrees of nutrient sequestration. Residence times of 24-hours or longer typically yielded 80 %+ nitrate reduction. Residence times less than 2 hours showed 5-10% nitrate reduction.

This work will be of benefit to row-crop producers who desire to capture any excess nutrients leaving a corn field prior to entering a stream. Further, this work has the potential to guide the type and location of a buffer required under the 2015 buffer legislation.

# Effects of Time of N Application and Instinct® on Corn Production and Nitrate Losses from Tile Drainage Water (2013)

Jeffrey Vetsch and John Lamb
University of Minnesota

## Objectives

The objective of this study was to evaluate the effects of the nitrification inhibitor Instinct® (Dow AgroSciences) added to spring and fall-applied urea and sidedress-applied urea and ammonium nitrate (UAN) on corn yield, nitrogen (N) use efficiency, NO3-N concentration and losses in tile water, and residual soil N.

The goal of this project was to collect new research data and then to use these data to educate Minnesota farmers on the agronomic performance and environmental consequences of fall urea application in south-central Minnesota.

## Introduction

Fall is a desirable time to apply N fertilizer for corn in the northern Corn Belt. Generally, more time is available in the fall for the farmer or custom applicator, soils are drier, compaction is less, and time is saved for earlier spring planting.

About 75% of the N taken up in a corn plant occurs during the months of June and July. The period of time between fall N application and N uptake is of concern as significant N loss can occur as a result of denitrification and/or leaching. Therefore, the potential for N loss is greater with fall application. Nitrogen loss contributes to NO3-N contamination of ground and surface waters, reduced grain yields and profitability for the producers, and results in poor N use efficiency.

In south-central Minnesota, anhydrous ammonia (AA) is recommended as the N source for fall application when applied in late October and November. Urea is not recommended for fall application based on research conducted from the late 70's through the early 90's. This research showed corn grain yields were reduced substantially when urea was applied in late October.

In recent years, urea has become a more popular choice of N for both dealers and farmers; therefore, interest exists among both parties to be able to fall-apply urea without the risk of losing N, grain yield, and profit. Research (Randall *et al.*, 2005) has shown adding the nitrification inhibitor nitrapyrin (N-Serve®) to fall-applied AA increased corn grain yields on poorly drained soils in south-central Minnesota. Can the addition of a nitrification inhibitor to fall-applied urea reduce N loss and increase corn yields?

## Abstract

Fall is a desirable time to apply nitrogen (N) fertilizer for corn in south-central Minnesota; however, the potential for N loss is greater with fall application. A research study was conducted to determine if adding a nitrification inhibitor to fall and spring-applied N fertilizers could increase corn grain yield and/or reduce N loss to tile drainage.

The objective of this study was to measure the agronomic and environmental effects of adding the nitrification inhibitor Nitrapyrin (Instinct®, Dow AgroSciences) to spring and fall-applied urea and sidedress-applied UAN. Spring-applied urea or split-applied UAN had 22 bu/ac greater grain yields than fall-applied urea in 2 of 4 years in this study. Fall-applied urea had slightly greater grain yields than spring urea in 1 of 4 years. The addition of Instinct® to fall-applied urea increased grain yield and reduced NO3 concentration and loss in tile drainage water in 1 of 4 years. Fall-applied urea resulted in 38% greater NO3 loads to tile drainage water than did spring urea. These data do not support the application of fall-applied urea with or without Instinct® in south-central Minnesota.

## Root River Stream Bank Stabilization (2016)

Ron Meiners

Root River Soil and Water Conservation District

### Objectives

The Root River Soil and Water Conservation District (SWCD) objective was to treat and stabilize as many critical areas on the Riceford Creek as possible in one season. Given the scope of our project we set a goal of approximately one mile of stream bank restoration to be completed each year. The project is labor intensive and requires many hours of "hands on work" to complete the installation process. Individual landowners were not capable of committing to this extreme work load.

**Figure 1. Eroded Site**

### Introduction

The Riceford Creek, a tributary to the Root River, was identified by technical staff as a priority stream to treat.

Previous efforts in this watershed to aid in the stabilization of this stream included brush removal to invigorate grassy vegetation, controlled grazing and minimal bank shaping where feasible. Success was minimal.

