Fertilizer Efficiency in High Yield Environments

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“Fixing the Global Nitrogen Problem” (Townshed & Howarth, Sci. Amer. Feb 2010)

- Typical of titles in science-oriented media.
- Human fixation of N = ~2 x natural fixation
  - fertilizer production and fossil fuel use
  - biological nitrogen fixation and lightning
- Current fixation greatly exceeds denitrification
  - an on-going accumulation of reactive N
  - effects on natural terrestrial and marine ecosystems

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Topics

- What is nutrient (nitrogen) use efficiency (NUE)?
- Why is NUE important?
- What are the components of NUE?
- Nebraska corn results
- Nebraska soybean results

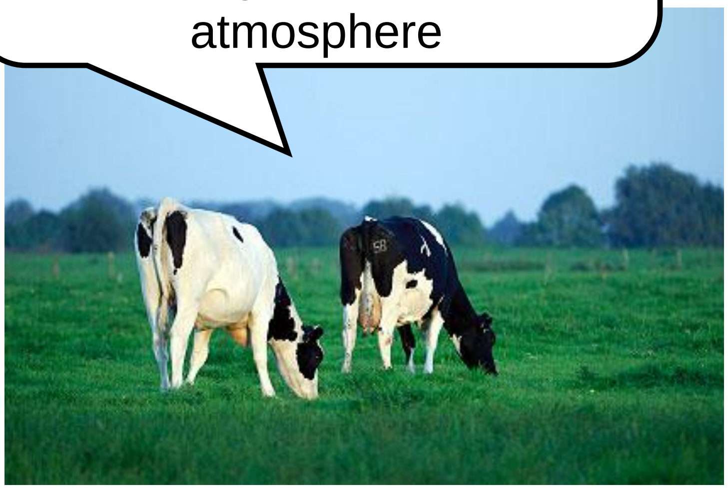
Nitrogen use efficiency

- NUE = yield per unit of plant available N (from soil, fertilizer and other sources; bu/lb)
  - Minimize losses
  - High productivity per available N
  - However, need to maximize profitability

The Nitrogen Cycle

Volatilization: surface applied manure or fertilizer ammonium N may convert to ammonia gas and be lost to atmosphere

Runoff: causes N loss and water contamination



Denitrification: reduction of nitrate-N to N_2 or nitrous oxide under low O_2 conditions

Leaching of nitrate-N below the rooting zone

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N use efficiency (NUE): importance

- Profitability
- Efficient use of fossil fuel
- Environmental protection
  - Surface water
  - Ground water NO_3-N
  - Air
- Greenhouse gas emissions
  - Fossil fuel use (CO_2)
  - Nitrous oxide (N_2O)

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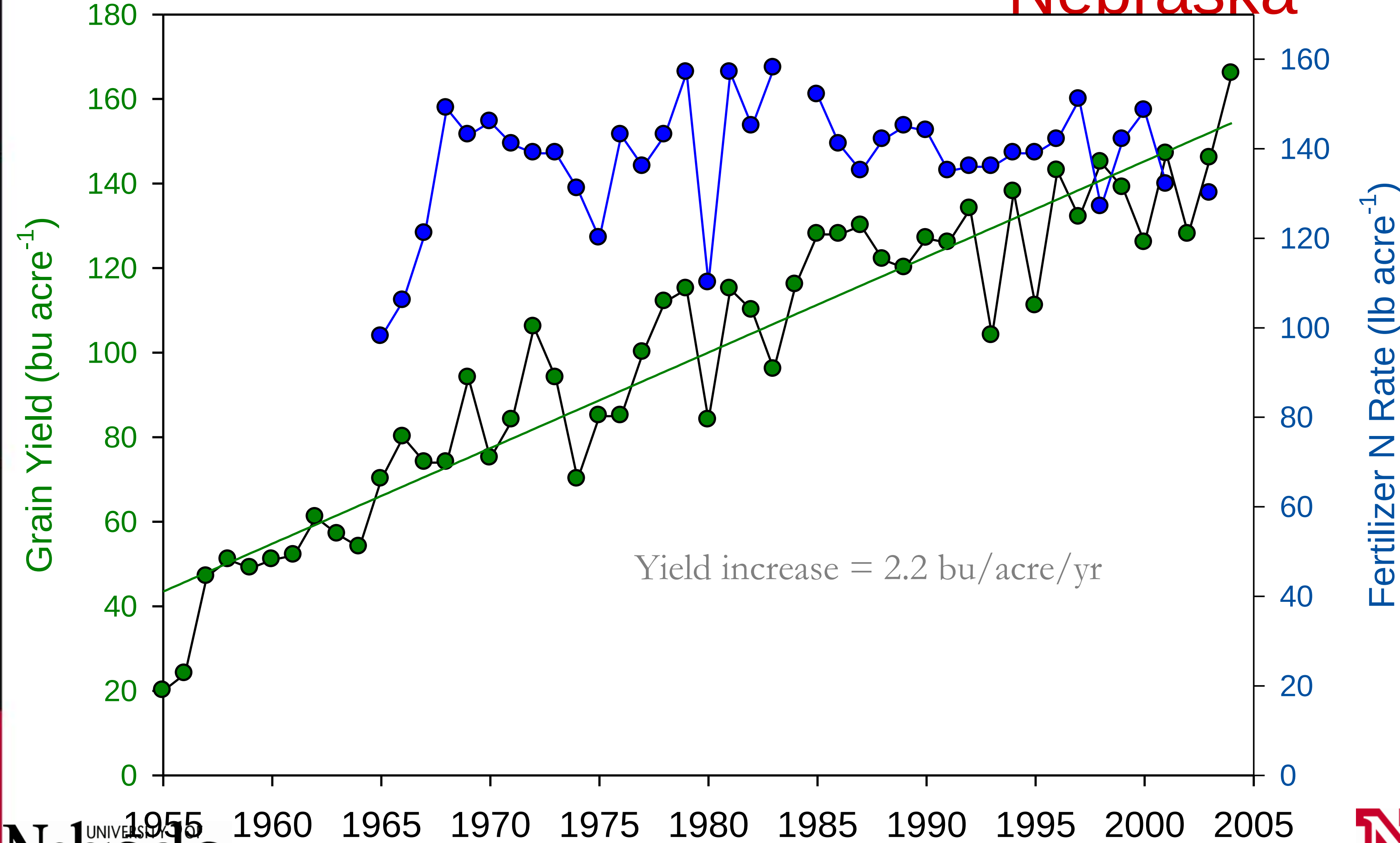
NUE: partial factor productivity

