Nitrogen Timing and Crop Uptake

Nitrogen Management Research

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Topics I will Cover

- Nutrient Management:
  - A very Complex System
  - It is much more than just putting on some fertilizer!
  - Must have an appreciation of the complexity of plant
  - Must have an appreciation of the complexity of the soil

- I will cover some basic plant physiology

- Nutrient Use Efficiency

- Touch on fertilizer management

Nitrogen, why is it important?

- It makes the crop grow and turn green………Right?
  - Growing and turning green are consequences of how the plant uses Nitrogen
- Nitrogen is a major component of ALL amino acids
  - Amino Acids are building blocks of proteins and enzymes
  - Life could not exist without the biochemical reactions mitigated by the proteins and enzymes.

Nitrogen, why is it important?

- 78% of the atmosphere is nitrogen (N_2)
  - Plants cannot use N_2
  - Nitrogen must be converted to a useable form
    - Requires a lot of energy input for conversion
      - Lightning
      - Symbiotic relationships
      - Electricity or Fossil fuel
  - Ammonium (NH_4^+) and nitrate (NO_3^-)
    - Primary N species used by agronomic crops
    - Absorption and assimilation are different

Nitrogen Absorption and Assimilation

- Root cells
  - Inside has negative charge compared to outside
    - Attracts cations (+ charged molecules…. NH_4^+)
    - Repels anions (- charged molecules……NO_3^-)
  - Inside has higher concentration of nitrate compared to outside.
    - Nitrate tends to want to diffuse out and not in cell
  - Together: electrochemical potential gradient.
    - Down hill gradient for NH_4^+
    - Up hill gradient for NO_3^-

Nitrogen Absorption and Assimilation

- Ammonium (NH_4^+) absorption and assimilation
  - Absorption is almost a passive uptake
    - Downhill electrochemical potential gradient
    - Very little energy input
  - Must maintain electrochemical potential gradient
    - Energy input to maintain the gradient
  - NH_4^+ is toxic to the plant at relatively low concentrations
    - Carbohydrates sent to roots to assimilate NH_4^+ immediately.
    - Assimilated NH_4^+ is transported throughout plant and converted to amino acids, proteins, and enzymes

Nitrogen Absorption and Assimilation

- Nitrate (NO_3^-) absorption and assimilation
  - Absorption is an active uptake process
    - Uphill electrochemical potential gradient
    - Requires substantial energy
  - NO_3^- can be transported and stored in the plant
    - not toxic
    - Stored in roots or above ground plant parts
  - NO_3^- must be reduced to NH_4^+ before it can be assimilated
    - Requires substantial energy
    - NH_4^+ assimilated as before

Nitrogen Absorption and Assimilation

- Where does that energy come from?
  - Photosynthesis
    - Sun energy captured in chloroplasts
    - Converts CO_2 and H_2O to carbohydrates (energy captured in carbon bonds.
  - Respiration
    - Carbohydrates translocated to root (other plant parts)
    - Carbohydrate plus O_2 produces CO_2 and H_2O
      - Energy released as carbon bonds break

Nitrogen Management

- The soil complexity eliminates simplicity of nutrient management.

- For some, N management simply means how much fertilizer to apply, how to apply it, when to apply it, and where to apply it.
  - We could talk about this
    - This information is readily available
    - Extension, News articles, local fertilizer dealer etc.

- I want to take this talk to a little higher level

  - 10,000 ft level

Nitrogen Use Efficiency (NUE)

- The goal of most nutrient management specialists and researchers:
  - Maximize the effectiveness of the nitrogen that is available to the crop.
  - We call this, Nitrogen Use Efficiency (NUE)

- Maximize NUE!!!
  - Maximize returns for inputs
    - Dollars
    - Resource Use
  - Minimize risks to the environment

Nitrogen Use Efficiency (NUE)

- Many definitions of NUE
  - Depends on who is evaluating NUE
  - Overall NUE is composed of several different components.
  - Each component offers different pieces of information
    - Can be used for different interpretations and meanings.
    - Allows us to study different components of a complex system.
  - If someone uses this term, ask them to define it.

Nitrogen Use Efficiency (NUE)

Nitrogen Use Efficiency (NUE)…as I am using it.

NUE = N Agronomic Eff. X N Uptake Eff.

