WHAT'S NEW WITH ENHANCED EFFICIENCY NITROGEN FERTILIZERS: CLIMBING NEW MOUNTAINS TO SEE WHAT'S POSSIBLE

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ABSTRACT

Positive indications from a relatively small body of indicator plot work over six years suggest that a wide variety of nearly a dozen new nitrogen fertilizers, and blends thereof, need to be more fully evaluated at three levels: 1) in the lab for leaching potential, 2) in the field with nitrogen rate studies looking at yield, economics and environmental impact, and 3) at the small watershed level. National average rates of commercial nitrogen application have declined from a 5-year running average of 1.31 lb-N per bushel of corn produced in 1984 to 0.95 lb-N/bu in 2005. New enhanced efficiency fertilizers along with a systems approach of new equipment, management techniques and new corn hybrids could continue to increase the efficiency of nitrogen use towards a national average of 0.7 lb-N/bu of corn grown within the next decade. Nearly a dozen new nitrogen fertilizer products have been developed over the past 6 years and have just become or are on the verge of being commercially available:

• Ammonium Sulfate	Calcium Thiosulfate
• ESN Smart Nitrogen	Nitamin™
• Sazolene	Nurea™
• Stabl-U™	Sulfur Enhanced Fertilizer
• VitAg	WonderGreen®

Because these new products have different chemistries and modes of action, several were blended for first-time-ever-in-the-world indicator plots in 2004. Indications of interactions with different hybrids and soil types are also discussed.

INTRODUCTION

Between 2000 and 2006 at least 10 companies have proceeded with development of new nitrogen fertilizers that can be broadly classified as Enhanced Efficiency Fertilizers (EEFs). One of these (ESN) was commercialized in 2006 and targeted for agricultural use and the others are nearing commercialization for agricultural use. These new EEFs offer some of the most exciting advances in fertilizer since the introduction of anhydrous ammonia and urea. Each has a totally different

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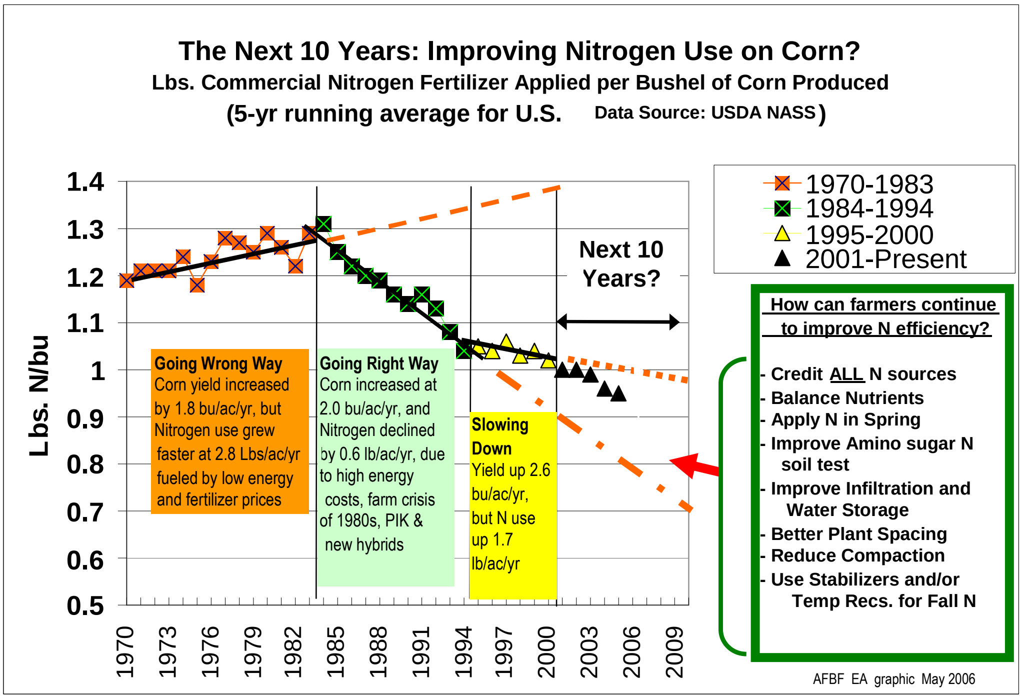
mode of action, and may react differently with different soil types. Most of our work was done with Stabl-U™ as it was the first one we became aware of in 1999 and were able to purchase a bench scale run of 50 pounds to test.
Our goal was to look at corn yield, economics and water quality.