- PFP = grain yield/N rate, lb/lb
- Components
  - Recovery efficiency of applied N
  - Agronomic efficiency: yield increase per lb of N applied
  - Internal efficiency: conversion of plant N to grain
    - Nitrogen harvest index
    - Grain N concentration

Grain yield and N fertilizer use for corn in Nebraska



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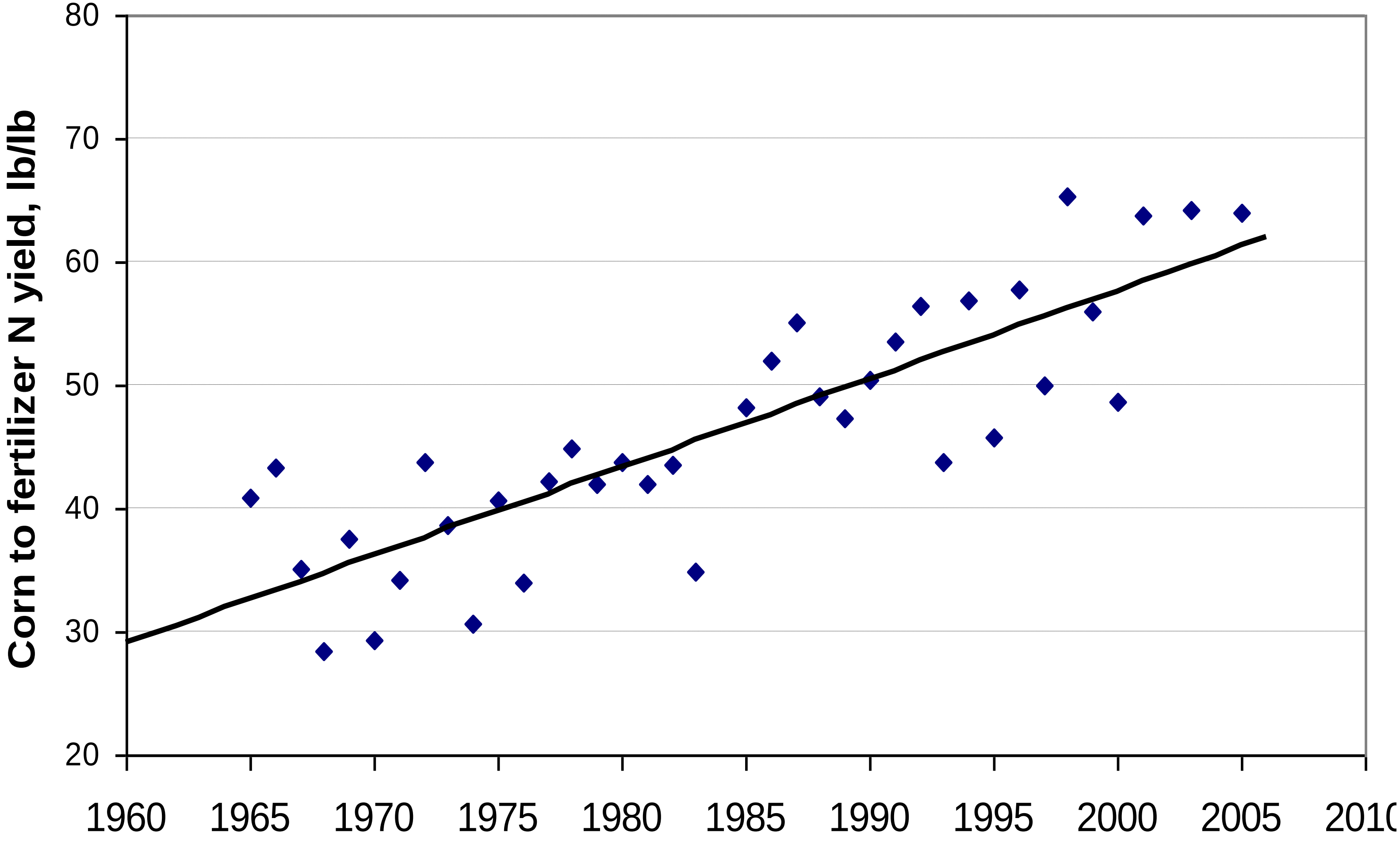
Nitrogen use efficiency

Corn produced per lb applied N: doubled since 1960.



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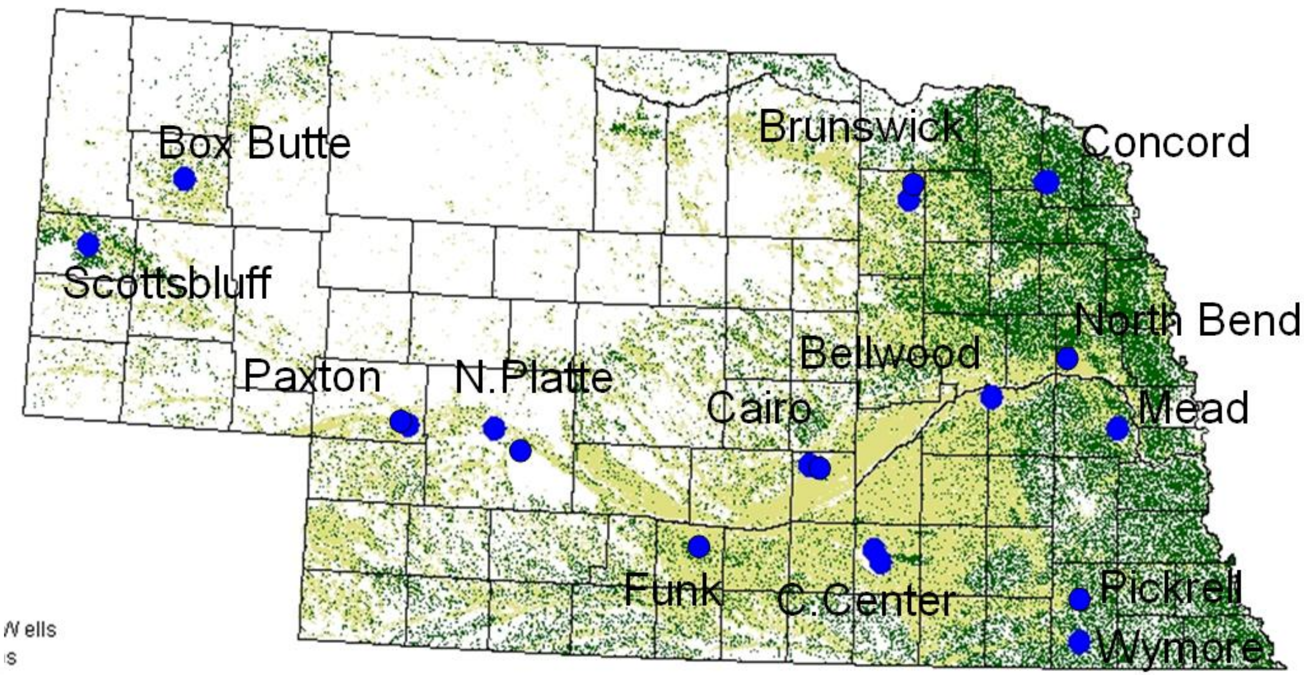
Nebraska high yield corn N research