N Agronomic Efficiency: lbs. grain produced / lbs. N uptake)

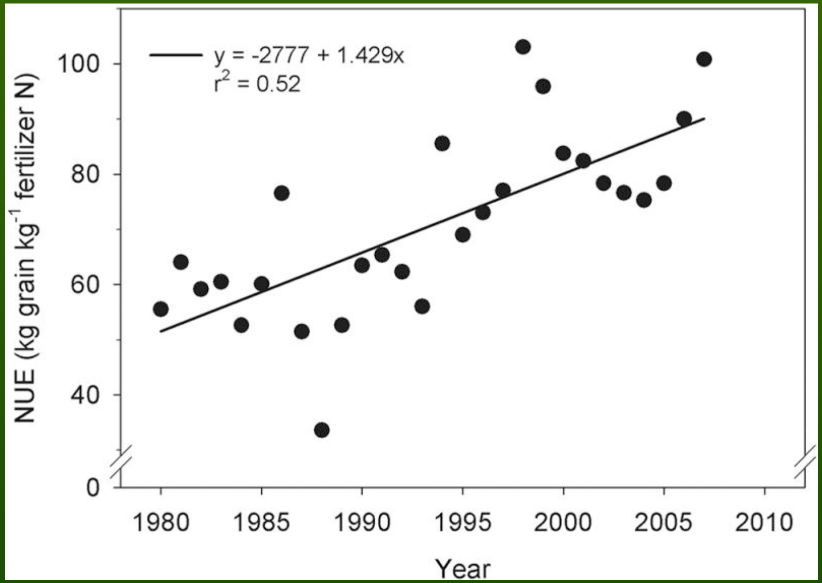
N Uptake Efficiency: lbs N accumulated / lbs. N available

NUE = lbs. grain produced / lbs. N available

Nitrogen Use Efficiency

- Agronomic Efficiency
  - Lb. of grain produced per lb. of N accumulated
- Combines elements of N accumulation and remobilization and their effects on dry matter accumulation and remobilization.
- Too complicated for a 30 minute general talk
  - Production efficiency
  - Remobilization/translocation efficiency
  - Accumulation efficiency before anthesis and after anthesis

Nitrogen Agronomic Efficiency in Corn



Adapted from Long-term continuous corn and nitrogen fertilizer effects on productivity and soil properties, Bundy, Andraski, Ruark, and Peterson. 2011. Agron. J. 103:1346-1351

Another source: Nitrogen use efficiency of corn increased from about 30 lbs. of grain per lbs. of nitrogen in 1960 to 60+ lbs. grain per lbs. of nitrogen in 2006.

Other sources indicate yields have increased about 2.2 bu. Ac^{-1} yr^{-1} will N rates have remained relatively static or perhaps decreased.

Nitrogen Agronomic Efficiency

- Why is the Agronomic Efficiency increasing?
  - At the field level
    - Better Hybrids/Varieties
    - Less stress from pests
      - Stacked traits
      - Better pesticides and pesticide management
    - Better agronomic cultural practices
    - Maybe some environmental issues?
  - Appears to be happening in several crops
    - Corn
    - HRSW
    - Sugar Beets

Nitrogen Agronomic Efficiency

- Regardless of the reason, it seems to be happening
  - People are nervous about it.
    - Question current N guidelines
      - Want to increase N fertilizer applications
    - We must maintain vigilance with continued Nitrogen research
      - Things change over time
      - Principals probably remain the same
      - Their application to real world situations may change
    - Vulnerable to sales pitches with no or shaky research data.
      - A pitch with no data…..is an untested hypothesis!