While the hypoxia issue in the northern Gulf of Mexico drove the conversation about nitrogen fertilizer and water quality in the 1990's, most people failed to recognize the steady improvement in nitrogen efficiency that had occurred in corn fields across the U.S starting in 1983, which coincided with the government's payment-in-kind (PIK) program. Nitrogen use efficiency on a 5-year running average dropped from an all-time high of 1.31 lb-N/bu of commercial nitrogen applied in 1984 to 1.04 lb-N/bu by 1994, a stunning 20 percent improvement in efficiency.

Since 1994, the number of pounds of nitrogen needed to produce a bushel of corn has continued to decline, but at slower rate than during the decade from 1984-1994. The 160.4 bu/ac national average record corn crop of 2004 produced a one-year nitrogen efficiency rating of 0.84 lb-N/bu, which indicates that we are still on the right track.

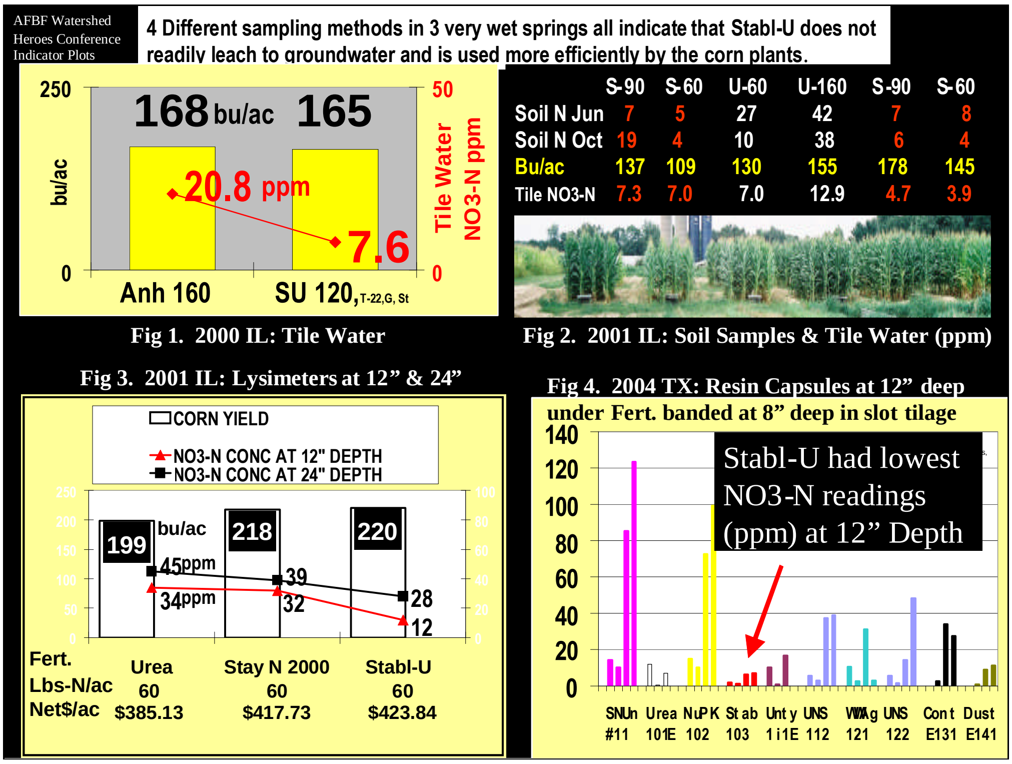
Have we reached the point of diminishing returns or can we continue to improve efficiency of use and reach a national N-use efficiency number of 0.70 lb-N/bu as projected by extending the 1984-1994 trend line out to the year 2010? **If you look closely at the limited data we have on hand from the newer controlled release fertilizers that are under development and/or commercialization, add**

in management systems mentioned in the sidebar above and factor in the next round of genetic improvements that are in the pipeline for corn, <u>the answer is yes, nitrogen use efficiencies can still improve dramatically.</u>

