2008
Combining Recent Innovations into Corn Production Systems
For
Higher Yields, Net Returns, Starch Energy and Lower Environmental Impact

Conducted by Arise Research and Discovery, Inc., Martinsville, IL
for Bi-En Corp., Portland Oregon
Supported by HMP Trust, Park Ridge, IL and Yara, Belle Plaine, Saskatchewan

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February 11, 2009

Working together for improved Yields, Net Returns, Starch Energy and the Environment

1. Stabl-U™

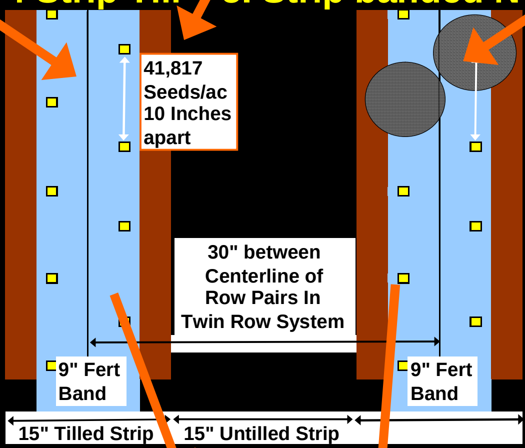
2. Twin Rows

3. HFC Hybrids

Microchip of LN in Stabl-U™ reduces N leaching of urea

Twin row's higher plant populations and banded nitrogen reduced N per thousand plants by 30%

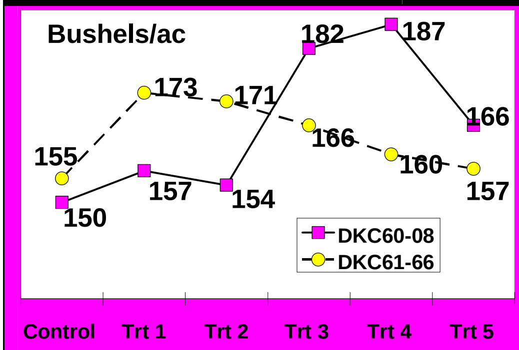
4 Strip Till 5. Strip banded N



Strip Till, strip banded Stabl-U plots had the highest average percent starch in the grain

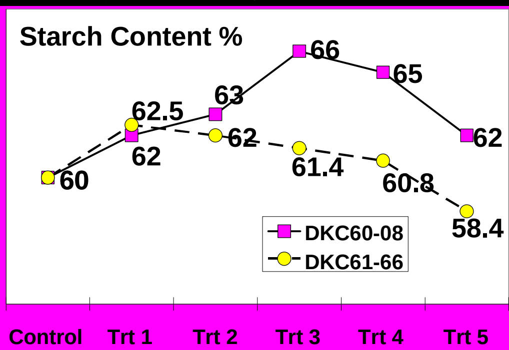
Imprints save water and reduce NO3-N up to 55% and erosion by 50 to 90%

6. TerraStar Soil Imprinting



Two roads diverged
in a wood, and I,
I took the one less
traveled by,
And that has made
all the difference.

Robert Frost



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Executive Summary

Compared to normal farming practices, this study's intensive management treatments boosted corn yields up to 21 percent, total starch and subsequent ethanol output per acre by up to 42 percent, net dollars per acre by up to 28 percent and reduced nitrous oxide (N2O) emissions by 16.7 percent. Under soil types and management systems used in this study, our results suggest that some current "normal" fertilizer, tillage and management practices may be limiting corn hybrids' abilities to express their increased starch producing potential for ethanol production. Compared to control plots with mulch tillage, broadcast urea and 35,000 plants per acre, the intensive management systems increased starch content of three hybrids by an average of 3 to 4.4 percentage points, with some differences being as high as 6 to 10 percentage points.

With an estimated 37 percent of the nation's 2015 projected corn crop being required for ethanol production, this study's treatments provide an important "look see" at how more fermentable starch can be produced from corn with less environmental impact. The innovative systems used in this study increased pounds of starch produced per pound of nitrogen applied by up to 70 percent. Net income per acre increased by up to \$97/ac, an increase of 28 percent.

Corn farmers are facing the dual pressures of trying to survive by profitably producing more renewable food, feed, fiber and fuel while improving the environmental impacts of their farming systems. The work reported here includes results from two studies which combined several recent innovations into different systems. The goals were to increase fermentable starch content for ethanol production, increase corn yield and economic sustainability for the farmer, and improve the environment.

The treatments included various combinations of:

1) Stabl-U™ (a new stabilized urea allowing more efficient nitrogen rates),
2) Twin Row planting with higher plant populations,
3) Three High Fermentable Corn (HFC) hybrids that produce more starch for ethanol,
4) Strip Tillage,
5) Strip banding of nitrogen, and
6) TerraStar Wheels for geometric ordered roughness (GOR) imprinting of soil.

Using strip banded Stabl-U turned out to be one of the most productive systems in this study. It increased starch content by as much as 10 percentage points compared to other individual HFC hybrids in the control systems. Compared to the control plots, total starch yield increased by up to 1,992 pounds per acre, which translates into an extra 151 gallons of ethanol per acre. The best system and hybrid in Treatment 3 also produced 32 more bushels per acre and had the highest per acre value to the farmer, increasing potential income by 28 percent compared to control plots.

Three treatments used 16.7% less nitrogen fertilizer than the controls but increased average treatment yields for the three hybrids by 11 to 20.7 bu/ac, while increasing nitrogen use efficiency by 23 to 27 percent. For individual hybrids, the ranges were greater, increasing yields by 0 to 32 bu/ac and increasing nitrogen use efficiency by 21 to 33 percent.

On an individual hybrid basis, the following observations can be made from this systems study for the 2008 growing season at Martinsville, IL:

- TerraStar imprinted plots yielded more than plots that were not imprinted.
- Stabl-U plots had equal or better yields than those with urea.
- For two hybrids, strip till banded Stabl-U yielded more than mulch till with broadcast nitrogen.
- $ returns/ac were better for 100 LbN/ac and 42,000 seeds plots than Control and high rate plots.
- For each hybrid, the treatment that produced its highest starch content also produced its highest yield.
- Tillage, nitrogen type and placement had a large effect on two of the three hybrids.

For treatments using mulch tillage, broadcast nitrogen, and soil imprints, one hybrid averaged 172 bu/ac with 62.3% starch, the other only 155 bu/ac with 62.5% starch. However, under strip tillage and strip banding of nitrogen the first hybrid's yield slipped to an average of 163 bu/ac (61.6% starch) while the second hybrid climbed to an average of 185 bu/ac (65.5% starch).

Reducing nitrogen from 120 pounds of N per acre to 100 pounds of N per acre also reduces potential for air and water pollution. Nitrous oxide (N2O) is a greenhouse gas that is estimated to be 300 times more potent on a per unit basis than CO_2. The Intergovernmental Panel on Climate Change (IPCC) calculates direct N2O emissions as 1.25 percent of total nitrogen applied. By this measure, the intensive systems used in this study would reduce N2O emissions by at least 16.7 percent.

Previous studies had independently shown Stabl-U and TerraStar soil imprints reduced nitrate concentration in tile water by as much as 65 percent and 55 percent, respectively, while producing equal or significantly better yields. Thus, while we did not measure tile water or soil water nitrate concentrations in this study, it made environmental and economic sense to include both of them as part of the treatments.

Sugar brix was measured from sap of the corn leaves using a hand held refractometer at tassel stage in July and at grain milk stage at the end of August. Brix readings are an indication of the amount of minerals and sugar in the sap. Increased sugar production by the leaves will hopefully translate into more starch "energy" in the grain that will produce more ethanol per bushel. Brix "energy" readings in corn leaves increased by 8 to 12 percent, providing an early indication of success during the growing season. Higher yields and starch content at harvest were also correlated to the higher sugar brix readings. The increased sugar brix may have added value in livestock feed, similar to higher prices that are paid for high brix hay and fruit. It may also be valuable to cellulosic ethanol processors. This may be an attribute that farmers could use in selecting hybrids.

Our work suggests that if the best performing hybrid was linked with the best management system on all 85 million corn acres in the U.S., we could easily supply all 15 billion gallons of ethanol allowed for credits by current law in 2015 and still have 2.8 times more corn available to eat than is currently consumed.

Key Words: Corn, Ethanol, Biofuels, Starch, Nitrogen, Fertilizer, TerraStar, Stabl-U, Brix, Hypoxia, Climate Change, Erosion, Livestock, Water Quality, Nitrous Oxide

"We will harness the sun and the winds and the soil to fuel our cars and run our factories."

Barrack Obama, President
Inaugural Address, January 20, 2009

"Based on the trend…* [of] *nitrogen application per bushel of corn produced, one possible outcome would be 0.6 pounds of nitrogen per bushel of corn produced in 2030 with continued increases in yield per acre." **Ross Korves 2008.**

Introduction:

At the start of this study in early 2008, the ethanol industry was the fastest growing segment in agriculture accounting for about 14% of corn acres. The Energy Independence and Security Act of 2007 effectively caps grain to ethanol conversion at 15 billion gallons per year in 2015, or roughly 37% of the nation's projected corn crop. To help meet the anticipated demand, ethanol plants are asking for Processor Preferred® High Fermentable Corn (HFC) through the Fuel Your Profits® Initiative. Some processors were beginning to pay a premium for HFC corn.

Arise Research and Discovery, Inc., an independent agricultural research company in Martinsville, Illinois, put together a multi-client project to examine products that will benefit or enhance the fermenting quality of multiple lines of High Fermentable Corn. Genetics of hybrids are known to be influenced by multiple soil and foliar applications. Information is desired by growers to examine various practices. Normally, farmers carefully study potential changes to their cropping systems and implement them one at a time. The original concept of Arise's project was to allow clients a "look see" under limited variables with only two reps per treatment at how their products might enhance starch content of the grain.