- 12 trials with corn-corn
- 16 corn-soybean
- Split application of N
- Mean maximum yield = 240 bu



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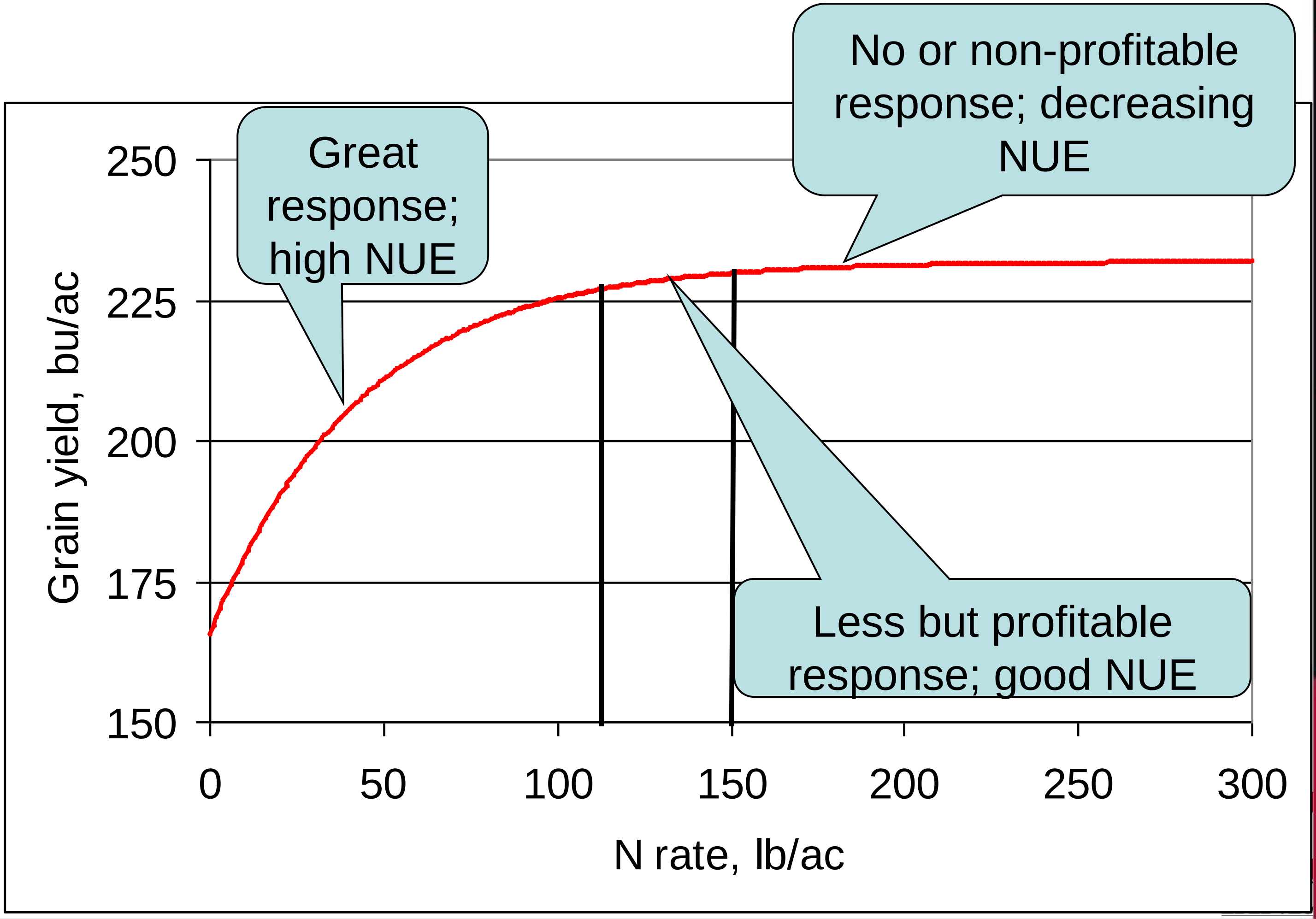
Response to applied N is a typically curvilinear-plateau response



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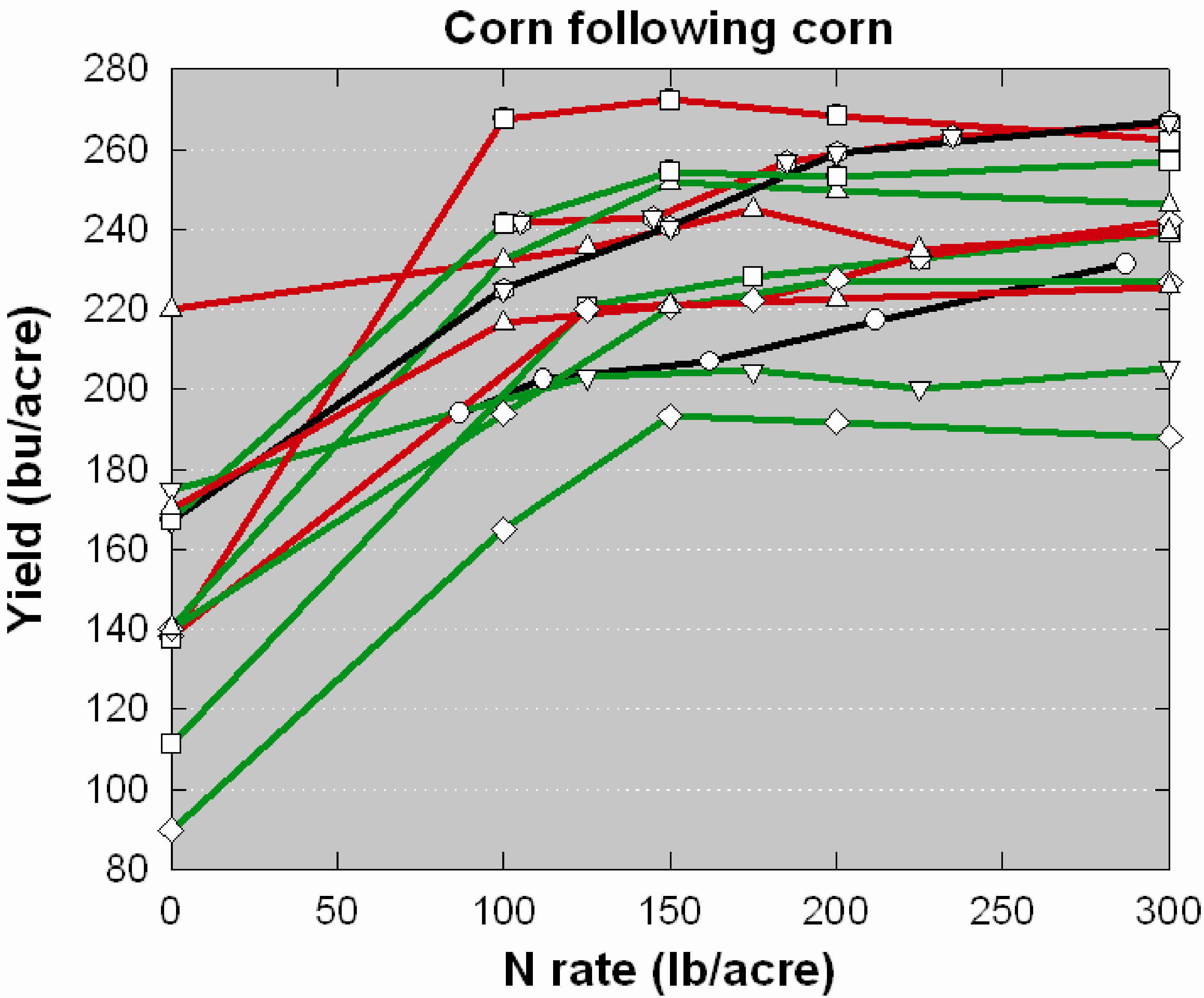