WATER QUALITY RESULTS

<u>Summary of Groundwater Quality Work</u>

Over 3 wet springs and 4 different measurement techniques in Watershed Heroes Conference plots, Stabl-U™ consistently reduced concentrations of NO_3-N leaching to groundwater and was used more efficiently by the corn plants, (Porterfield, 2000-2004). In each case, the previous year's crop was corn, so that makes the yield response to the lower rates of Stabl-U™ even more impressive.



Figures 1-4. Summary of Water Quality Indicators

<u>Figure 1. Martinsville, IL, 2000, First Look</u>. Our first indicator plot compared anhydrous ammonia at 160 lb-N/ac vs. Stabl-U at 120 lb-N/ac. Research by Randall in Minnesota suggests a 5 to 7 ppm decrease in nitrate-nitrogen concentration in tile drainage water for a 40 lb-N/ac reduction in nitrogen fertilizer. However, we got nearly the same yield with 25 percent less N applied and got twice as big a decrease in NO_3-N concentration in tile water than expected. This seemed to indicate that further testing was warranted.

Fig 2. Martinsville, IL, 2001, Containment Bays. After a very wet spring in 2001 at Martinsville, IL, urea and Stabl-U™ were broadcast and incorporated June 12, and corn was planted June 13. Soil samples were taken from the top 7 inches on June 27 and October 3. Plots were in containment bays with one tile line at 30 inches deep under the center of each bay. There was only one rep per treatment.

The soil tests found very little nitrate in the topsoil of the plots fertilized with 60 and 90 lb-N/ac of Stabl-U in either June or October. However, in June, nitrate levels in the soil tests in the plots treated with 60 and 160 lb-N/ac of urea were 3 to 8 times higher respectively than in any of the Stabl-U plots. The plot with 160 lb-N/ac of urea had nearly as much nitrate in the soil test in October as it did in June, even though the average concentration measured in its tile water was about 2 to 3 times higher than any of the other plots. What was most interesting was that the immediately adjacent plot with only about half as much nitrogen (90 lb-N/ac) applied as Stabl-U grew 178 bu /ac or 15 percent more corn than the urea plot which produced only 155 bu/ac. Assuming $2.00/bu for corn, urea at $200 per ton or $0.22/lb of N, and Stabl-U™ at $294 per ton or $0.32/lb of N, the advantage for using about half as much of the more expensive Stabl-U was $52 per acre. It sounded too good to be true, and results were suspect because it was only one plot versus one plot. However, as can be seen from Fig. 3, Stabl-U's yield advantage of 21 bu/ac was almost the same magnitude when it went head to head with urea in a randomized complete block design field plot trial with 4 reps per treatment. Since we took 100 lb-N/ac of urea out of the trials in Fig 3, the end result was that Stabl-U's profit advantage slipped to only $38 per acre over urea.

Fig. 3. Martinsville, IL, 2001, Yield Plots. Another set of field plots with 4 reps per treatment was also planted in Martinsville, IL, in 2001. We compared Urea, Urea with Stay N 2000 and Stabl-U™. Each plot received 60 lb-N/ac of the main fertilizer plus another 27 lb-N/ac from DAP for a total of 87 lb-N/ac.
Stabl-U™ yielded 10% more corn than urea and had 37% to 65% lower concentrations of nitrate in the water collected in the lysimeter tubes. NO_3-N concentrations in the soil water were also 28 to 62% lower than those under the plots treated with Stay N 2000. At that point, we felt like we may be looking a rare win-win situation of a new fertilizer that was used much more efficiently, produced higher yields with less fertilizer, was more profitable per acre by an amount that should make most farmers sit up and take notice, and was leaching substantially less nitrate to groundwater.