However, we asked Arise to use 16 variables in different combinations with three hybrids in a systems approach involving soil and water management equipment and practices, advanced planting techniques, and a new stabilized urea. All of these had been studied separately in previous university and independent trials with positive results:

1. **Stabl-U™** was selected because of its fast acting, but long lasting nature due to the unique incorporation of a small chip of lime nitrogen in the center of each urea granule during the manufacturing process. AAPFCO fertilizer regulations classify the chip as a nitrification inhibitor. Stabl-U had worked extremely well in very wet springs and reduced nitrate leaching 28 to 65 percent.
2. **Twin Row Planting** was selected for its ability to accurately space seed in an alternating pattern that increased the number of plants per acre and still allowed roots of each plant to explore twice as much soil volume than normal plant spacings, before competing with roots of its nearest neighbor.
3. **HFC Hybrids** High fermentable corn (HFC) hybrids were chosen for their propensity to produce higher than average amounts of fermentable starch which can be processed into ethanol and distillers dried grains and solubles by dry mill ethanol processors.
4. **Strip Tillage** could reduce soil compaction and erosion and reduce energy needed for tillage.
5. **Strip Banded Nitrogen** was used to put all of the nitrogen fertilizer within easy reach of plant roots.
6. **TerraStar Wheels** After the corn was planted, the TerraStar wheels would be used to imprint thousands of one-liter sized little reservoirs into the tilled strips to catch and infiltrate more rainfall. This would provide more water for the increased number of plants. The geometric ordered roughness (GOR) imprints had also shown ability to reduce soil erosion by 50 to 90 percent and reduce nitrate concentrations of nitrate in water reaching tile lines by up to 55 percent.
7. **Nitrogen Rates** Nitrogen rates were reduced by 20 LbN/ac from 120 to 100 LbN/ac in 3 treatments. University of Illinois research suggested that lower N rates were better for forcing corn plants to produce starch rather than protein. Secondly, air pollution studies suggested we could reduce nitrous oxide (N_2O) emissions by at least 16.7 percent by reducing nitrogen application by 16.7 percent.
8. **Plant Populations** We started the control at 35,000 plants per acre which is what a lot of farmers are using today. Twin rows allowed populations to be pushed to 41,817 and 59,740 plants per acre.

The following matrix correlates the Technology Numbers to the eight items discussed on page 5 and to the pictures in the graphic on page 2. It shows how the 16 variables and three hybrids were incorporated into the controls and five treatments.

		Technology Number	Control	Trt 1	Trt 2	Trt 3	Trt 4	Trt 5
Variable technologies								
N Fertilizer	Urea	1	Urea	Urea				Urea
	Stabl-U	1a			Stabl-U	Stab-U	Stabl-U	
Planter	Single	2	Single					
	Twin Row	2a		TwinR	TwinR	TwinR	TwinR	TwinR
HFC Hybrids Constant Technology		3	--- Three hybrids across all technologies ---					
Tillage	Strip	4				Strip	Strip	
	Mulch	4a	Mulch	Mulch	Mulch			Mulch
N Placement	Broadcast	5	Broad	Broad	Broad			Broad
	Strip Banded	5a				Sband	Sband	
Water Mgt	No Imprint	6	None					None
	Imprinting	6a		Imprint	Imprint	Imprint	Imprint	
N-Rate LbN/ac	120	7	120					
	100	7a		100	100	100		
	200	7b					200	200
Population	35,000	8	35,000					
	41,817	8a		41,817	41,817	41,817		
	59,740	8b					59,740	59,740

Acknowledgements: 2008 was the 9th year of field tests by Bi-En Corp. on its stabilized urea. The work reported here includes results from two studies the author helped Bi-En Corp design on systems approaches to increasing fermentable starch content of corn. The field work was conducted by Arise Research and Discovery, Inc. at Martinsville, IL in 2008. The studies were supported by Yara, Belle Plaine, Saskatchewan, and the H&M Porterfield Trust. Thanks to reviewers Richard Hartmann, Mark Jenner and Sharon Porterfield for their insights and suggestions for improving the text and structure of this paper.

Background

Outside economic pressures and public regulations influence what farmers produce and how they produce it. Corn farmers are facing the dual pressures of trying to survive by profitably producing more renewable food, feed, fiber and fuel while reducing the environmental impacts of their farming systems. Farmers must deal with specific issues of nitrogen and phosphorus leaving Midwest corn fields and producing hypoxia in the Gulf of Mexico. Along with fresh river water, N and P are considered the three main factors that drive the biologic systems of the Gulf's waters to use up oxygen. This creates zones of low or no oxygen in the shallow coastal waters making it particularly hard for bottom dwelling creatures to survive.[1] The 2008 EPA Scientific Advisory Board report on Hypoxia has recommended a 45% reduction in the amount of nitrogen delivered to the Gulf of Mexico by the Mississippi River.[2]

Air quality and climate change are driving increased demands for less polluting renewable energy sources, including ethanol produced from the starch contained in corn grain.[3] To help address this issue, seed companies have indicated some of their corn hybrids produce up to 7% extra starch which can increase ethanol production by up to 4 percent.[4 5 6] Some believe this should be worth an extra 5 to 15 cents per bushel when used to make ethanol.[7] Research at the University of Illinois suggests that grain extractable starch concentration can be maximized by using a continuous corn rotation with increased plant populations and avoiding over fertilization of N.[8] However, ethanol processors are finding that they cannot get a consistent supply of high total fermentable (HTF) starch corn that makes it worth their while to pay the farmer more for the grain.[9]

Public perception linking higher food prices to corn being used to make ethanol fuel is also a challenge. Renewable ethanol fuel, food for humans and feed for livestock all benefit from the starch energy that is contained in corn grain. Producing more corn energy from the same acres in an environmentally friendly fashion could lessen the pressures farmers face from both issues, but that requires change.

Our current situation has it roots in history. All green plants are solar collectors. They "mine" the sun for energy via photosynthesis and the soil for minerals, particularly nitrogen. Perennials ultimately mine all available topsoil for most of the 6 to 7 month frost free growing season. But annuals, such as corn often grown in rows spaced 30 inches apart, can only mine a portion of the topsoil for 3 to 4 months before they are harvested. Therefore, some plant foods can be lost via soil erosion, leaching to groundwater, volatilization and denitrification.

The advent of John Deere's steel plow allowed the perennial prairies in the Midwest to be broken up and annual grains (field corn, oats & wheat) to be produced. Initial yields from the rich prairie soils were excellent. Much of that went to feed horses which powered our farming and transportation needs. Later, a growing human population's demand for animal protein was met as annual grains provided the starch energy needed to grow livestock. However, the tilled soils were exposed to oxidation and wind and water erosion which removed valuable minerals and water holding capacity and yields declined. From 1904 to 1973, soil organic matter on the famed University of Illinois Morrow Plots declined 37% on plots grown in continuous corn without any fertilizer.[10]

The loss of minerals was overcome to some extent when low cost oil allowed cheaper mining of high analysis mineral fertilizers and the production of cheap nitrogen fertilizer from nature's atmosphere by combining it with then waste natural gas from oil drilling. In 1997, continuous corn that had never been fertilized at the Morrow Plots yielded only 54 bushels per acre, but the subplots treated with the "recommended" soil test level of fertilizer since 1955 jumped to 151 bushels per acre in continuous corn. Evidence accumulated at the Morrow Plots indicates that soil treatments create larger differences in corn yield than cropping sequences.[11] However, the replacement nutrients do not overcome the loss of water holding capacity. They simply mask that loss.

The miracle of mechanized agriculture allowed farmers to produce more corn and wheat for animal feed and human food energy. Aided by the Land Grant Universities' research and the Extension Service, farmers produced a surplus of corn, causing low prices. To deal with this, the U.S. government policy has shifted over time from storing surplus grain, to encouraging its export, to subsidizing production and use of renewable ethanol fuel to offset the high price of oil and the growing dependency of the U.S. on imported oil. By 2010, USDA expects fully 32 percent of the corn produced will provide starch energy to make renewable ethanol fuel.[12] The Energy Independence and Security Act of 2007 effectively caps grain to ethanol conversion at 15 billion gallons per year in 2015, or roughly 37% nation's projected corn crop.

However, a growing "industrialized world's" demand for oil caused speculators to swamp financial markets with investment money that drove oil prices to a new high of over $140 per barrel in 2008. Since the world runs on oil, prices of all goods including farm inputs and food increased. Suddenly, in 2007 and 2008 concerns were voiced that corn ethanol was the reason for increased food prices. Meanwhile, the dramatic down swing of the economy and financial markets in 2008 has caused some ethanol plants to file for bankruptcy. Even so, in his inaugural address President Obama promised, "We will harness the sun and the winds and the soil to fuel our cars and run our factories." With all that in mind, the intersection of higher input costs and public concern that ethanol use was increasing food prices and farming practices were causing environmental issues caused farmers to ask the question, "Can we do more with less?"

That question and the fact that all farmers use their own "systems" to produce their crops, led to other more specific questions:

1.) Can a new eco-safe fertilizer reduce nitrogen loss to the environment, and put more energy into plants and grain?
2.) Can precision seed placement technology allow plants to use strip banded fertilizer more efficiently than broadcast applications?
3.) Can tillage be managed to reduce wind and water erosion, and keep more moisture and nitrogen in the topsoil?
4.) Can new hybrids better express their fermentable starch potential if grown via various combinations of recently developed innovative management practices?

Normally, farmers carefully study potential changes to their cropping systems and implement them one at a time. However, recent innovations such as Stabl-U™ nitrogen fertilizer and TerraStar soil imprinting have shown substantial ability to increase corn yield and economic stability, while reducing nitrate leaching, runoff and soil erosion.[13] [14] They had not been tested together, nor had they been tested with other established practices like strip tillage, strip banded nitrogen and twin row planting. These also improve efficiency of nutrient use and reduce the chance of off site movement of valuable nitrogen and phosphorus into streams, lakes and the Gulf of Mexico.

University of Illinois research also suggests hybrids produce more starch when the previous crop was corn and when lower rates of N and higher seed populations are used.[15] That work spurred the idea of putting all six parts together as a systems study.

The objective of this study was to test the approach of putting recent, but typically isolated, management innovations together as systems to increase yields of corn and ethanol while reducing environmental exposure without compromising other Food/Feed/Fiber needs.

The Innovations

Many of the most innovative agricultural ideas take place in the minds of individuals who are singularly focused on their idea. Three ideas from such innovators were selected as keys to this system approach.