Nitrogen Uptake Efficiency

- Most nutrient management specialist, regardless of specific role, work on this component of NUE.
- How do we maximize, or optimize, the uptake of nitrogen into the crop?
  - Crop gets it Nitrogen from:
    - Leaves……foliar absorption
    - Roots...... this talk will focus on this part
  - Uptake Efficiency relates to uptake efficiency of available N

Nitrogen Uptake Efficiency

- Where does the crop get its nitrogen?
  - Residual soil nitrate
    - Estimated by a soil test
  - Mineralization of organic N to inorganic N
    - Very difficult to predict
    - Depends on:
      - Moisture, temperature, oxygen, amount and type of organic matter, time
  - Fertilizer
    - Manure (more difficult to estimate)
    - Commercial fertilizer (known N content and availability

Nitrogen Uptake Efficiency

- Fertilizer management offers us the best opportunity to manage nitrogen
  - We can manage:
    - Rate
    - Timing
    - Placement
    - Source
    - Summarized into The 4 Rs:
      - Right Source, Right rate, Right Time, Right Place
- We want to maximize the Recovery of Fertilizer Nitrogen

Fertilizer Recovery Efficiency (FRE)

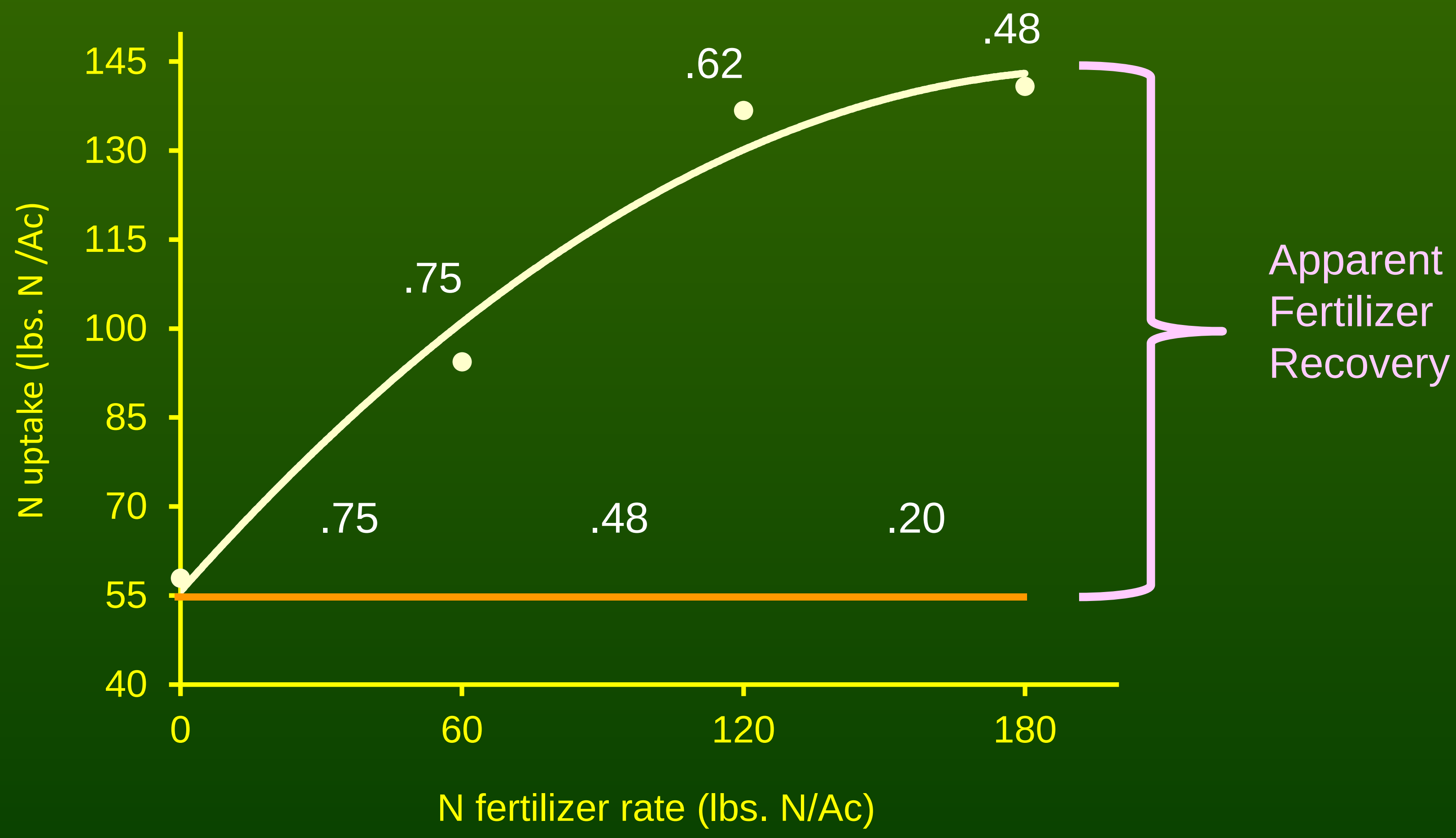
- The goal of Fertilizer management:
  - Maximize Fertilizer Recovery Efficiency (FRE)

- Two ways to study FRE

1. ^{15}N (fertilizer with a chemical isotope of N)
   - Can apply fertilizer with enriched or depleted ^{15}N isotope relative to natural
   - Evaluate N in plant for enrichment or depletion of ^{15}N.