Fig 4. Waco, TX, 2004, Deep Banding and Blends.   Our next question was, could we make nitrogen use even more efficient by blending one or more of these new fertilizers to take advantage of their different modes of action? After a wet spring in 2004 near Waco, Texas, we banded fertilizers 8 inches deep into slots that had been chiseled 14 inches deep in late summer of 2003. The fertilizer was applied March 20 and the corn was planted into the same slots on March 22. All fertilizer rates shown are 100 lb-N/ac. We used four different fertilizers– Urea, NureaNPK, Stabl-U™, and Unity NS Plus and two blends thereof (UNS = 1/3 of N from urea, 1/3 from NureaNPK and 1/3 from Stabl-U; SNUn= 1/3 of N from Stabl-U, 1/3 from NureaNPK and 1/3 from Unity NS Plus.) WWAg = UNS blend + WaterWorks Crystals, Dust= UNS Blend + Enliven Mineral dust at 500 lb/ac. Control = 5 gal /acre of starter fertilizer and no other fertilizer. One PVC access tube was installed to a depth of 12 inches right under a fertilizer band in each of the 10 plots. Resin capsules were inserted into the tube and then replaced weekly and adsorbed NO_3-N and 13 other nutrient ions on a cumulative basis. 5.25 inches of rain fell during the middle of the 3rd sampling week and 4.0” of rain fell during the middle of the 4th week (April 29- May 6) and moved NO_3-N and nutrients past the 12-inch depth. The capsule under the Stabl-U plot recorded only 6 to 7 ppm NO_3-N from the big rains while capsules in all other plots recorded 2 to 20 times higher NO_3-N concentrations.