Since the stream bank revetment project started in 2014 there have been 3,610 linear feet of bank stabilized. Post assessment work has been done on the previous sites and there are signs of significant sediment deposits that hold better established vegetation and other reaches that clearly reflect lower erosion rates. The Board of Soil and Water Resources pollution reduction estimator was used to determine soil losses. Approximately 4,039.2 tons of sediment per year will be saved.

While all of these are positive signs that alternative practices can be successful, abnormal rainfall events can still have devastating effects on previous work. Our goal of long-term bank stabilization is very demanding yet within reach.

### Abstract

Stream bank erosion within the Root River watershed continues to be a concern for many landowners. Seasonal floods along with increased annual rainfall events have emphasized the need for installing additional conservation practices to aid in stabilizing critical reaches along our streams. Ariel photography, stream mapping and landowner testimonials provided the evidence that significant soil losses were occurring.

While discussing options for stream bank stabilization it was determined that the cost for tradition stabilization work, such as bank shaping and placement of adequate breaker rock, was far too expensive and beyond feasibility. Landowners were searching for other low cost alternatives to address the problem. Even though no stream bank restoration project is guaranteed to work, the cedar tree revetment practice seemed to be a very good fit for our topography. The Root River SWCD decided to pursue the revetment project and has recently completed their third successful year of stream revetment work.

The Root River watershed has many riparian areas that contain a significant amount of highly productive cropland. The steady and permanent loss of these acres to excessive stream bank erosion is a financial loss to landowners that cannot be recovered.

## Role of Structural Modifications along the Mississippi River on Sediment Transport to Lake Pepin (2014)

Satish Gupta, Melinda Brown, Ashely Grundtner, Andrew Kessler, Kari Wolf, Carl Rosen, Viktor Polyakov and Mark Nearing

University of Minnesota

### Objectives

- Summarize the information in the literature on the effects of river training structures (wing dams, closing dams, levees) on downstream sedimentation.
- Gather some core samples from floodplain areas and analyze them for particle size distribution, as well as for 210Pb and 137Cs concentration.
- Characterize Lake Pepin sediments for exchangeable NH4 concentrations.
- Complete the work on identification of P sources in the Minnesota River Basin.

### Introduction

Excessive sediments have been a major concern in the Minnesota River and its tributaries since the mid1990s. United State Geological Survey (USGS) studies showed that as much as 55% of the sediment load in the Minnesota River at Mankato is from the rivers in Greater Blue Earth River Basin.

Lidar characterization in 2001-2002 and 2005-2009, partially funded by Minnesota Corn and Soybean Councils, showed that as much as 79% of the measured suspended solids at the mouth of the Blue Earth and the Le Sueur Rivers may be coming from bank sloughing (Thoma *et al.*, 2005; Kessler *et al.*, 2012).

There are several reasons for bank slumping along these rivers which include seepage, freezing and thawing, wetting and drying, sapping, early spring floods, and of course regular scouring of the bank from river flow. Most of these processes are natural and are mainly controlled by the make-up of the landscape (how it was laid during the glaciation period) and the availability of water which is mainly from precipitation. Since the 1930s, there has been a continuous increase in precipitation amounting to an additional 2-4 inches per year. In some locations such as Waseca, the increase in precipitation has been as much as 8 inches per year. In addition to increased precipitation, the rainfall intensities are also much higher now than in the past.

The Minnesota River Basin is the major source of sediments to Lake Pepin on the Mississippi River. Engstrom *et al*. (2009) showed that the current sedimentation rates in Lake Pepin are 10 times higher than the rates in 1830s and before. These authors argue that increased rates are partially due to increased cultivation of the basin from 1830 to 1900 (when European immigrants came to this area) and then increased tile drainage thereafter. Gupta *et al*. (2011) have suggested an alternative hypothesis for some of the increased sedimentation rates in Lake Pepin.

Figure 1. An example of series of wing dams (small black lines) along the Upper Mississippi River (From Army Corps of Engineers). The PIs have gathered series of these maps showing the location of wing dams in the upper Mississippi River.

The authors believe part of the increased rate of sedimentation in Lake Pepin is due to increased precipitation in the area and part due to structural modifications of river channels. These modifications include construction of levees along the Minnesota River and the Mississippi River and their tributaries, construction of wing dams and closing dams along the Mississippi River, deepening of the channel by dredging, and straightening of rivers to ease barge traffic.