1. STABL-U™: We selected a new nitrogen source that had shown to be fast acting, but long lasting, and had ability to reduce nitrate leaching.[16] This was important because we also intended to increase rainfall infiltration via another soil management technique.

In the early 1900s, Lime Nitrogen (24-0-0-44%Ca) (LN) was known as a very good nitrate-N inhibition slow release fertilizer. It was a black dusty powder with a high pH that was nasty to work with. It was replaced by fast release, lower cost, high analysis urea (46-0-0) and anhydrous ammonia (82-0-0) as those products became more available in the mid-1900s. It took the mind of Richard Hartmann, who could speak and translate German research, and had spent his career working in the agricultural chemical and fertilizer industry, to visualize a radical innovation in urea production. His experience in product development, marketing and sales in the western U.S. led him to see the possibility of stabilizing the fast release action of urea with a small chip of Lime Nitrogen chemically bonded within the center of each urea granule.

10 X Cross Section view of a Stabl-U granule with the black LN chip inside.

His idea was patented in the U.S. as Stabl-U™ in 2003[17] and then in Europe and India. Its analysis is 46 percent nitrogen with trace amounts of calcium (46-0-0trCa). It is urea whose chemical properties have been changed by injecting a small black chip of Lime Nitrogen into the urea production process to act as the starter crystal to which the molten urea will attach and grow to the proper size granule. The crystal is a stabilizer material that acts as a nitrification inhibitor. While urea hydrolyzes quickly, the Stabl-U stabilizer inside urea granules moves it to the ammonium form which attaches to clay particles. Ammonium does not leach like nitrate and also allows the plant to expend less energy to convert it to useful plant tissue and grain.

Early field tests, starting in 2000, sponsored by the American Farm Bureau Federation's Watershed Heroes Conference indicated 28 to 65% reductions in nitrate-nitrogen in the soil and soil water while using substantially less nitrogen than university recommendations and still producing equal or better yields.[18]

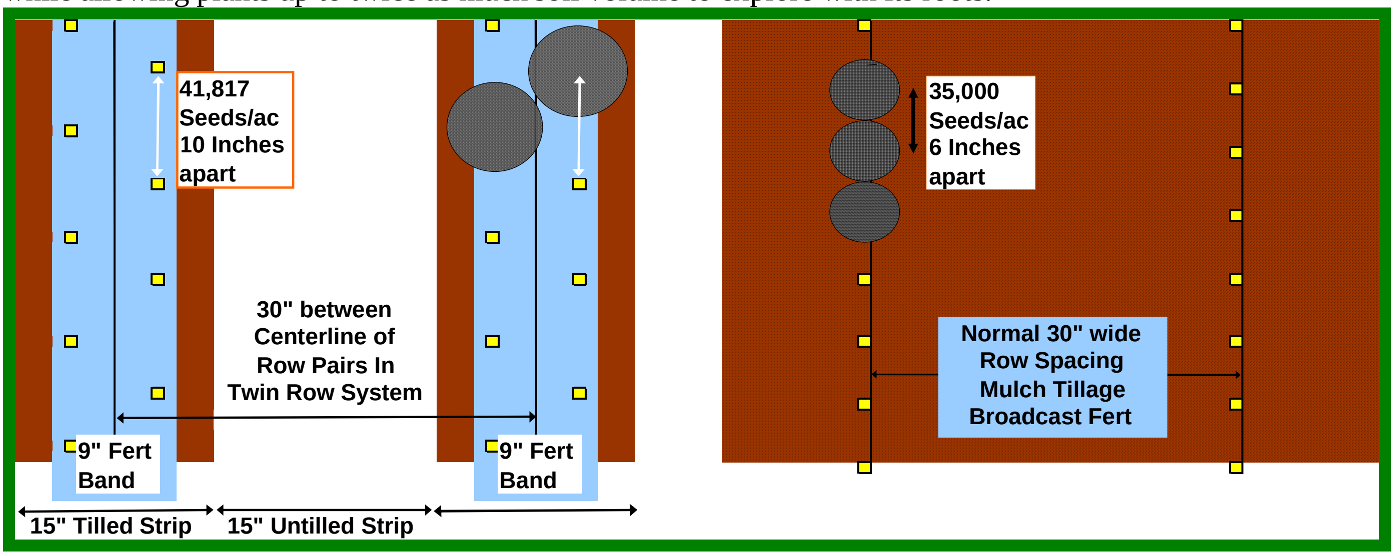
In 2000, 2001, 2004, and 2008, lab analysis of soil, water within the soil profile, tile water leaving the field and in-soil resin beads confirmed significant reductions in nitrate-N readings from Stabl-U vs. urea. In 2001, greenhouse tray studies confirmed increased early root production from Stabl-U vs. urea. In 2003, a field study suggested that Stabl-U functions like a starter fertilizer. A 512 plot Royster Clark field corn study in 2002 revealed average yield increases of 19, 19, 14 and 4 bushels per acre from Stabl-U from four different hybrids at seeding rates of 28,000, 36,000, 40,000 and 44,000 plants when compared with urea.

Studies done for Bi-En Corp in 2007 found increases in leaf chlorophyll of 6 to 24% and increased yields for corn fertilized with Stabl-U vs. UAN and anhydrous ammonia. That year's Stabl-U was produced by Saskferco (which has since been purchased by Yara) at their urea factory in Belle Plaine, Saskatchewan.

In 2008, the 9th year of field testing, leaf sugar brix readings were also collected and found to be 8 to 12% higher when Stabl-U was used, following the same trend as chlorophyll readings from 2007. A University of Illinois study at its Dixon Springs Experiment Station found ear leaf nitrogen was significantly higher with stabilized urea (2.13%) vs. urea (2.02%).[19] Also, research at the U of Illinois Agronomy Research Center near DeKalb, IL, found soil tests in plots fertilized with Stabl-U at 120 LbN/ac averaged 10.54 parts per million nitrate nitrogen or 16% less compared to 12.58 ppm NO_3-N for those fertilized with urea.[20] The Stabl-U used at Dixon Springs and DeKalb was six years old, having been produced by Royster Clark (now Rentech) in a small scale production test run at its granulated curtain urea factory in East Dubuque, Illinois.

2. TWIN ROWS: Studies by Pioneer Hi-Bred researchers suggest a yield decrease of 3.4 bu/ac for every inch increase in standard deviation of plant spacing.[21] Thinking about that issue, North Dakota farmer Tom Heimbuch was inspired by his college physics class to invent a seed metering and delivery system that moves seed backwards as fast as the planter moves forwards, thus creating zero relative velocity as the seed contacts the soil. The result is less seed bounce and therefore more uniform placement of the seed within the row. There are less skips (empty space between plants) and less doubles (two seeds dropped right next to each other). He also knew that placing plants too close together limited the area that a plant's roots could explore for water and nutrients without competing with a neighboring plant.

With more accurate seed placement, he could use pairs of rows spaced 7 inches apart with the centerline of the row pair spaced 30 inches apart and still achieve higher plant populations while allowing plants up to twice as much soil volume to explore with its roots.



Some of his early experiments increased the number of ears per acre, improved the uniformity of those ears and also increased the diameter of the corn stalk by about 0.25 inches. Increased cellulose in the stalks may be useful to the cellulosic ethanol industry.

3. TERRASTAR WHEEL: This new soil imprinting technology was used to improve rain water capture and reduce soil erosion. All crops, and especially high yielding crops, need at steady supply of water and nutrients. Soil erosion reduces the capacity of the soil to supply both these needs. Attempting to overcome these problems**,** American Robert Dixon invented a wheel that created small imprints in the soil, but being made of steel, the resulting compaction prevented the full effects of imprinting to be realized. A farmer in England improved on this idea with a foam polymer wheel that still created some compaction and left the soil somewhat loose.

Recently, the American company TerraManus Technology LLC developed a hollow polymer wheel of a successful shape and material which has made the concept of imprinting a practical and profitable concept capable of meeting existing USDA sustainable use standards.

Now called TerraStar, the wheel's geometric ordered roughness (GOR) imprints have proven to increase soil surface area by 30 percent. They increase the time before runoff occurs, allowing more water to infiltrate the soil laterally as well as downward. Work in Mexico[22] has shown dramatic increases in yields and up to 50 percent reduction in erosion. Studies at Martinsville, IL have shown surprising results of holding nitrogen in the upper foot of soil for longer periods of time and reducing the bulk density of the soil during the growing season.[23] Yields increased by 12 to 18 bu/ac and concentrations of nitrate in the tile water were reduced by 55%. Having evolved through extensive testing, TerraStar wheels were patented in 2008 and are commercially available starting in 2009.

Goals

Against this backdrop, it seemed logical to combine several of the innovations in an attempt to increase corn yield and starch content, reduce environmental impacts and increase the value of corn production.

The goals of these studies were to see if increasingly intensive "systems" of management using twin row planting, higher plant populations, geometric ordered roughness soil imprinting, a new stabilized urea (Stabl-U™), strip banding of nitrogen and strip tillage could:

1. increase corn yield and fermentable starch content of 3 high total fermentable starch corn hybrids,
2. increase net $ returns by using nitrogen and water more efficiently, and
3. increase sugar brix readings (a measure of plant energy) in the corn leaves.

Methodology and System Treatments

This study is not a typical research study. It is a "look see" study using only 2 reps per treatment instead of the normal 3 or 4 reps. It is not a randomized complete block study design. And, instead of the normal one or two variables, it uses up to six major innovations per treatment (actually 19 variables if you count the different rates of nitrogen, different seeding rates and the three hybrids.)

Plot Setup and Soil Characteristics

The previous crop was soybeans.
Two reps of each hybrid were used for each set of Controls A&B and the five treatments (6 plots/treatment).
Each plot was 10 feet wide by 40 feet long, consisting of 4 rows spaced 30-inches on center.
The soil was a Piasa Silty Clay Loam, 2% OM, pH 6.3, CEC 7.7 with high fertility.

Controls A&B-- Mulch Tillage, 35,000 seeds/ac, single 30" rows and broadcast urea 120 LbN.
These management practices are typical of some current normal farming practices that broadcast and incorporate urea. Urea nitrogen was applied at 120 LbN/ac.