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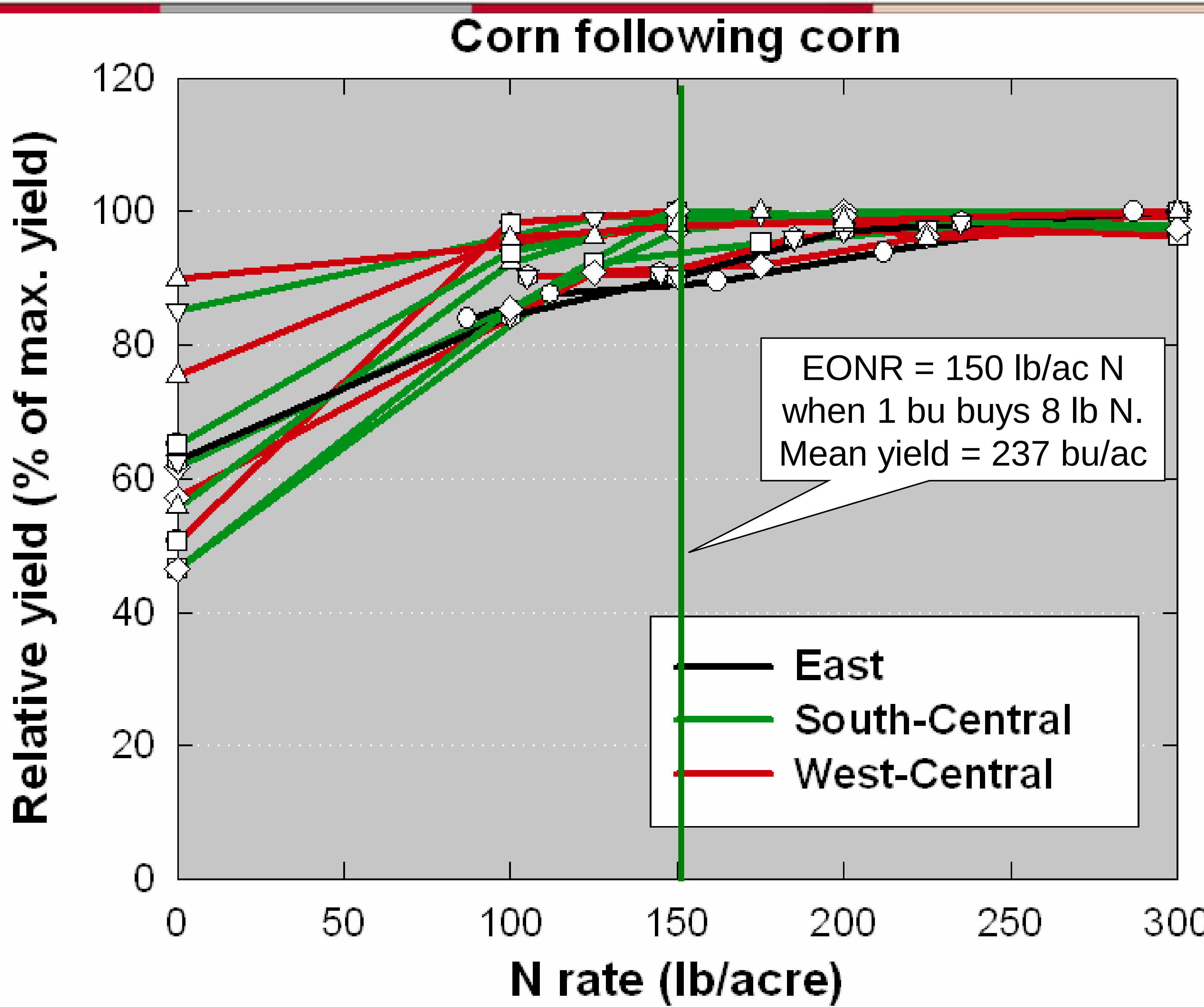
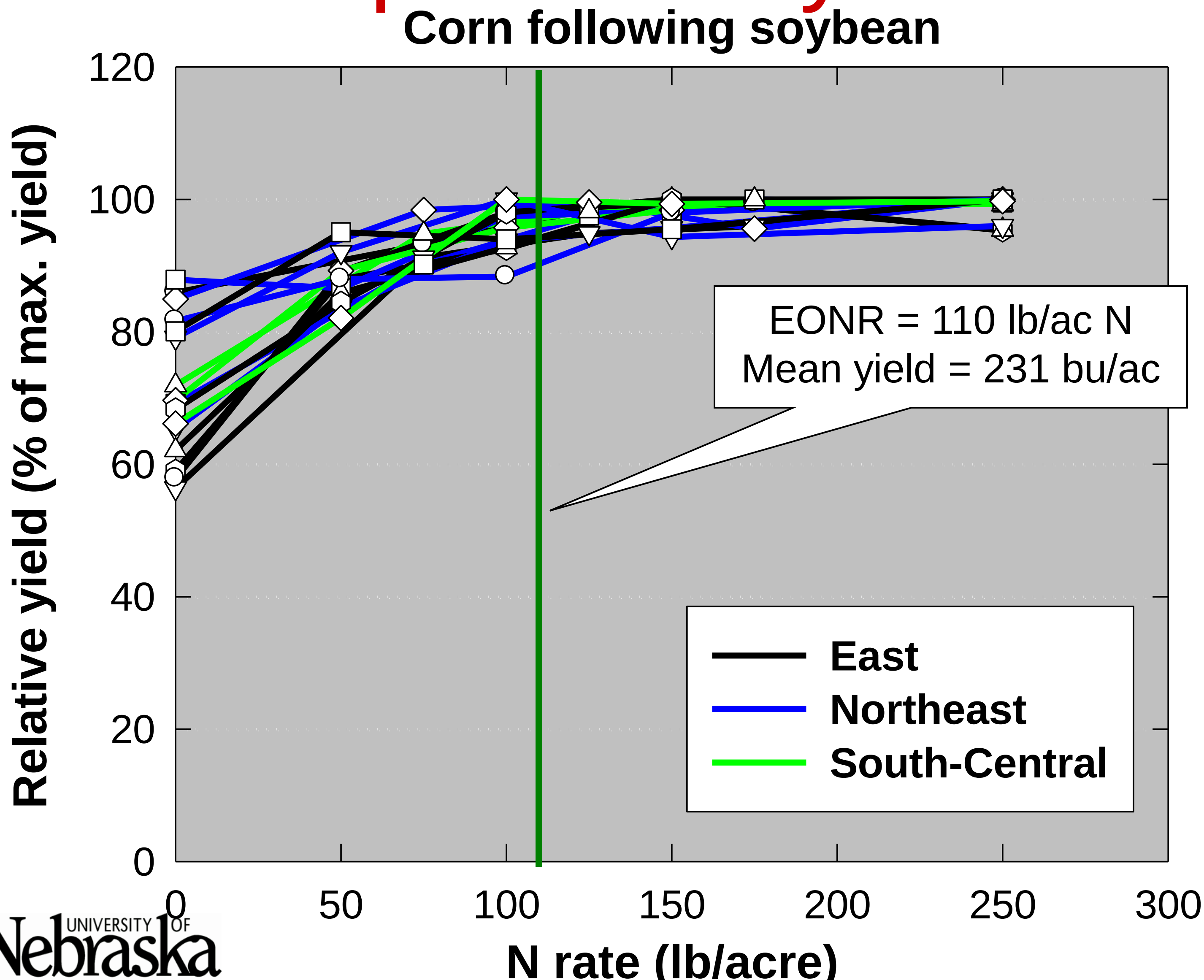
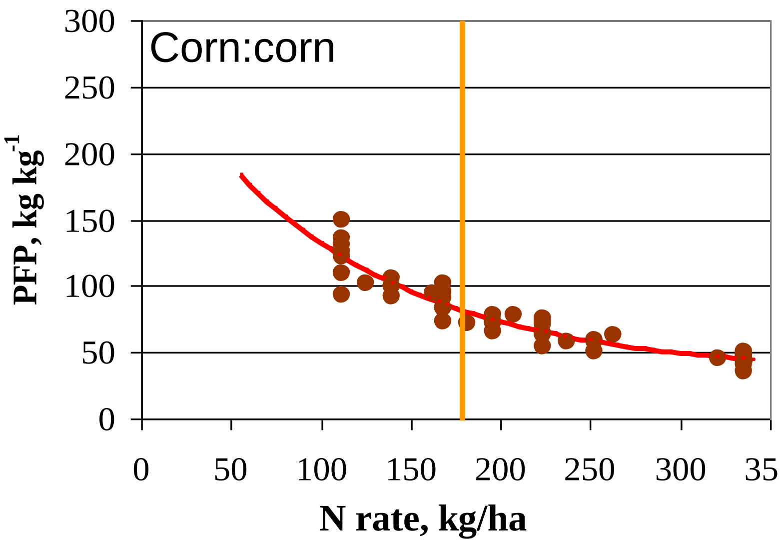