All of these modifications eliminate river- floodplain interactions thus forcing additional river water and associated sediments to move downstream to Lake Pepin. Prior to these modifications some of the sediments likely settled in the floodplains. The overarching goal of this study was to summarize the information that PI and his associates have gathered from the U.S. Army Corps of Engineers (USACE) and the literature.

**Abstract**
The Minnesota River and its tributaries are the major source of sediments to Lake Pepin on the Mississippi River. Engstrom *et al*. (2009) showed that the current sedimentation rates in Lake Pepin are 10 times higher than the rates in 1830s and before.

These authors argue that increased rates are partially due to increased cultivation of the basin from 1830 to 1900 (when European immigrants came to this area) and then increased tile drainage thereafter. Gupta *et al*. (2011) have suggested an alternative hypothesis for some of the increased sedimentation rates in Lake Pepin.

For example, some of increased sedimentation rate in Lake Pepin may be due to increased precipitation in the area and some due to structural modifications of river channels. These structural modifications include construction of levees along the Minnesota and the Mississippi Rivers and their tributaries, construction of wing dams and closing dams along the Mississippi River, deepening of the channel by dredging, and straightening of rivers to ease barge traffic.

The end result of these modifications is eliminating river-floodplain interactions and thus forcing more water and associated sediments in the channel. This study surveyed the literature including old documents from Army Corps of Engineer; took two sets of flood plain cores to characterize radionuclide, total phosphorus (P) and heavy metals concentrations; compared old sonar data on Lake Pepin sedimentation with Engstrom's data; characterized Lake Pepin sediments for exchangeable ammonium, total P, and heavy metal concentrations; and completed work on identification of P sources in the basin.

There is lack of long term measurements on sediment budget and thus there is no consensus in the literature on the effects of river training structures on increased flow or sediment transport. A sediment budget study using historical records on sediment transport as well as what has been dredged in the past will be highly desirable.

Compared to the past sonar data, Engstrom *et al*. (2009) sedimentations rates looked reasonable, at least for the majority of Lake Pepin's area. Since sonar scans are cheaper, easier (than extracting sediment cores), and cover large areas quickly, efforts should be made to develop and standardize this technology for future characterization of sedimentation rates in Lake Pepin.

We found high exchangeable NH4 concentrations in Lake Pepin sediments which could be due to particle enrichment of bank materials as well as some adsorption from past river pollution. The bedload and suspended sediment analysis for various P fractions showed that the readily adsorbed particulate P leaving the Minnesota River Basin and depositing in Lake Pepin may be near the background P levels. The work on 1) radionuclide characterization to estimate sedimentation in floodplains and 2) sources of exchangeable NH4 in Lake Pepin, initiated under this project, is still continuing.

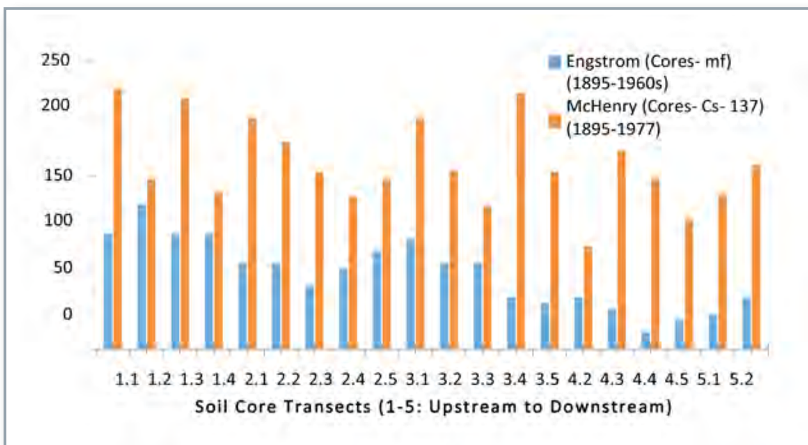



**Figure 2. Comparison of sedimentation (loss of water depth) in Lake Pepin between estimates for 1895-1977 from McHenry *et al.* and for 1895-1960s from Engstrom *et al.* at various soil core transects.**

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