Treatment 1-- Mulch Till, 42,000 seeds/ac, Twin Rows, broadcast urea 100 LbN, and GOR Imprinting. Studies by Pioneer Hi-Bred researchers suggest a yield decrease of 3.4 bu/ac for every inch increase in standard deviation of plant spacing. To minimize this problem, Treatment 1 used Twin Row planting (also used in Treatments 2, 3, 4, &5) to improve plant spacing and increase the volume of soil the roots could explore without competing with adjacent plants for water and nutrients. For our study, pairs of rows were spaced 7 inches apart. Seed spacing within each row was 10 inches. With seeds alternately offset from each other between the rows, ideally no seed should be closer than 8.6 inches (on the diagonal) to the closest seed in the other paired row. Roots of each plant should then have a circle with an area of 58 square inches to expand into without touching the roots of another plant. Plants in the control plots were spaced 6 inches apart and have a circle with an area of only 28.2 square inches to expand into before contacting the roots of an adjacent plant. With better plant spacing, we increased the number of seeds by 6,817 to 41,817 per acre.

The fertilizer rate was reduced by 16.7% from 120 to 100 LbN/acre. After planting, the entire soil surface was imprinted with small liter-sized depressions that would act like small ponds holding more rain in place and increasing infiltration laterally and downward. The mini-reservoirs also reduce erosion by lengthening the time before runoff begins to occur, as well as reducing the amount of runoff. The imprints were made with special resin wheels called TerraStars that consolidated the tilled soil, but did not cause compaction. The result of the imprinting process is called Geometric Ordered Roughness (GOR).

Treatment 2-- Mulch Till, 42,000 seeds/ac, Twin Rows, broadcast Stabl-U 100LbN, & GOR Imprinting
Since imprints would cause more water to infiltrate and percolate downward carrying soluble nitrate with it, we replaced Urea with Stabl-U™ (46-0-0trCa) in Treatment 2. Stabl-U is mostly urea whose chemical properties have been changed by injecting a small chip of Lime Nitrogen into the urea production process to act as the starter crystal to which the molten urea will attach and grow to the proper size granule. The crystal is a stabilizer material that acts as a nitrification inhibitor. While urea hydrolyzes quickly, the Stabl-U stabilizer inside urea granules moves it to the ammonium form which attaches to clay particles. Ammonium does not leach like nitrate and also allows the plant to expend less energy to convert it to useful plant tissue and grain. The idea was to combine the powers of Stabl-U and TerraStar wheels to reduce nitrate leaching and turn that nitrogen into increased yield and more efficient use of nitrogen fertilizer. Stabl-U was broadcast preplant and incorporated at 100 LbN/ac.

Treatment 3-- Strip Till, 42,000 seeds/ac, Twin Rows, banded Stabl-U 100 LbN &GOR Imprinting.
Treatment 3 builds upon Treatment 2 by adding a sixth component, namely, Strip Tillage, instead of full width tillage. The same total amount of Stabl-U as used in Treatment 2 (100lbN/ac) could then be banded in a 9-inch wide strip centered on the 15” wide tilled strip into which the twin rows were planted. This effectively makes more nitrogen available to the plant roots more quickly than if broadcast evenly over the entire field.

Treatment 4-- Strip Till, 60,000 seeds/ac, Twin Rows, banded Stabl-U 200 LbN, & GOR Imprinting.
To establish an extreme outer limit, we changed Treatment 4 to include strip banding of Stabl-U at 200 LbN/ac and used three TerraStar wheels to imprint the 15” tilled strip after planting. Treatments 4 and 5 decreased the plant spacing within each set of paired rows to 7 inches, which allowed a total of 59,740 seeds per acre to be planted. With more plants**,** we decided to keep the amount of nitrogen close to 3.4 LbN per thousand plants ratio used in the control plots

Treatment 5-- Mulch Till, 60,000 seeds/ac, Twins Rows, Broadcast Urea 200 LbN.
Treatment 5 was similar to the Control plots except for the Twin Rows and 71% more plants and proportionately more nitrogen. We did not use soil imprinting in this treatment.

Nitrogen, Tillage and TerraStar Treatments

Nitrogen fertilizers were applied preplant on May 19 and incorporated the same day. Plots were planted and TerraStar imprinted the next day on May 20.

Since the previous crop was soybeans, which could be credited for an additional 40 LbN/ac, we felt 120 LbN/ac was an appropriate amount of urea for the control plots.

Because University of Illinois research concluded that starch content increased with lower nitrogen rates, we reduced the rate of nitrogen applied by 16% down to 100 LbN/ac in treatments 1, 2, and 3. We also elected to bump the seeding rate to 60,000 plants per acre in Treatments 4 and 5, so we increased the rate of N applied to 200 LbN/ac which is roughly proportional to the increased number of plants. At 3.34 LbN per thousand plants, it is also very close to the 3.42 pounds of N applied per thousand plants in the Control plots.

Hybrids

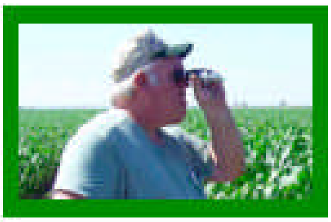
Plots were planted on May 20, using three DEKALB® hybrids. DKC60-08 RR is rated as Processor Preferred for High Fermentable Corn (HFC) for dry mill ethanol processors and also as HES, short for highly extractable starch preferred by wet mill corn processors. The other two varieties were DKC61-72 RR, and DKC61-66 RR, both listed only as HFC hybrids, best used by dry mill processors.

Planting Note

A Twin Row small plot planter of the type developed by Tom Heimbuch was not available at planting time. The researchers improvised and planted the Twin Row plots by hand using seed boards to achieve very accurate offset alternate spacing. 1"x 12" boards were drilled with two rows of holes with 7 inches between the rows. Within each row, the holes were spaced 10 inches apart for Treatments 1,2&3 and 7 inches apart for treatments 4&5, and offset in an alternating pattern from the other row of holes.

Leaf Sugar Brix Testing

The picture below demonstrates field use of a handheld refractometer to measure sugar brix levels. Leaf



sugar brix readings are an indication of the amount of minerals and sugar in the sap. Increased sugar production by the leaves will hopefully translate into more starch “energy” in the grain, and in turn, produce more ethanol per bushel. Stabl-U had produced higher chlorophyll readings and higher yields in a study sponsored by Bi-En Corp in 2007. We suspected that higher chlorophyll production also meant higher brix and starch content. In an attempt to confirm this, sugar brix was measured from sap of the corn leaves at tassel stage in July and at grain milk stage at the end of August. This was done by squeezing the leaves to produce a sap that could then be put into a hand-held refractometer for visual readings. Only Control A and Treatments 1 and 2 were tested.

Starch Testing

Harvested grain samples were dried to 15% moisture content, weighed and run through a soil grinder with new cutting dies to make a fine powder. The powder was sieved through a fine screen mesh to eliminate hulls and debris. The dry weight of the remaining powder was considered to be the fermentable starch.

RESULTS AND DISCUSSION

Rainfall

Rainfall	Inches
May	6.0
June	17.1
July	6.9
Aug	0.2
Sept	2.5

The test location was drenched with 13 inches of rainfall the first week of June. Rainfall totaled 17.1 inches for the month of June and nearly 7 inches in July. Root systems stayed small as a result. Leaching of nitrate in the urea fertilized plots was evident by their yields being lower than those fertilized with Stabl-U. With all the moisture in the soil, plots did not need to be irrigated even though there was virtually no rainfall during August.

Harvest: Results Averaged by Treatment

Corn was harvested on October 16th. Moisture content ranged from 26 to 30% due to late planting and a wet fall. Yields and economic results are in Table 1 and Fig 1.

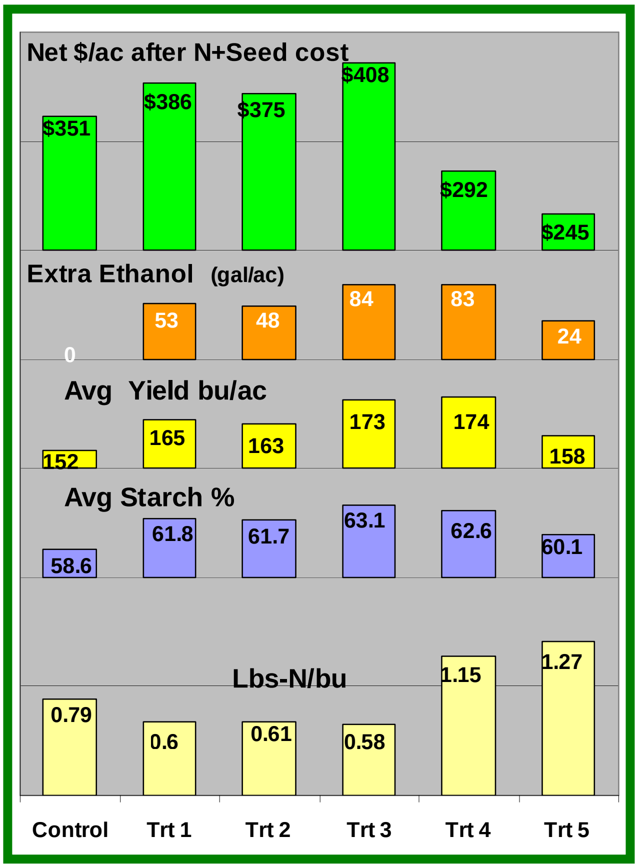
TABLE 1 Averages by Treatment for 3 HFC Hybrids

Treatment	Controls	Treat. 1	Treat. 2	Treat. 3	Treat. 4	Treat. 5
Seeds/ac	35,000	41,817	41,817	41,817	59,740	59,740
Lb-N/ac	120	100	100	100	200	200
Fert	Urea	Urea	Stabl-U	Stabl-U	Stabl-U	Urea
N Application	Broadcast	Broadcast	Broadcast	9" Band	9" Band	Broadcast
Tillage	Mulch Till	Mulch Till	Mulch Till	Strip Till	Strip Till	Mulch Till
Row Type	Single Row	Twin Row	Twin Row	Twin Row	Twin Row	Twin Row
Soil Imprinting		TerraStar	TerraStar	TerraStar	TerraStar	
Avg bu/ac	**152.0**	**164.7**	**163.0**	**172.7**	**174.0**	**157.7**
Avg % Starch	**58.67**	**61.83**	**61.67**	**63.13**	**62.60**	**60.13**
Starch Lb/ac *	**4,994**	**5,703**	**5,630**	**6,105**	**6,100**	**5309**
Extra Starch $/ac $0.02/%point/bu		**$10.43**	**$9.78**	**$15.42**	**$13.69**	**$4.62**
Ethanol gal/ac *	**378**	**431**	**426**	**462**	**461**	**402**
Avg. Brix %	45 - 48.8	50.5 - 54.3	49.1 - 52.8			
Net $/ac after N & Seed Cost *	**$351**	**$386**	**$375**	**$408**	**$292**	**$245**
Average LbN/bu	**0.79**	**0.61**	**0.61**	**0.58**	**1.15**	**1.27**

* Means are averages of two reps. Controls are averages of four reps. Corn @$3.50/bu, Urea @ $0.60/LbN, Stabl-N Stabilizer @ $0.0543/LbN Seed Cost assumed to be $250 for 80,000 seeds.
Starch Lb/ac = bu/ac x 56 lb/bu x % starch. Ethanol gal/ac = Starch Lb/ac x 0.5 lb Ethanol/Lb Starch divided by 6.61 LbE/gal.