Corn following corn
Relative yield (% of max. yield)
0
20
40
60
80
100
120
N rate (lb/acre)
0
50
100
150
200
250
300
EONR = 150 lb/ac N
when 1 bu buys 8 lb N.
Mean yield = 237 bu/ac
East
South-Central
West-Central

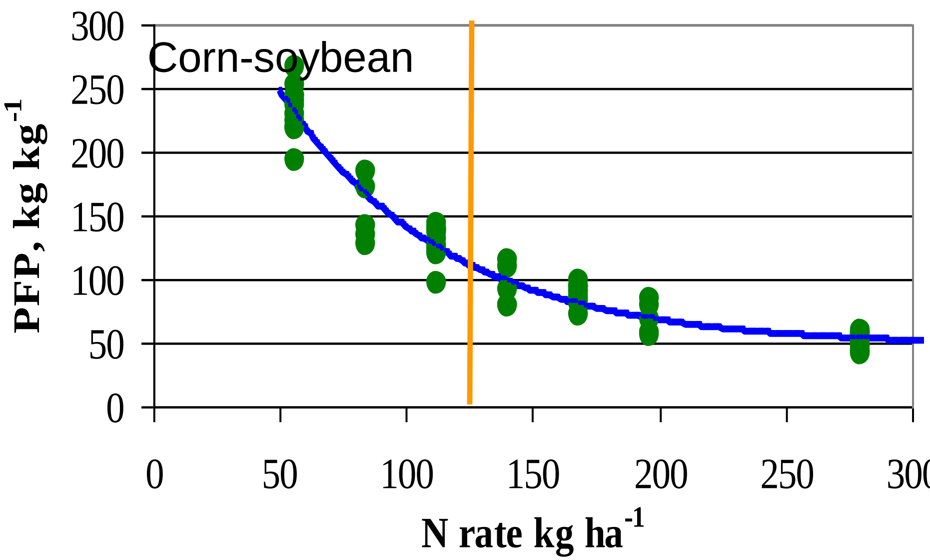
N response: soybean - corn



Grain yield : fertilizer N (kg:kg)

partial factor productivity (PFP)