2. Difference Method
   - (lbs. N (fert) – lbs. N (check))/N applied
   - Apparent Fertilizer Recovery Efficiency

Apparent Nitrogen Fertilizer Recovery in HRSW



Combined data from 4 Hard Red Spring
Wheat Varieties. Sims and Wiersma, 2011

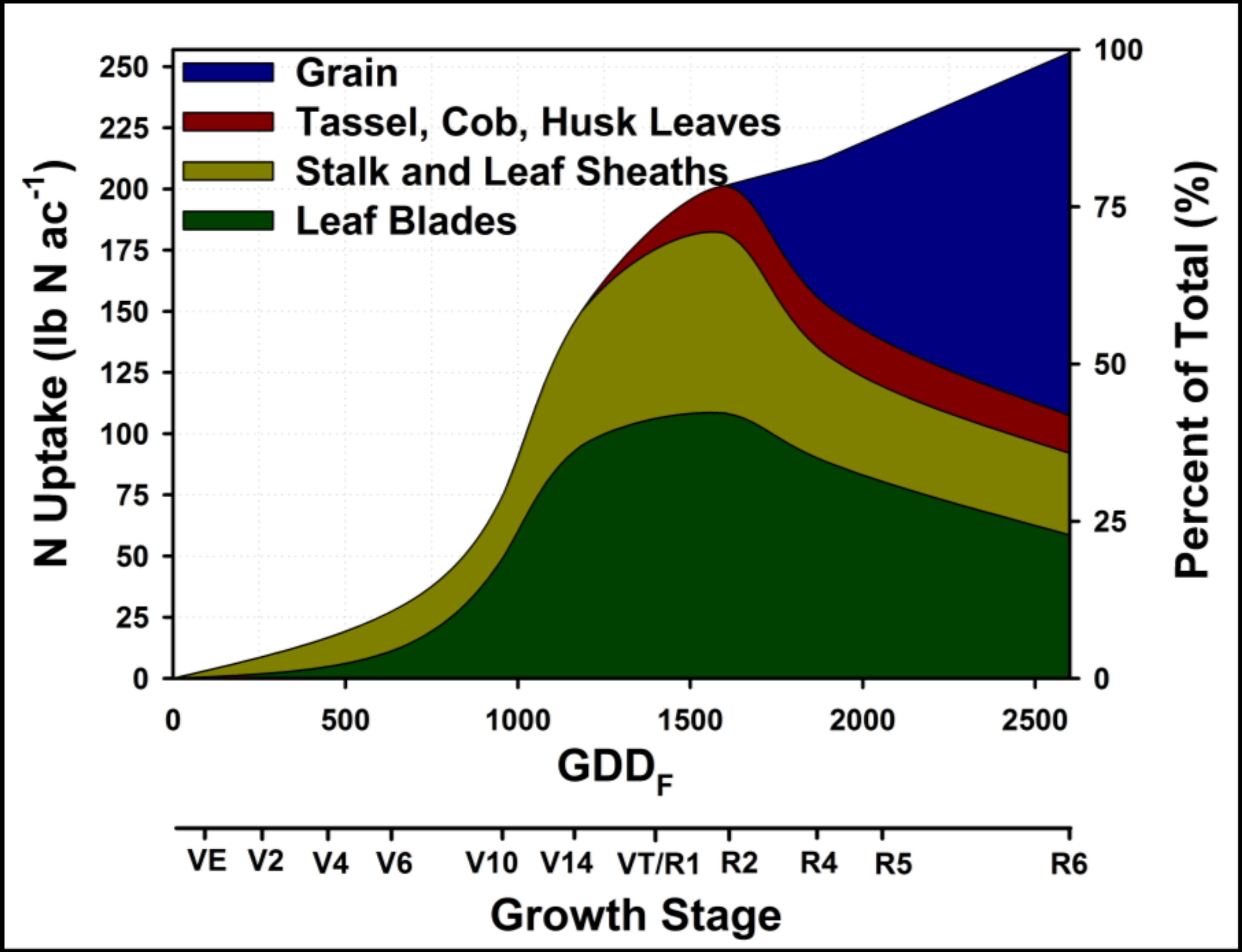
Nitrogen Fertilizer Recovery

- World wide: 33% of fertilizer is recovered
- What happens to that not recovered?
  - Measured as residual nitrate-N in soil test
  - Immobilized: converted from inorganic N to organic N
    - Some will remain in the labile organic N pool
  - Unaccounted for
    - Many trials do N balance using either Difference or ^{15}N
      - Frequently cannot account for 20 – 30% of fertilizer N
      - Leached below sampling zone?
      - Denitrification?
      - Volatilzation (from soil surface and the plant)?