Averaged across all three hybrids, all treatment yields were higher than the control. Treatments 1-3 with only 100 LbN/ac produced an average of $24 to $57/ac advantage over the Control. However, Treatments 4&5 with the 200LbN/ac and 60,000 plants/ac produced a large economic disadvantage.

Fig 1 Averages by Treatment for 3 Hybrids



By increasing the seed count by 6,817 seeds from 35,000 to 41,817 seeds per acre and using Twin Rows, broadcast nitrogen and the TerraStar soil imprinter, the average yield in Treatments 1 and 2 were nearly equal for Urea and Stabl-U, but still increased an average of 12 bu/ac compared to the Controls. This finding was consistent with results from a Royster Clark study at the same location in 2002 which found yield increases from Stabl-U were substantial at corn plant populations of less than 40,000 plants per acre, but yields were nearly even between urea and Stabl-U when the populations reached 44,000 per acre.[24]

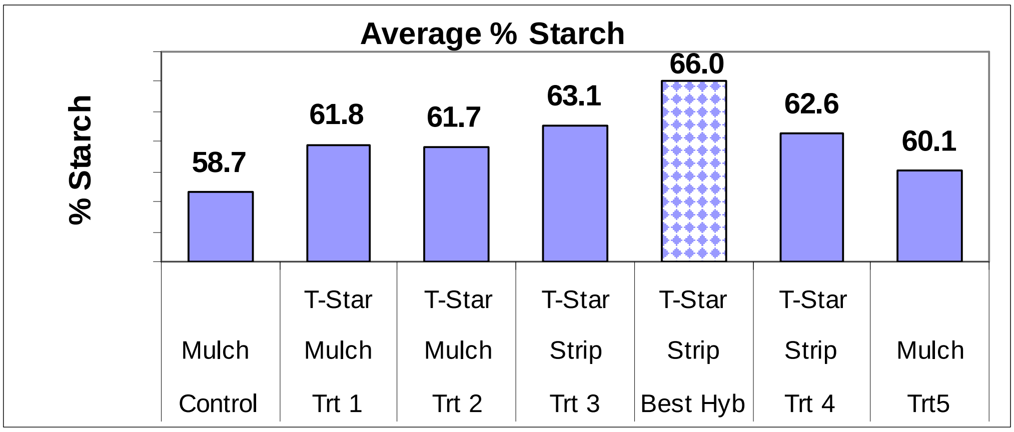
Starch content for Treatments 1 and 2 also increased an average of about 3 percentage points, Fig 1. Both of these increases occurred despite reducing nitrogen use to 100 LbN/ac (a 16.7% reduction from the 120 Lb/ac used in the Controls.) Two possible reasons for the starch content increase include more plants competing for less nitrogen and TerraStar imprints providing more soil moisture and nutrients during grain fill in August. There may also have been some response to the "microwells" of biological activity taking place within the bottom of the moister imprints.

Going one step further in Treatment 3 by concentrating the 100 LbN/ac of Stabl-U into a 9-inch wide band centered within each 15 inch wide tilled strip, the Twin Rows produced another jump of 8.9 bu/ac and an additional 1.4 percentage points increase in starch, on the average. Treatment 3 averaged 173 bu/ac and had an average starch content of 63.1%. The concentration of the nitrogen into the band would be equivalent to having broadcast nitrogen over the entire plot at a rate of 333 LbN/ac. The 200 Lbs N per acre rate concentrated in the 9 inch wide strip in Treatment 4 would be the equivalent of broadcasting nitrogen at a rate of 666 LbN/ac. That may have been too much nitrogen and may have actually retarded grain production even though it provided only 3.34 LbN per thousand plants. That rate is similar to the 3.42 LbN per thousand plants which was broadcast evenly at a rate of 120 LbN/ac in the Control plots.

Lack of TerraStar soil imprints in Treatment 5, which also used broadcast urea and mulch till, decreased yields by 16 bu/ac compared to Treatment 4. That is within the 12 to 18 bu/ac differences noted in studies from previous years where the TerraStar imprints were the only variable in a "normal" treatment with single rows, broadcast N and 32, 000 plants per acre.

Starch Content

Fig 2. Starch Content Averages for 3 Hybrids by Treatment.



As a point of reference, we have added the result from Hybrid DK60-08 in treatment 3 (diamond bar "Best Hyb" in Figs.2- 4) It had the highest starch content of all the plots in the study at 66% starch, outdistancing the control average by 7.33 percentage points.

On average, Treatments 3 and 4 with strip banded Stabl-U produced higher percent starch content in the grain than any of the mulch till, broadcast nitrogen treatments. They averaged 62.85 percent starch or more than one full percentage point better than the closest mulch tillage broadcast nitrogen plots in Treatment 1. Treatment 5 and the Controls where urea was broadcast and soil was not imprinted with TerraStar wheels had the lowest percent starch contents. It appears this could be due to one or more of several factors. The broadcast nitrogen had more chances to leach before the plant roots could reach it. Also, there may have been less water available in the soil in August due lack of soil imprints to capture July rains. A flatter soil surface is also more likely to crust over after heavy rains and seal off moisture and air penetration.

Corn Production and Use USDA Estimate			
.	----------	Millions	----------
Year	2006	2010	2015
Corn Production	10,535	13,727	15,758
Food & Non-eth Industrial	1,354	1,519	1,761
Exports	2,100	2,100	2,100
Feed and Residual	5,875	5,600	5,350
Corn for Ethanol	2,190	4,508	6,547
Calculations based on USDA estimates			
Ethanol Gal.	6,023	12,397	18,004
Starch for Ethanol Lb	79,617	163,888	238,016
Wt of Corn for Ethanol Lb	122,640	252,448	366,632
% Starch in Corn	64.9%	64.9%	64.9%
Estimates based on Intensive Management Systems			
Yield X 21% Increase bu		16,610	19,067
Starch x 35% Increase Lb		673,422	773,060
Tot Wt Corn Lb		930,142	1,067,762
% Starch		72.4%	72.4%
Ethanol possible gal		50,940	58,477
Max Eth with credits gal		15,000	15,000
Left over for other uses bu		11,719	14,176
All other Corn Uses bu		9,219	9,211
Extra Left over for Food and Non Industrial Uses bu		2,500	4,965

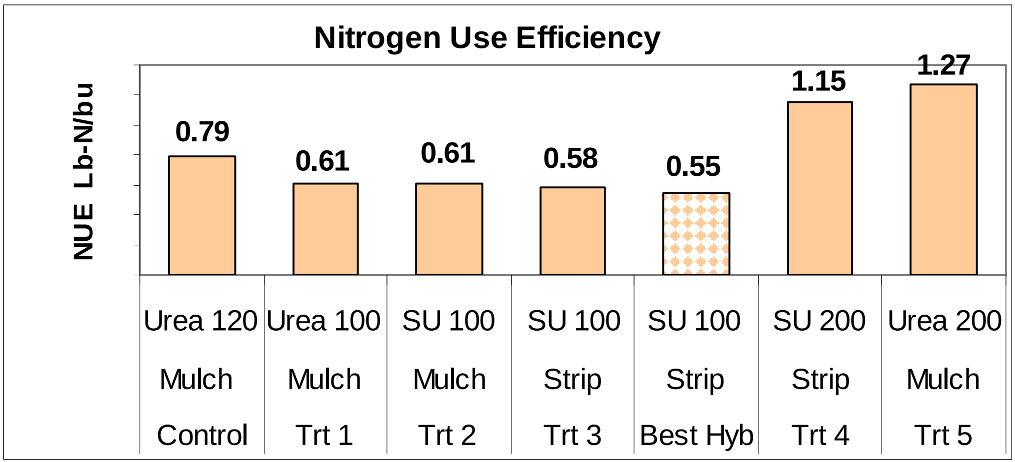
Starch energy is important to all categories of uses that USDA reports in its annual projections of corn production and use. Food and Non-Industrial uses are projected to account for 1,519 million bushels of corn in the year 2010 and 1,761 million bushels in 2015. Besides the 6,547 million bushels estimated for ethanol use, all other uses for corn, including Food, are projected to consume 9,211 million bushels in 2015. Assuming all 85 million acres of corn were to adapt new production systems and get results similar to our study, we could produce enough corn to process 15 billion gallons of ethanol, cover the 9,211 million bushels of other corn use needs and still have an extra 4,965 million bushels left for food and non-industrial needs. That extra corn would be 2.8 times more food than the 1,761 million bushels that USDA projects we will eat in 2015.