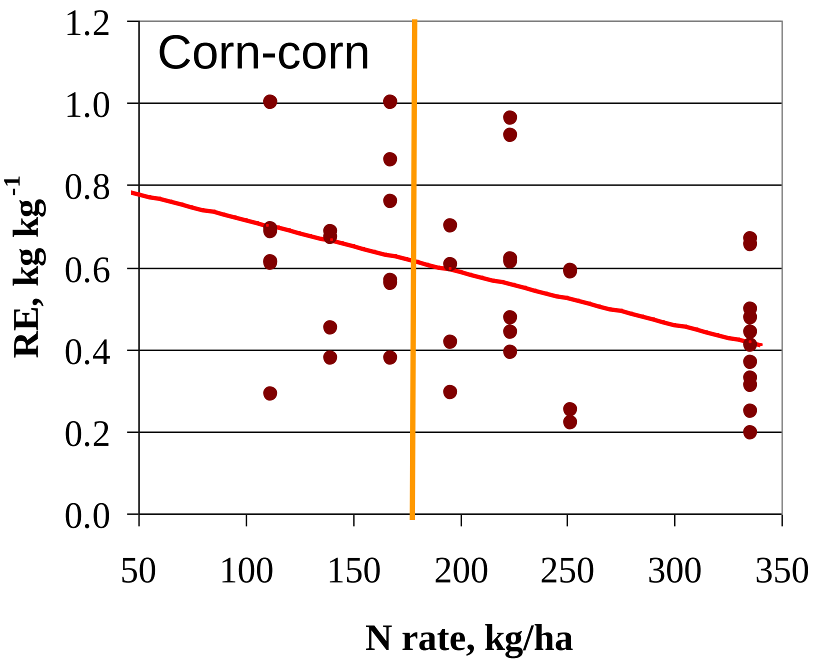


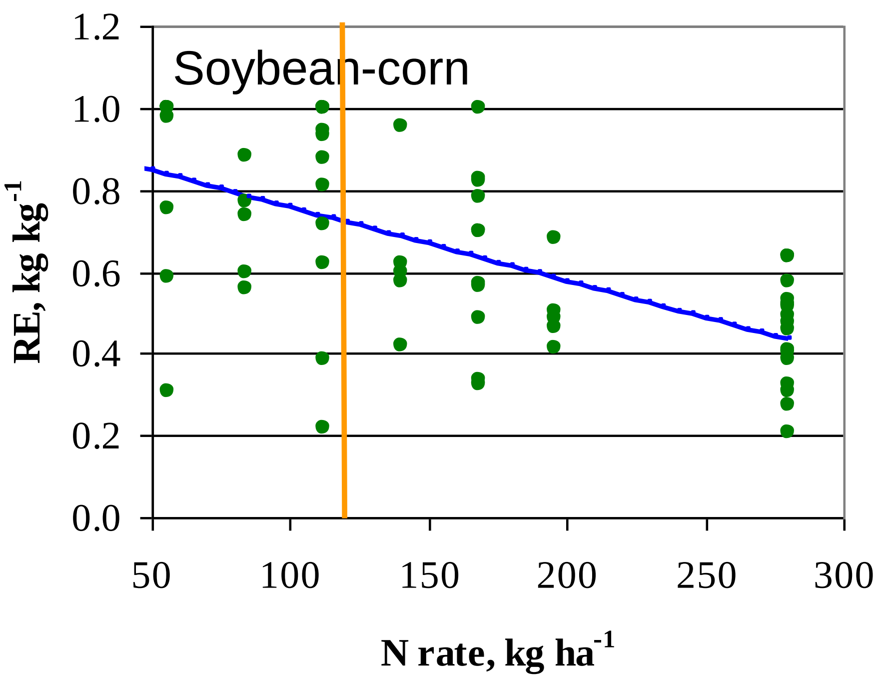


Recovery efficiency

- % of applied N recovered in the aboveground plant
- Requires
  - healthy crop with good root system
  - Minimal N losses

Fertilizer N recovery efficiency





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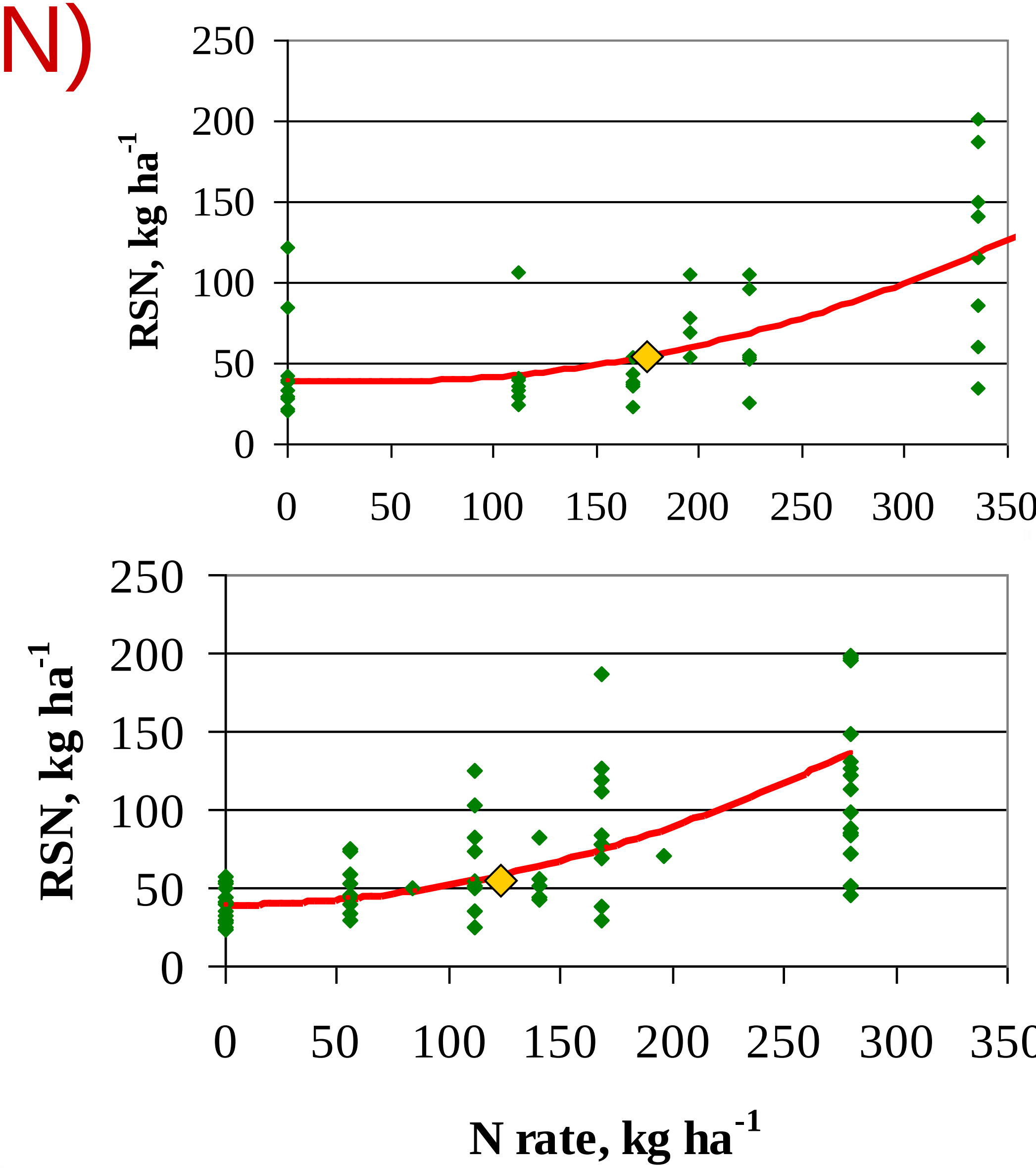
Residual soil nitrate after harvest (RSN)