YIELDS AND ECONOMICS AND NITROGEN USE EFFICIENCIES

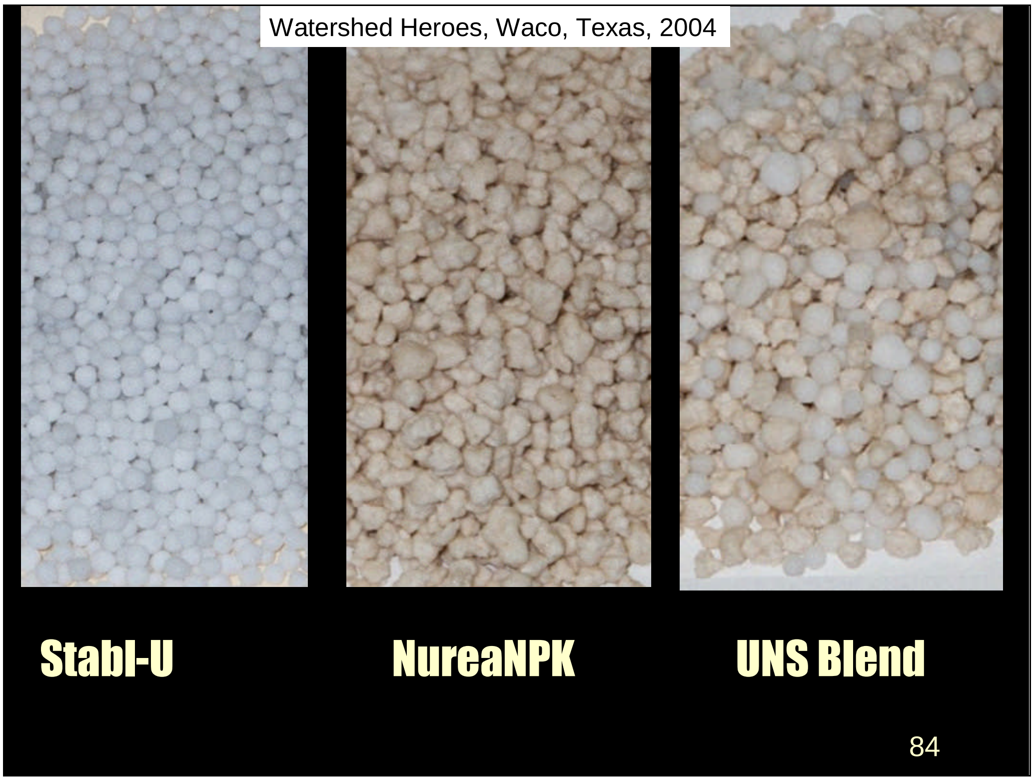


Figure 5. Two new N fertilizers and a Blend

Figure 5 shows the smooth, round, very evenly sized Stabl-U granules, the angular, blocky uneven granules of NureaNPK and a blend of Urea, NureaNPK and Stabl-U.

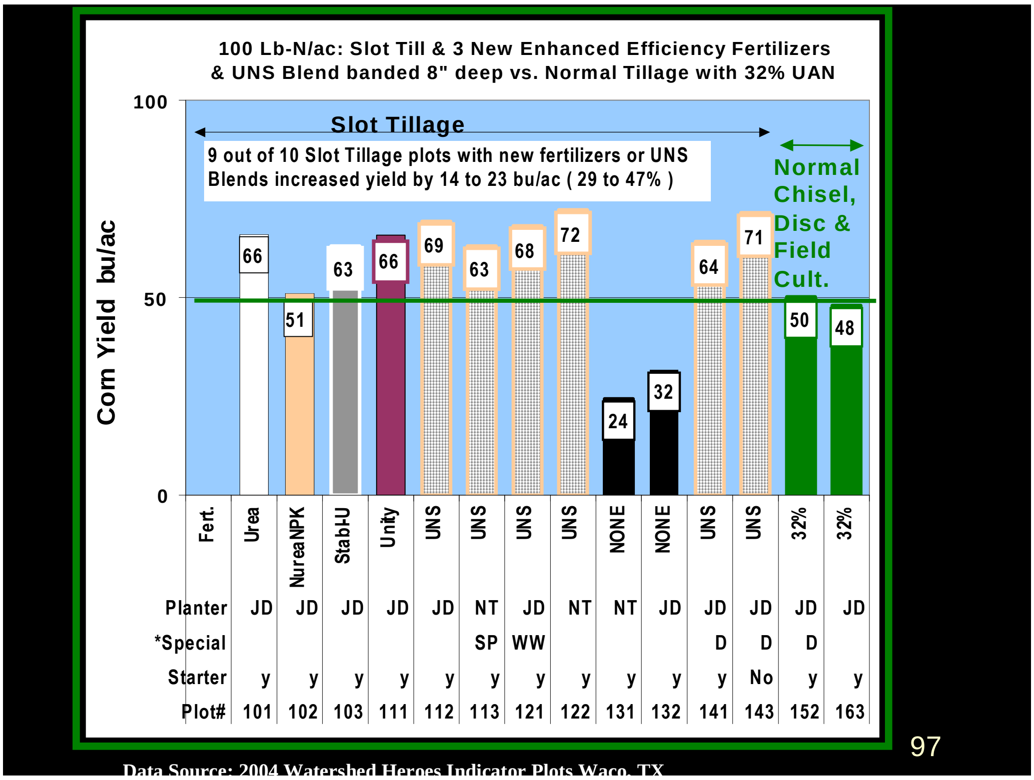


Figure 6. Single N Sources vs. Blends

Bars in Figure 6 with diamond-shading show corn yields for plots where the UNS blend (Urea, NureaNPK, and Stabl-U) was banded 8 inches deep in a slot tillage system and corn was planted directly over the slot. Each bar represents a single "indicator" plot. In order to make it easier for the farmer to use his normal 12-row planter, the plots were not randomized or replicated.

Because of a wet spring, the corn in these plots near Waco, Texas, was about two weeks late getting planted. That, coupled with a dry summer, really reduced the yield from the 90 to 120 bu/ac yields which are more common for that area of the state. The blends generally yielded slightly better than any of the fertilizers did individually. It is probably worth continuing to test blends as energy prices and fertilizer prices continue to rise.