From Research to Recommendation

- Intensive research efforts on many subcomponents of:
  - Agronomic Efficiency
  - Uptake Efficiency
- Recommendations
  - Apply smaller pieces from the intensive research
  - Expand them to the broader picture
  - Nitrogen Utilization Efficiency
    - Managed Nitrogen to produced the greatest amount of product
    - Optimize Profit and Resource Utilization
    - Minimize Risk to the Environment
  - Develop Best Management Practices (BMPs)

Nitrogen uptake and Distribution in Corn



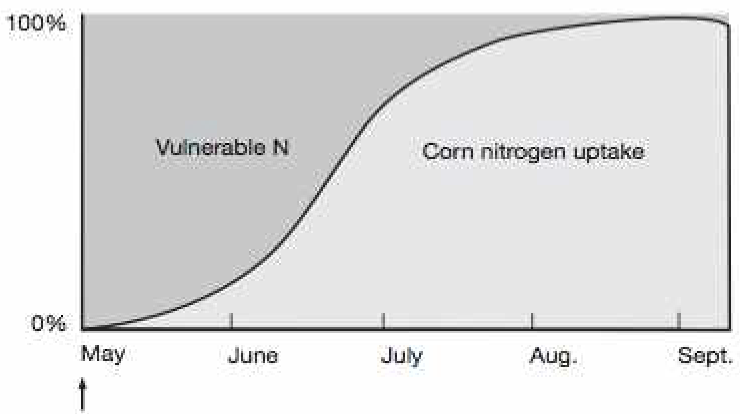
230 bushel Ac^{-1} corn crop

Adapted from Ross Bender, Corn Nutrient uptake and partitioning, Illinois Crop Physiology, University of Illinois. http://cropphysiology. Cropsci.illonois.edu/research/ Nutrient_uptake.html