- ➢When N is applied at EONR, RSN is not excessive.
- ➢RSN increases rapidly as N rate exceeds EONR.
  - ➢Lost profit
  - ➢Environmental consequences



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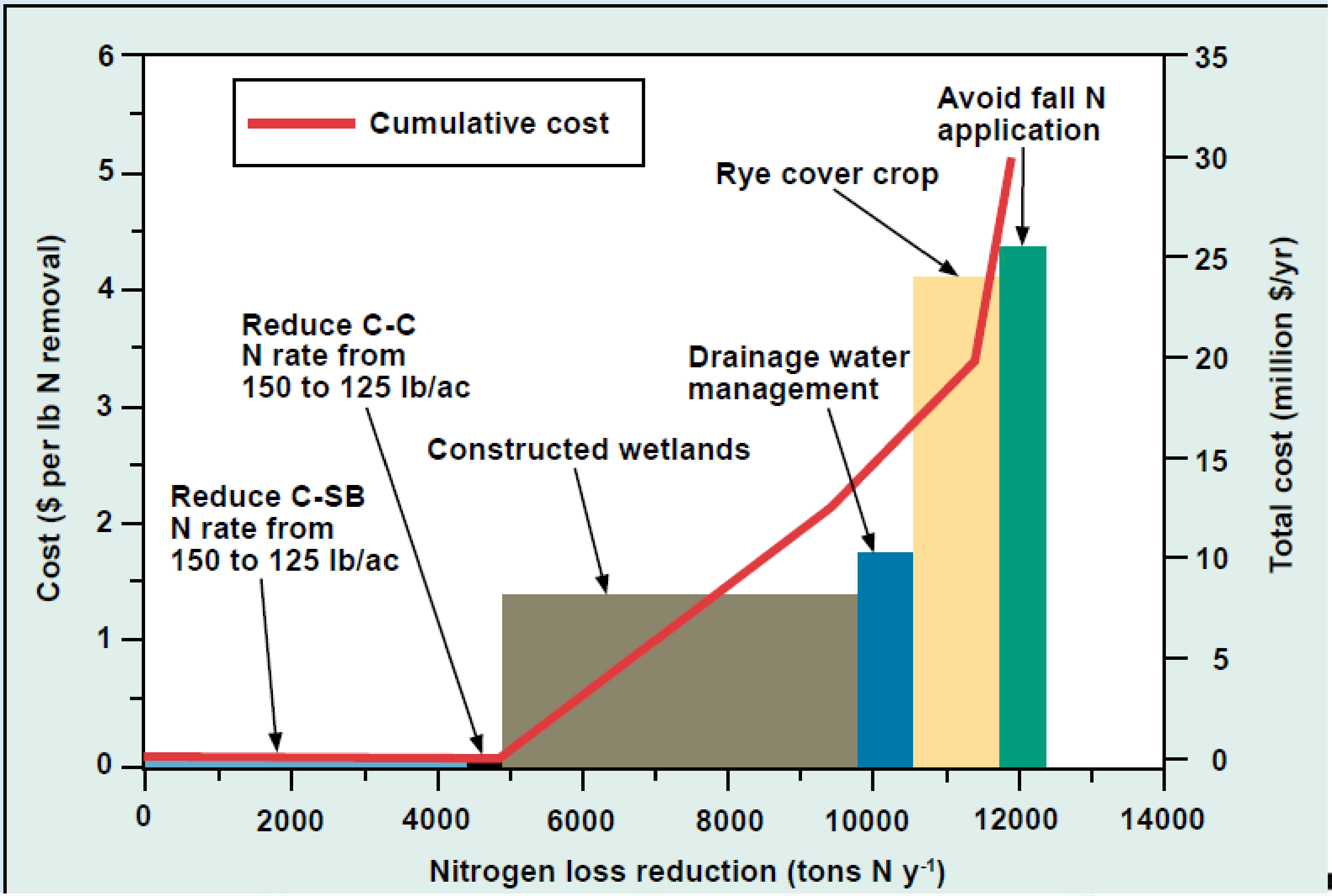
A case from Iowa: target of reducing nitrate-N loss to surface waters by 12,000 ton N /yr.



Agronomic efficiency:

increase in grain yield per lb of applied N; lb/lb.

Depends on:

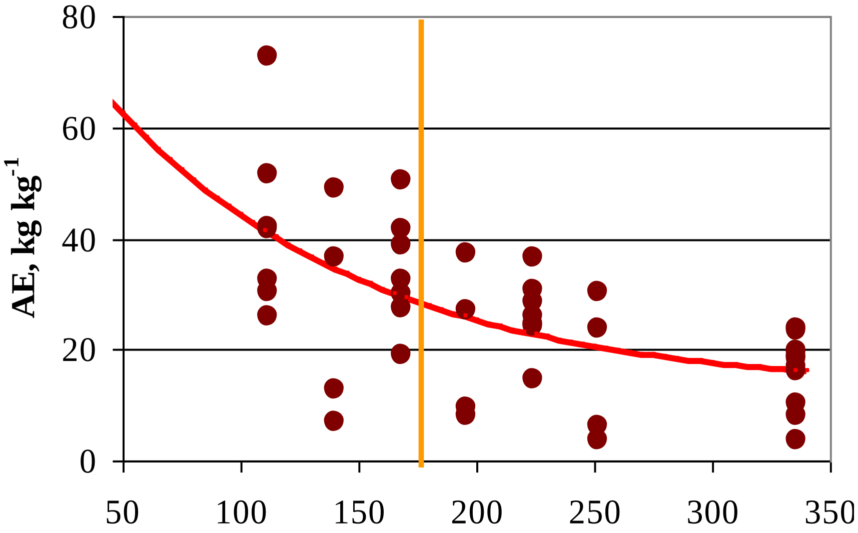
recovery efficiency;