Soil Type vs. Fertilizer Type

A set of information collected at Saunemin, IL in 2002, suggests that soil type may make a big difference in fertilizer performance of Stabl-U™. Stabl-U™ was broadcast on top of soil after planting, but before emergence, and was not incorporated as it probably should have been. GPS yield maps were overlaid with soil survey maps and yield data was extracted from each strip by soil type. In the silty clay loam soils, Stabl-U™ yielded 8 to12 bu/ac more than it did on silt loam soils. Sidedressed 32% UAN was just the opposite; it yielded 6 to 7 bu/ac better on silt loam soils than on silty clay loam soils.

Differences by Hybrid and Plant Population

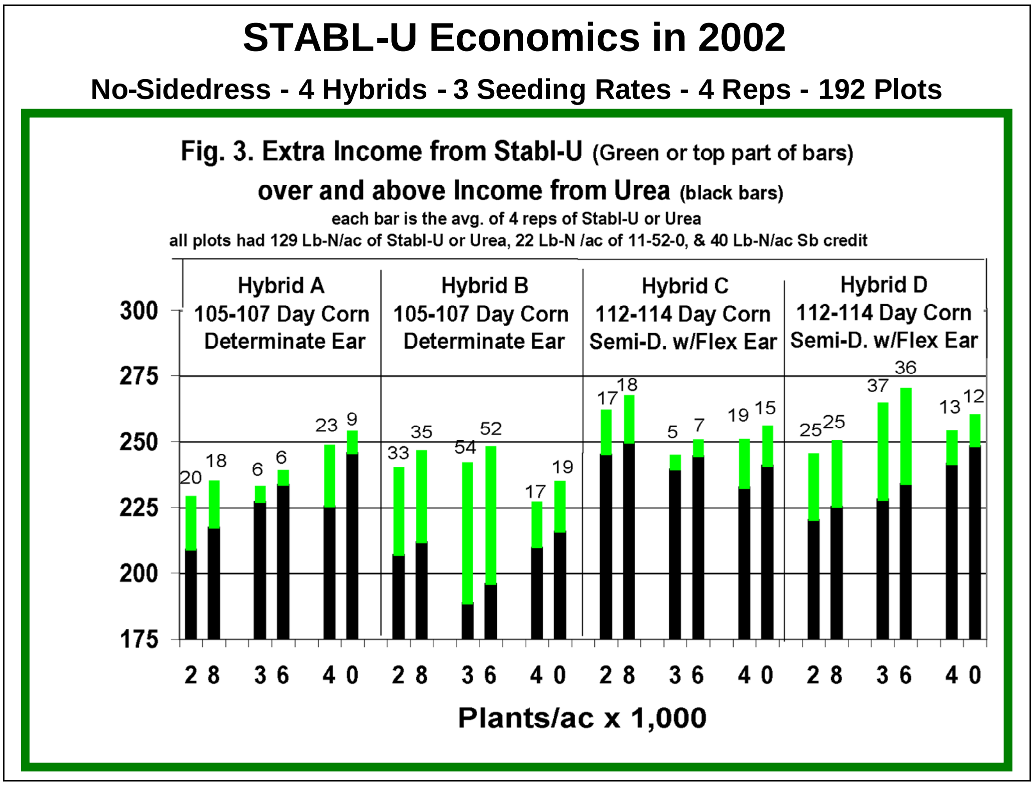


Figure 7. Hybrids and Plant Populations

Data Source: Royster Clark 2002. It is clear that different hybrids react differently to various seeding rates and to urea versus Stabl-U™.

Fall vs. Spring Application of Stabl-U

Watershed Heroes Conference plots near St. Peter, MN in 2003 showed only a 3 to 6 bushel per acre advantage for spring applied Stabl-U vs. fall application. However, a small rate study done at the University of Illinois in 2004 had a 50 to 75 bu/ac reduction in corn yield for both fall applied urea and Stabl-U™. The key to this may be that the soils in Minnesota were cold when the nitrogen fertilizer was spread and disced in—indeed, the ground froze up within a day or two after application. In Illinois, it was applied earlier in the fall when soil temperatures were higher and the winter was open and milder than Minnesota's. Stabl-U's stabilizing effect seems to last about 28 days, but it will dissolve in water nearly as rapidly as urea. From this information, it would appear that fall application would not be a recommended practice for either urea or Stabl-U™ in any area of the Corn Belt.