Nitrogen Use Efficiency

The current measure of nitrogen use efficiency is the national 5-year running average of about 0.94 pounds of commercial nitrogen applied per bushel of corn produced. Korves (2008) notes in his paper for the Illinois Corn Marketing Board that if the current trend of innovations and increasing yield were to continue over the long term, one possible outcome would be a nitrogen use efficiency of 0.6 pounds of nitrogen per bushel of corn produced in 2030.[25]

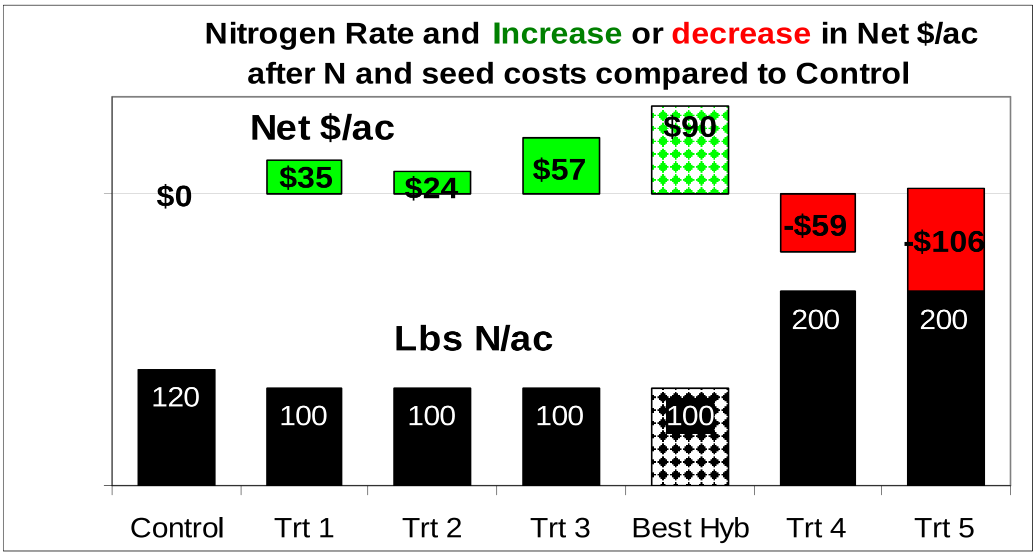
In our study, the average nitrogen use efficiency for Treatment 3 was 0.58 LbN/bu, (Table 1 and Fig 3). This suggests that farmers in the Martinsville, IL area who are planting corn after soybeans in soil types similar to this study could probably produce corn more efficiently than Korves' suggested 0.60 LbN/bu mark as early as 2009, if they used the right hybrid, twin row planting, 42,000 seeds/acre, strip tillage, Stabl-U fertilizer, nitrogen banding and TerraStar soil imprinting.

Fig 3. NUE Averages for 3 Hybrids by Treatment



Another way to look at nitrogen application rates in Fig 4 is that for the 100 LbN/ac rate there was a net gain of $1.20 to $4.50 per acre for every pound of N that was not applied compared to the 120 LbN rate used on the controls. On the other hand, the plots with the 200 LbN/ac rate lost an average of $0.73 to $1.32 per acre for each of the 80 additional LbN applied compared to the controls.

Fig 4. Net $/ac Averages for 3 Hybrids by Treatment



Increased nitrogen and seeding rates added a total of $121/ac to the costs for both Trt 4 and 5. Treatment 4's five bu/ac increase over the "Best Hyb" was not enough to offset the additional N and seed costs. Without imprinting's water management, yield losses in Trt 5 caused additional reductions in $ returns.

Environmental Improvements

Nitrogen use efficiency is an indirect measure of environment improvement. Reducing nitrogen from 120 pounds of N per acre to 100 pounds of N per acre also reduces potential for air and water pollution, especially when it is used more efficiently to produce more grain, as indicated by our results.

Nitrous oxide (N_2O) is a greenhouse gas that is estimated to be 300 times more potent on a per unit basis than CO_2. The Intergovernmental Panel on Climate Change (IPCC) currently assumes direct N_2O emissions as 1.25 percent of total nitrogen applied. By this measure alone, the intensive systems that used only 100 lbs N/ac in this study would reduce N_2O emissions by at least 16.7 percent compared to the 120 lbs N/ac used in the control plots.

While we did not measure water quality in runoff or leachate, it would have been a tremendous year to do so considering the deluges that hit in the first week of June within 12 to 19 days after fertilizer application. Arise's chief researcher noted that of the 15 products that were tested as part of their multi-client study, our yields and yield increases were the highest of all those tested. All of the other products were tested at the 120 LbN/ac rate. The nitrification inhibitor effect of Stabl-U seems to last about 28 days, so it should have helped considerably in preventing nitrate leaching to groundwater. Studies in two previous wet springs at this test location and during one very wet spring in Texas showed 28 to 65 percent reductions in concentrations of nitrate in soil water and tile water. This would suggest that Stabl-U would also reduce N_2O emissions more than an equivalent rate of urea, making it an area that is ripe for future investigation.

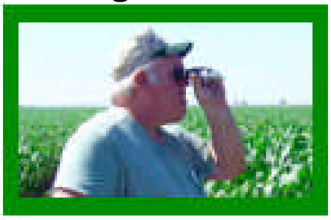
SUMMARY for 100 LbN/ac Treatment Averages vs. Control Average

Factor	Range of Increases Due to Systems Approach	% Increases
Corn Yield Increase	11 to 21 bu/ac	7 to 14%
Starch Increase	3.02 to 4.46 % pts	5 to 7.6%
Fermentable Starch Energy/acre Increase (Bu/ac x 56 Lb/bu x % Starch)	636 to 1,111 lbs	12 to 22%
Increase in Net$/ac after N and seed costs	$24 to $57/ac	8 to 16%
Increase in Nitrogen Use Efficiency (Less Environmental Exposure To Applied N/Unit Of Production)	0.18 to 0.21 LbN/bu	23 to 27%
Increase in Total Starch per Lb N applied	14.7 to 19.5 Lb starch/LbN	35 to 47%

Results by Hybrid

The responses of individual hybrids to the various treatment systems varied to a larger degree and are likely to be of more interest to farmers than treatment averages.

Leaf Sugar Brix Testing

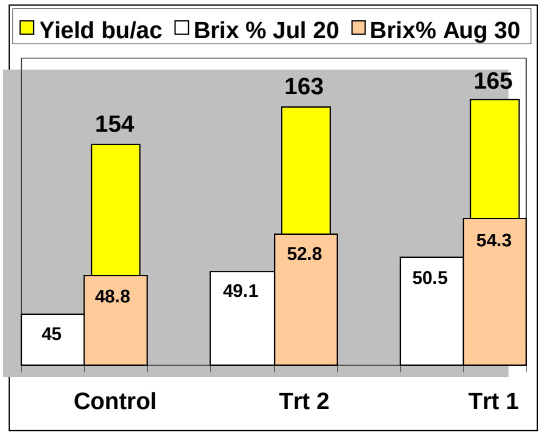


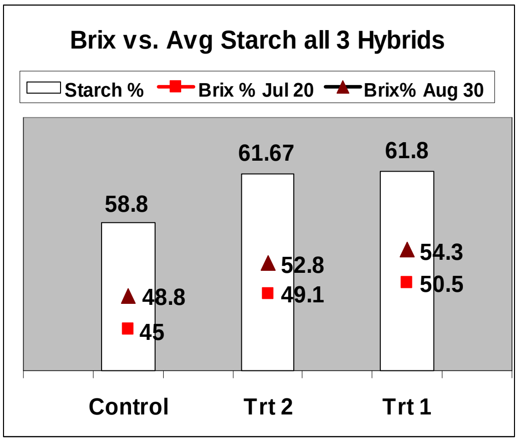
To get an early idea and document whether the treatments were having an effect, we took sugar brix readings of the sap of the leaves of the corn plants at tassel on June 20 and at grain milk stage on August 30. Brix “energy” readings in corn leaves in treatments 1&2 increased by 8 to 12% compared to those in the controls. This provided an indication during the growing season that the intensified treatments were going to successfully increase the number of bushels/ac, as well as starch content of the grain itself. Results are in Table 2.

Table 2	Control A	Control B	Treat. 1	Treat. 2
Seeds/ac	35,000	35,000	41,817	41,817
Lb-N/ac	120	120	100	100
Fert	Urea	Urea	Urea	Stabl-U
N Application	Broadcast	Broadcast	Broadcast	Broadcast
Tillage	Mulch Till	Mulch Till	Mulch Till	Mulch Till
Row Type	Single Row	Single Row	Twin Row	Twin Row
Soil Imprinting			TerraStar	TerraStar
	Brix %		Brix %	Brix %
Sample Date	7/20 - 8/30		7/20 - 8/30	7/20 - 8/30
DK60-08	44.5 - 47		50.5 - 56	50.5 - 53
DK61-72	47.5 - 51		50.5 - 54	50.5 - 54
DK61-66	43 - 48.5		50.5 - 53	46.5 - 51.5
Avg. Brix %	45 - 48.8		50.5 - 54.3	49.1 - 52.8
% Increase vs Controls	--- - ----		12% - 11%	10% - 8%

The increased sugar brix may also have added value in grain and silage for livestock feed. From the corn farmer’s perspective, hopefully this could allow development of a payment system that would command slightly higher prices similar to the way higher prices are paid for high brix hay and fruit.

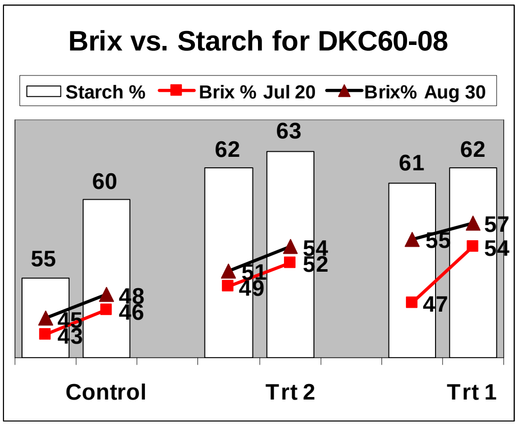
The series of charts on the following page indicate that higher yields and starch content at harvest were also correlated to the higher sugar brix readings.