Applied N vs N uptake

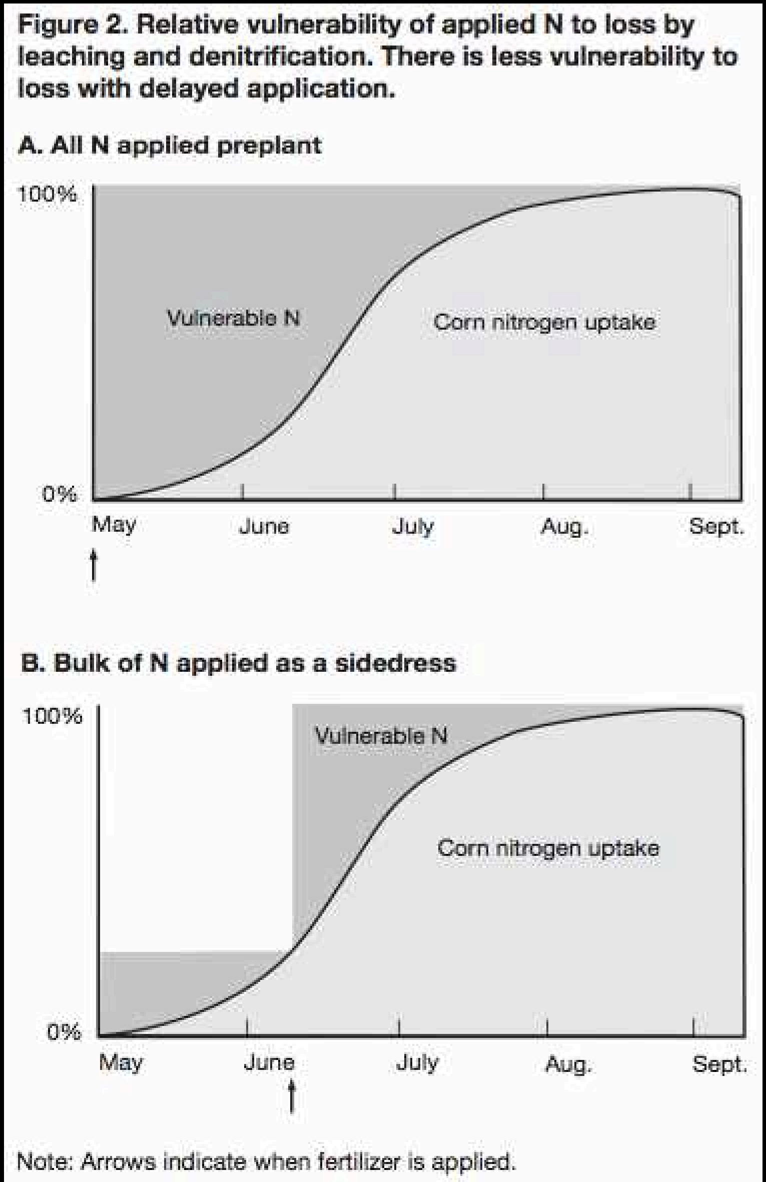
Figure 2. Relative vulnerability of applied N to loss by leaching and denitrification. There is less vulnerability to loss with delayed application.

A. All N applied preplant



- The longer nitrate/ammonium is in the soil the more vulnerable it is to loss.
- Manage N fertilizer to reduce its exposure to potential losses.

Adapted from Nitrogen Fertilization Of Corn,
Penn State Extension Agronomy Facts 12.
http://extension.psu. edu/cmeg/facts/agronomy-facts-12



- How do we protect the N during that vulnerable period?
- What are the risks?
    - Leaching
    - Denitrification
    - Volitilization
    - Immobilization
- Use BMPs in terms of source, rate, and timing of applications
    - Consider your soil, location and climate
    - Soil Test
    - Adequate soil incorporation
    - Spring N applications
    - Fall applications:
        - $< 50^{o}$ F temps
        - Ammonical Fertilizers
        - Urease or Nitrification inhibitors
    - Split applications
        - Applies N at beginning of rapid uptake phase

In-Season N in HRSW

N timing	Grain yld	Test Wt.	Protein
	Bu/ac	Lbs/bu	%
Preplant	59.8	60.5	15.6
Preplant+Postplant	57.4	60.7	15.3
Postplant	59.1	60.7	15.1
Lsd (0.05)	NS	NS	0.4

- 100 lbs. N: all preplant was urea incorporated prior to plant; all postplant was 28% through stream nozzles. Preplant + Post plant: 50:50
- Consistent with earlier work in NW Minnesota (Lamb and Rehm)
- In-season N application: Must have moisture in the application zone for N to be effective

Endres, Schatz, and Maine. 2005. HRS wheat variety response to N application timing and seeding rate. www.ag.ndsu.edu/archive/carringt/05data

In-Season N in Corn

Time of Application		Year/Site	
Preplant N	Sidedress N	1991	1992
--- N rate (lbs N /Ac)		Waseca Co.	Blue Earth Co.
0	0	84	77107.0
60	0	143	144
30	30	161	141
90	0	158	156
30	60	157	137
120	0	165	164
30	90	182	153
Advantage of Split-N		+11	-11

Rainfall was 56% above normal in 1991

Adapted from Randall et al., 2008. Best management practices for nitrogen use in South-Central Minnesota. Univ. of Minn. Extension #08554

Summary

- Allot of work has been done on nitrogen
  - Current BMPs reflect our current state of knowledge
- Still more to do.
  - Ever changing dynamic of our crop production system
- Must always be thinking about:
  - Grower profitability
  - Resource utilization
  - Environmental preservation/protection