Nitrogen Use Efficiencies

Using less N just to say we used less is not the goal; using N much more efficiently is the goal.

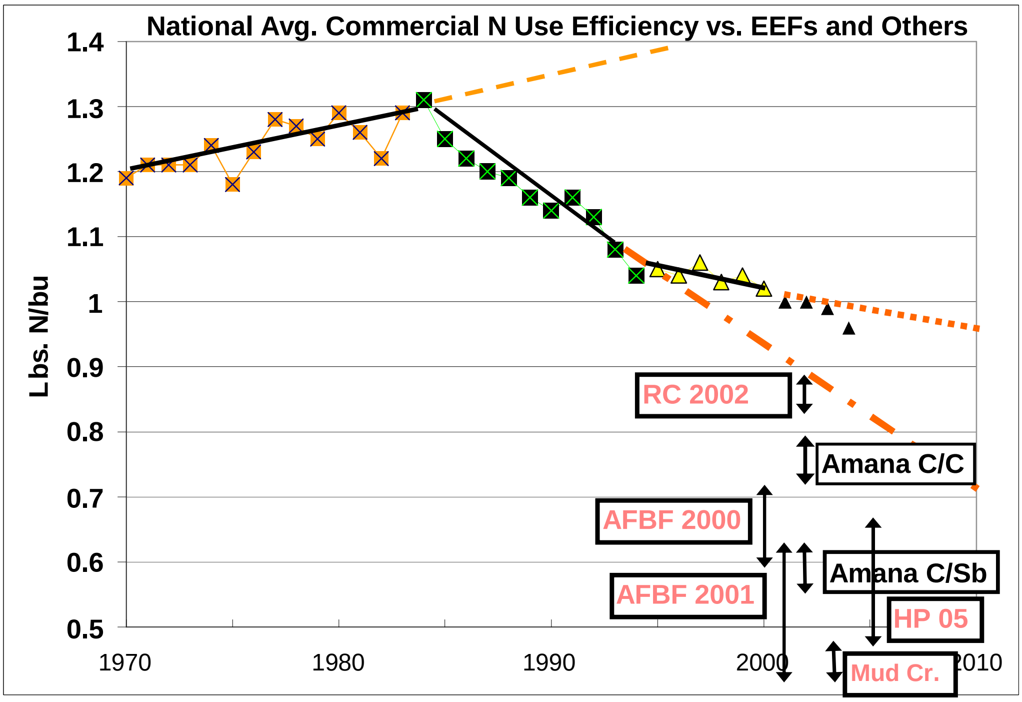


Figure 8. Long-term National N Efficiencies vs. Innovative Systems

The national 5-year running average of commercial nitrogen use efficiency by corn improved dramatically from 1984 to 1994. Since 1995 the overall rate of improvement has slowed down. However, anyone who is seriously doing anything with nitrogen is already way below the trendline created by projecting the 1984-1995 trendline out to 2010. Farmers participating in the Iowa Soybean Association's (ISA) Reduce N by 50 lb-N per acre program were in the efficiency range of 0.6 to 0.82 lb-N/bu. Farmers in the ISA program that compared 75 lb-N/ac vs. 125 lb-N/ac application rates had efficiencies ranging from 0.48 to 0.72 lb-N/bu.

Amana Society Farms Inc. which grows 3,000 to 4,000 acres of corn in east central Iowa was in the 0.7 to 0.8 lb-N/bu range on corn after corn, applying only about 130 lb-N/ac as part of their Nu-Till system. For corn following soybeans they were applying only 100 lb-N/ac, bringing commercial nitrogen use efficiency down into the 0.6 lb-N/bu range.
In 2004, Mud Creek Farms, in eastern Iowa used about 100 lb-N/ac and grew 200 to 275 bu/ac putting its range off the chart down into the 0.3 to 0.4 lb-N/bu range for much of its acreage.