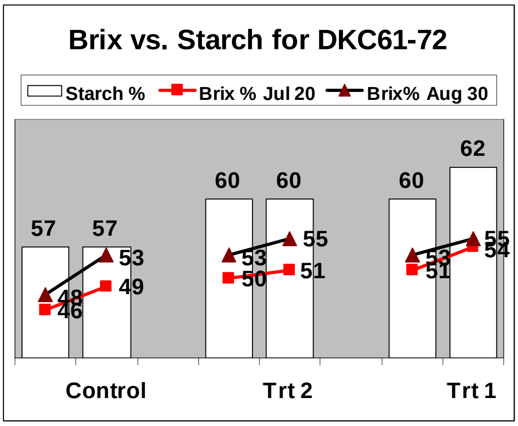


Trt 1 is shown last on this series of charts only because it allowed average yields and average sugar brix to be displayed in rank order from lowest to highest.

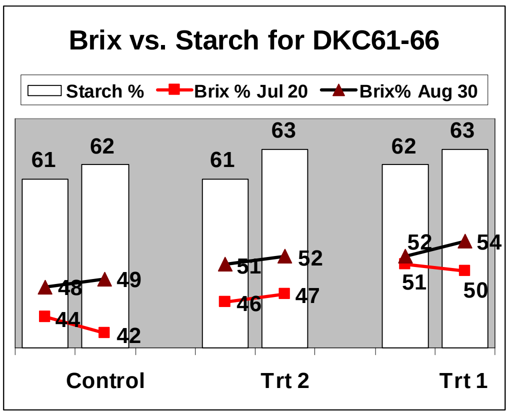
On average, across the three hybrids, higher brix readings in both July and late August predicted higher grain yield and higher starch content in the kernels.



However, the ability of brix readings to predict higher starch readings varied amongst hybrids. For hybrid DCK60-08, the higher brix reading in each of the two plots in each treatment on both July 20 and August 30 indicated which plot's grain would have the higher starch content at harvest.



For the DKC61-72 hybrid, two of the treatments had the same starch content and only in Treatment 1 with the urea did the higher brix reading also predict higher starch content. However, higher average brix readings did predict higher average starch contents of the treatments.



For hybrid DKC61-66, higher brix readings in July were not a good predictor of which plot within a treatment would have higher starch at harvest. On the other hand, the highest brix reading of each pair on Aug 30 did accurately predict which plot would have the higher starch content.

TABLE 3 Results by Hybrid

Treatment	Control	Treat. 1	Treat. 2	Treat. 3	Treat. 4	Treat. 5
Seeds/ac	35,000	41,817	41,817	41,817	59,740	59,740
Lb-N/ac	120	100	100	100	200	200
Fert	Urea	Urea	Stabl-U	Stabl-U	Stabl-U	Urea
N Application	Broadcast	Broadcast	Broadcast	9" Band	9" Band	Broadcast
Tillage	Mulch Till	Mulch Till	Mulch Till	Strip Till	Strip Till	Mulch Till
Row Type	Single Row	Twin Row	Twin Row	Twin Row	Twin Row	Twin Row
Soil Imprinting		TerraStar	TerraStar	TerraStar	TerraStar	
Hybrid/Yield	**Bu/ac**	**Bu/ac**	**Bu/ac**	**Bu/ac**	**Bu/ac**	**Bu/ac**
DKC60-08	150	156.6	153.6	182	187	166
DKC61-72	151	164.7	164.5	170	175	150
DKC61-66	155	172.8	171	166	160	157
Net $/ac after N & Seed Cost	**$/ac**	**$/ac**	**$/ac**	**$/ac**	**$/ac**	**$/ac**
DKC60-08	$344	$357	$341	$441	$337	$274
DKC61-72	$347	$386	$380	$399	$295	$218
DKC61-66	$361	$414	$402	$385	$242	$243
Starch Lb/ac	**lb/ac**	**lb/ac**	**lb/ac**	**lb/ac**	**lb/ac**	**lb/ac**
DKC60-08	5,040	5,437	5,419	6,727	6,807	5,764
DKC61-72	4,735	5,626	5,527	5,902	6,076	5,040
DKC61-66	5,208	6,048	5,937	5,708	5,448	5,135
Ethanol gal/ac	**gal/ac**	**gal/ac**	**gal/ac**	**gal/ac**	**gal/ac**	**gal/ac**
DKC60-08	381	411	410	509	515	436
DKC61-72	358	426	418	446	460	381
DKC61-66	394	457	449	432	412	388
% Starch	**% starch**	**% starch**	**% starch**	**% starch**	**% starch**	**% starch**
DKC60-08	60	62	63	66	65	62
DKC61-72	56	61	60	62	62	60
DKC61-66	60	62.5	62	61.4	60.8	58.4
Lb Starch/Ln N						
DKC60-08	42	54	54	67	34	29
DKC61-72	39	56	55	59	30	25
DKC61-66	43	60	59	57	27	26
% increase in Pounds Starch per LbN vs DKC61-72 Control						
DKC60-08	6%	38%	37%	70%	-14%	-27%
DKC61-72	0%	43%	40%	50%	-23%	-36%
DKC61-66	10%	53%	50%	45%	-31%	-35%
NUE	**LbN/bu**	**LbN/bu**	**LbN/bu**	**LbN/bu**	**LbN/bu**	**LbN/bu**
DKC60-08	0.82	0.64	0.65	0.55	1.07	1.20
DKC61-72	0.79	0.61	0.61	0.59	1.14	1.33
DKC61-66	0.75	0.58	0.58	0.60	1.25	1.27

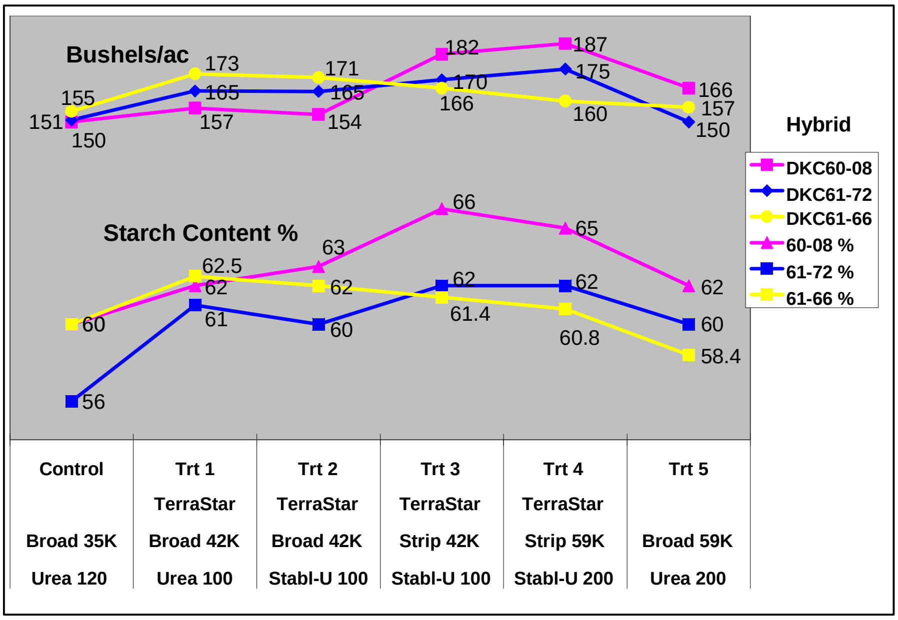
Here is where our changing multiple parts of the system seemed to be most informative.
Table 3 shows that the best combination in this study appeared to be hybrid DKC60-08 with banded Stabl-U in Treatment 3 which was the most intensively managed of the three 100 LbN/ac treatments. Compared to its own average of 150 bu/ac when grown in control plots, it increased yield by 32 bu/ac, increased starch by 6 percentage points and increased the value per acre (after subtracting costs of Nitrogen and seed) by $97 per acre, ($441 vs. an average of $344 for its controls). The Control average for the DKC61-72 hybrid was only 56% starch, a full 10 percentage points behind DKC60-08's best production of 66 % in Treatment 3.

Treatment 5 and the Controls where urea was broadcast and soil was not imprinted with TerraStar wheels had the lowest percent starch contents for each hybrid. It appears this could be due to several factors. One reason might be that broadcast nitrogen had more chances to leach before the plant roots could reach it, as previous studies have shown. Also, there may have been less water available in the soil in August due lack of soil imprints to capture July rains. A flatter soil surface is also more likely to crust over after heavy rains and seal off moisture and air penetration.

On an individual hybrid basis, the following observations can be made from this systems study for the 2008 growing season at Martinsville, IL:

- TerraStar imprinted plots yielded more than plots that were not imprinted.
- Stabl-U plots had equal or better yields than those with urea.
- For two hybrids, strip till banded Stabl-U yielded more than mulch till with broadcast nitrogen.
- $ returns/ac were better for 100 lbN/ac and 42,000 seeds plots than Control and high rate plots.
- For each hybrid, the treatment that produced its highest starch content also produced its highest yield.

Fig 5. Hybrid Response for Yield and Starch Content



Tillage, nitrogen type and placement had considerable effect on two of the hybrids

Fig 5, on the left, indicates tillage, nitrogen type and placement had noticeable effects on the performance of two hybrids in particular. The DK60-08 hybrid distinguished itself within Trt 3 and Trt 4 by producing the highest yields at 182 and 187 bu/ac and the highest percentage of starch at 66 and 65 percent. It had the highest starch content in four of the five treatments. It seemed to thrive on the strip banded Stabl-U, but had the lowest yields of all at 157 and 154 bu/ac with the 100LbN broadcast rates.

Hybrid 61-66 (yellow lines) yielded best with the broadcast 100 LbN rate in Trt 1 and 2. Its performance dropped off considerably for both yield and starch content when subjected to strip banded nitrogen and very high plant populations.

Fig 6.

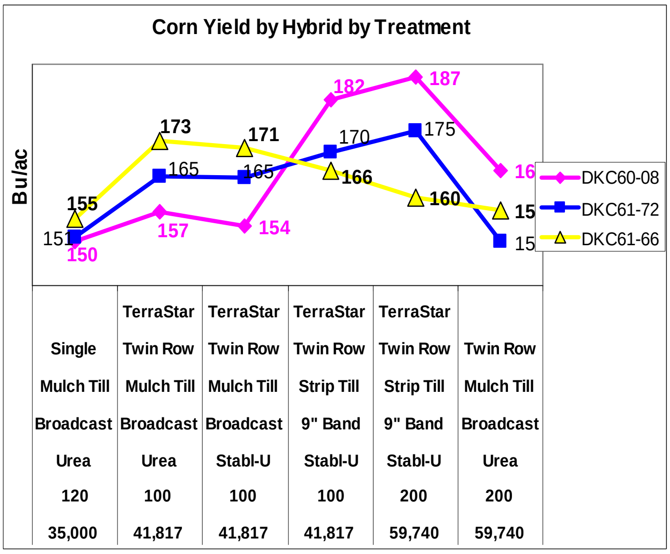
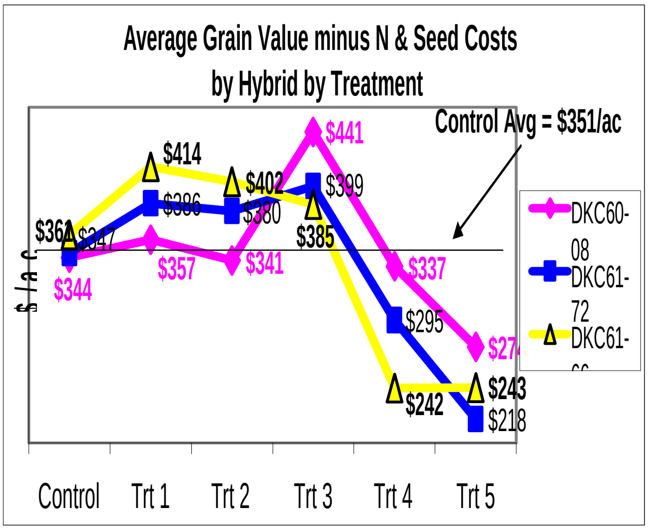


Fig 7.



The message from Fig 6 and Fig 7 is clear: Don't assume all hybrids perform equally well under all management systems.

The only real difference between Treatment 2 and Treatment 3 was the type of tillage and the placement of the Stabl-U. Fig 7 shows that with the DK60-08 hybrid a farmer would have lost money using Treatment 2 just on seed and fertilizer compared to the controls. But tweaking the system to strip tillage and placing a 9 inch band of Stabl-U in the center of the twin rows provided an extra $90 per acre compared to the control average with corn at $3.50/bu. Cash is king today. With 1,000 acres of corn in similar soil types and weather, the DK60-08 hybrid in Treatment 3 would have improved income enough to pay for a decent 12-

row twin row planter in the first year. None of the other hybrids or treatment combinations were able to do that. Had the early growing season been not so stressful, it might have been a different story for some of the other treatments.

Fig 8.

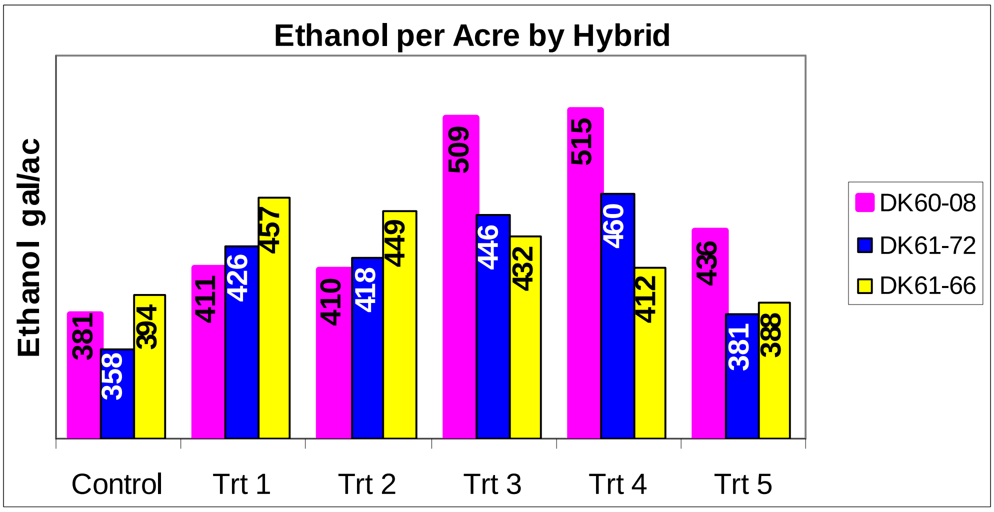


Fig 8 estimates the amount of ethanol produced per acre from the three hybrids under the different treatments. Again, DK61-66 (yellow bars) shows up the best under mulch tillage and broadcast nitrogen. But DK60-08 and DK66-72 increased the potential for ethanol production substantially with strip tillage and strip banded Stabl-U.

In this particular year, even though Treatment 4 had 42 percent more plants, it barely edged out Treatment 3 in terms of corn grain yield and potential ethanol yield. It may be that with the equivalent of 666 LbN/ac concentrated in the 9-inch strip, it was just too much nitrogen for the plants to handle and/or there were just too many plants crowded together. Again, this poses additional questions for research on N rates, nitrogen placement and plant populations.

SUMMARY Hybrid Responses for 100 LbN/ac Treatments vs. lowest hybrid in Controls

Factor	Range of Increases Due to Systems Approach	% Increases
Corn Yield Increase	0 to 32 bu/ac	0 to 21%
Starch Increase	2.4 to 10 % pts	4 to 18%
Fermentable Starch Energy/acre Increase (Bu/ac x 56 Lb/bu x % Starch)	648 to 1,992 lbs	14 to 42%
Increase in Net$/ac after N and seed costs	-$3 to $97/ac	-1 to 28%
Increase in Nitrogen Use Efficiency (Less Environmental Exposure To Applied N/Unit Of Production)	0.17 to 0.27 LbN/bu	21 to 33%
Increase in Total Starch per Lb N applied	15 to 28 Lb starch/LbN	38 to 70%

Conclusions

Our results indicate it is possible for intensive management practices to increase fermentable starch content for ethanol production, increase corn yield and economic sustainability for the farmer, and improve the environment. However, it remains to be seen if ethanol processors will ever pay farmers an incentive for growing corn with elevated starch levels.

On the flip side of the coin, our results raise a red flag and suggest that some current "normal" fertilizer, tillage and management practices may be limiting corn hybrids' abilities to express their increased starch producing potential for ethanol production. Compared to control plots with mulch tillage, broadcast urea and 35,000 plants per acre, the intensive management systems we used increased starch content of three hybrids by an average of 3 to 4.4 percentage points, with some differences being as high as 6 to 10 percentage points.

On an individual hybrid basis, the following observations can be made from this systems study for the 2008 growing season at Martinsville, IL:

- TerraStar imprinted plots yielded more than plots that were not imprinted.
- Stabl-U plots had equal or better yields than those with urea.
- For two hybrids, strip till banded Stabl-U yielded more than mulch till with broadcast nitrogen.
- $ returns/ac were better for 100 lbN/ac and 42,000 seeds plots than Control and high rate plots.
- For each hybrid, the treatment that produced its highest starch content also produced its highest yield.
- Tillage, nitrogen type and placement had considerable effect on two of the hybrids.

Even if a farmer had to pay an extra $20 per acre, the greater output and additional $100/acre return might make the adoption of new planting, tillage and fertilizer practices worthwhile. When the additional environmental benefits are included, that change is even more compelling. However, changing six to eight items within their cropping systems all at once will require a total change in farmers' mindsets and management skills. That can only be accomplished with education and some kind of guarantee or insurance that the risk of change is minimal.

The most intensive treatments using 200 lbN/ac and 59,000 seeds acre did not fare well, especially the broadcast urea plot that was not imprinted with the TerraStar wheel. This may be an indication of 1) going past the point of diminishing returns, 2) too much nitrogen in a concentrated band, or 3) it may be case of a very wet spring putting too much stress on a high density planting.

We have literally opened Pandora 's Box for research. There are hundreds of hybrids and more than a dozen new nitrogen fertilizers and nitrogen stabilizers that are recently available or on the verge of becoming available. Farmers will be interested in knowing which products and practices work best with their soil types and climate conditions. One question we did not attempt to answer was whether strip banded nitrogen could work equally as well with mulch till and TerraStar imprints as it did with strip tillage. If it does, that would save buying special strip tillage equipment as part of the transition to the next generation of management practices. Also, further studies need to be done to determine the optimum N rates and seeding rates for these systems.

Also, based on field plots done in 2004[26] in Texas, attention needs to be paid to various blends of the new enhanced efficiency nitrogen fertilizers as they have numerous modes of action and rates of nitrogen release.

Leaf sugar brix "energy" readings could possibly be an early indication of system success during the growing season. Increases in starch content of the grain and increased brix levels in the leaves may also have implications for feed and silage rations for livestock, and for the cellulosic ethanol industry.

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http://www.agrigold.com/index.cfm?pageId=41

[5] "Pioneer has 69 varieties of what it calls high total fermentable corn. Its data shows an ethanol yield variance of 7 percent among different varieties. The industry standard is 2.5 to 2.7 gallons of ethanol per bushel."
"Pioneer said their HTF hybrids increase ethanol yield by up to 4 percent." Waterloo Cedar Falls Courier. January 31, 2005.
http://www.wcfcourier.com/articles/2005/01/31/news/metro/710a72243feeebbd86256f9a0051c068.txt

[6] "Monsanto has launched its Processor Preferred program, seeking to market its brand of more highly fermentable corn to farmers, which the company said increases ethanol yield by up to 4 percent."

"But in more established ethanol markets west of Illinois, farmers are already receiving premiums of 5 cents to 10 cents per bushel." Rob Elliott, marketing manager for the Monsanto program.
http://mywebtimes.com/archives/ottawa/display.php?id=267931

[7] "The highly extractable starch (HES) market is a result of corn wet millers trying to get the most value from their grind. Corn hybrids have been identified that more starch can be extracted from…. Premiums paid for HES corn ranges from $.05-$.15 per bushel."
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