Most of these forward-thinking, sharp-penciled growers shown here are not using manure in their systems so the efficiency numbers shown here are not leaving that source of applied N unaccounted for.

Energy Efficiency and Ethanol Production

While water quality issues drove the initial work on enhanced efficiency fertilizers, EEFs also appear to make sense from an energy standpoint. In 2005, the 5-yr running national average for all corn was about 133 lb-N/ac of commercial nitrogen applied. At 2.63 gallons of ethanol per bushel, the national average corn yield of about 140 bu/ac will produce about 9 barrels of ethanol per acre.

Our initial observations using Stabl-U at rates containing 25% less N than university recommendations have seen increased corn yields by about 10 percent. If, on the average, this would turn out to be true, Stabl-U would likely yield an average of 10 barrels of ethanol per acre. On 80 million acres of corn, that's 2 million Tons less N used as fertilizer and 3.3 billion more gallons of ethanol. It would also save about 1 MMBtu of natural gas per acre to use 100 lb-N/ac of Stabl-U as opposed to using 133 lb-N/ac which is about the current national average.

Future Improvements in Hybrids and Planters

Hybrids will improve, especially drought tolerant ones, improving yields and reliability of yields. Better planters are on the way that can lay down twin rows with kernels spaced alternately with standard deviations in spacing of less than 0.5 inches. Compare that to the normal planter which often has a standard deviation of seed spacing of 2 to 3 inches or more. With the new planter and seed metering mechanisms each corn plant has a more uniform volume of soil to explore for nutrients and water.

Research Needs

A controlled release lab test developed by Bill Hall (Mosaic) and Jerry Sartain (U of FL) should help sort out how the new fertilizers, and blends thereof, will react with different soil types and how much nitrate leaching will occur, (Hall 2005).

Nitrogen fertilizer rate studies, including blends of new and old fertilizers, need to be conducted.

Paired watershed research needs to done with some of the new EEF fertilizers compared to established ones like anhydrous, urea and UAN.

SUMMARY AND CONCLUSIONS

Nitrogen use efficiency on corn has improved dramatically since 1984 and will likely continue to improve substantially during the next decade. Hybrids will improve, especially drought tolerant ones, improving yields and reliability of yields. Better planters are on the way that can lay down twin rows with kernels spaced alternately with standard deviations in spacing of less than 0.5 inches, providing each plant a more uniform volume of soil to explore for nutrients and water. Nearly a dozen new Enhanced Efficiency Fertilizers are under some stage of development and commercialization and appear to have some promise for improving yield, profitability and environmental impact. Blends of these new fertilizers might also lower the cost per acre compared to using single sources of these new enhanced efficiency fertilizers.

The largest number of observations that we collected involved Stabl-U™ and initial results can be summarized as follows:

- It appears to reduce risk of yield loss while being more efficient
- It must be incorporated into the soil and spring application is preferred
- It uses 25% less natural gas to produce the necessary amount of nitrogen fertilizer
- It appears it could increase corn yield and net profits and reduce nitrate leaching to groundwater
- It may increase output of ethanol energy by up to 10 percent per acre.

Most importantly, our indicator plots suggest much research work needs to be done to determine the appropriate blends of the new fertilizers, and their interactions with soil types and hybrids, as well their impact on water quality. At a minimum, this will require using the controlled release lab test developed by Bill Hall (Mosaic) and Jerry Sartain (U of FL), performing nitrogen rate field studies on yield, economics and environmental impacts, and performing small scale paired watershed research.

REFERENCES

Hall, William L. Jr., J.B. Sartain, & R. C. Littell. Development of an Accelerated Laboratory Procedure for Determination of Slow Release Nutrients in Fertilizers. http://www.fertilizer.org/ifa/publicat/PDF/2005_ag_frankfurt_hall_poster.pdf

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