physiological efficiency of conversion

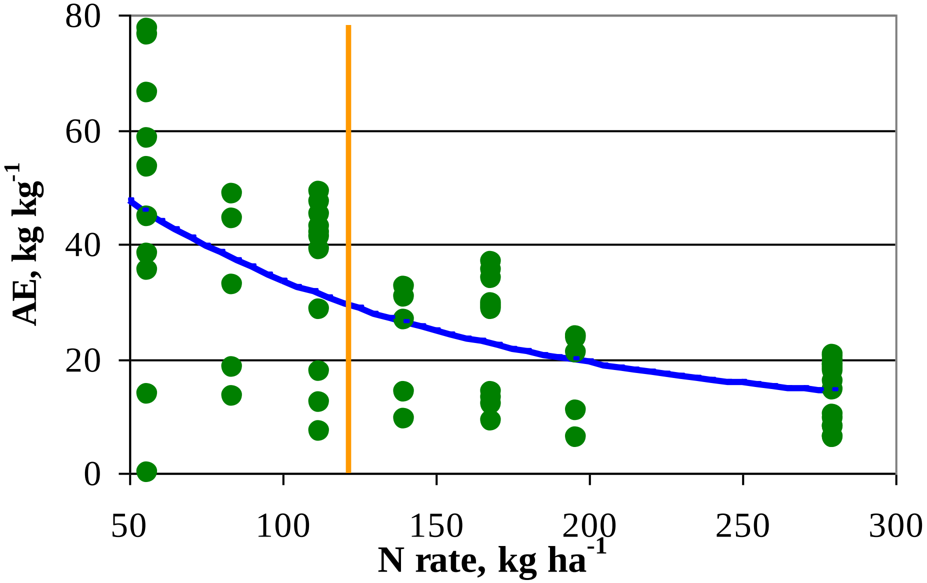
Agronomic efficiency (AE):

increase in grain yield per kg of N; kg/kg

Corn:corn

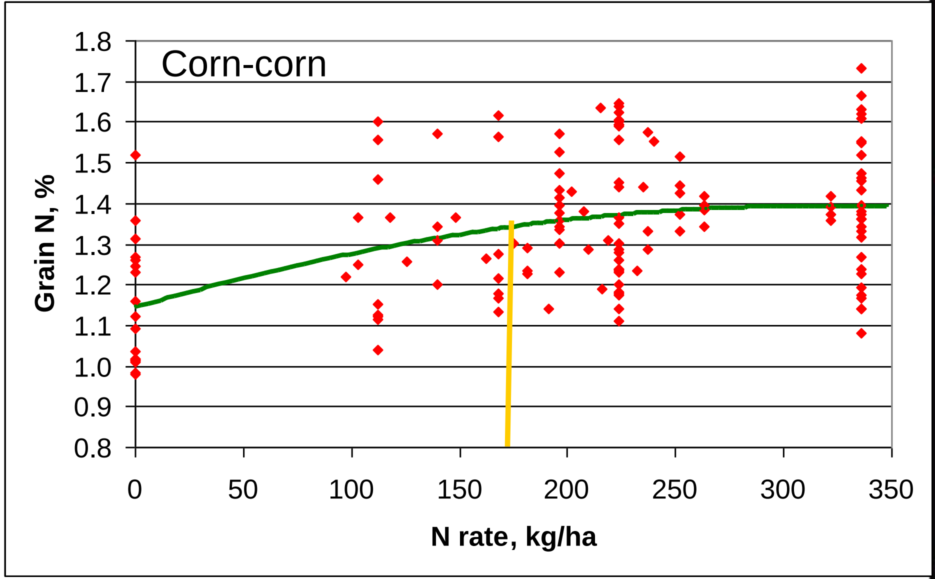


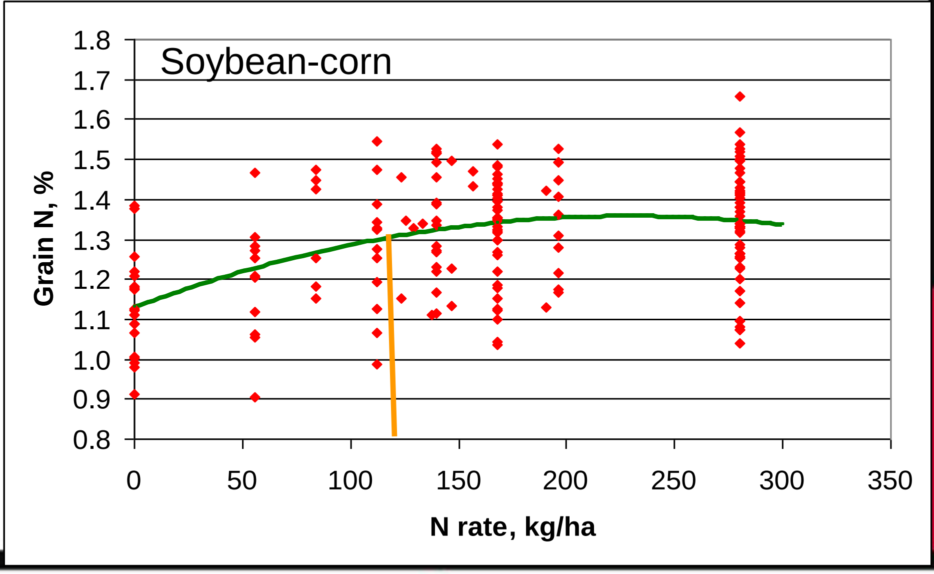
Corn:soybean



Grain N concentration

- Low %N means more grain per unit of N, but also lower protein content
- Grain N was 1.32% (8.8% protein) at EONR for high yield corn
  - Grain N was 14% higher at EONR compared to N0.
  - Grain protein could be increased with more N applied





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Mean nitrogen for high yield corn at most profitable N rates (EONR)

Means	Corn-corn	SB-corn
Yield, bu/ac	237	231
EONR, lb/ac	150	110
Grain:fertilizer N efficiency	85 lb/lb	115 lb/lb
Recovery efficiency	62%	76%

Can we further improve efficiency? Can we predict EONR accurately?

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N Use Efficiency

Highest

- Having a healthy, vigorous crop
- Appropriate N rate
- Water management
- Fertigation during rapid growth
- Sidedress with on-set of rapid growth
- Post-plant application
- Controlled release N
- Inhibitors
- Pre-plant application
- Fall application for next year

Lowest

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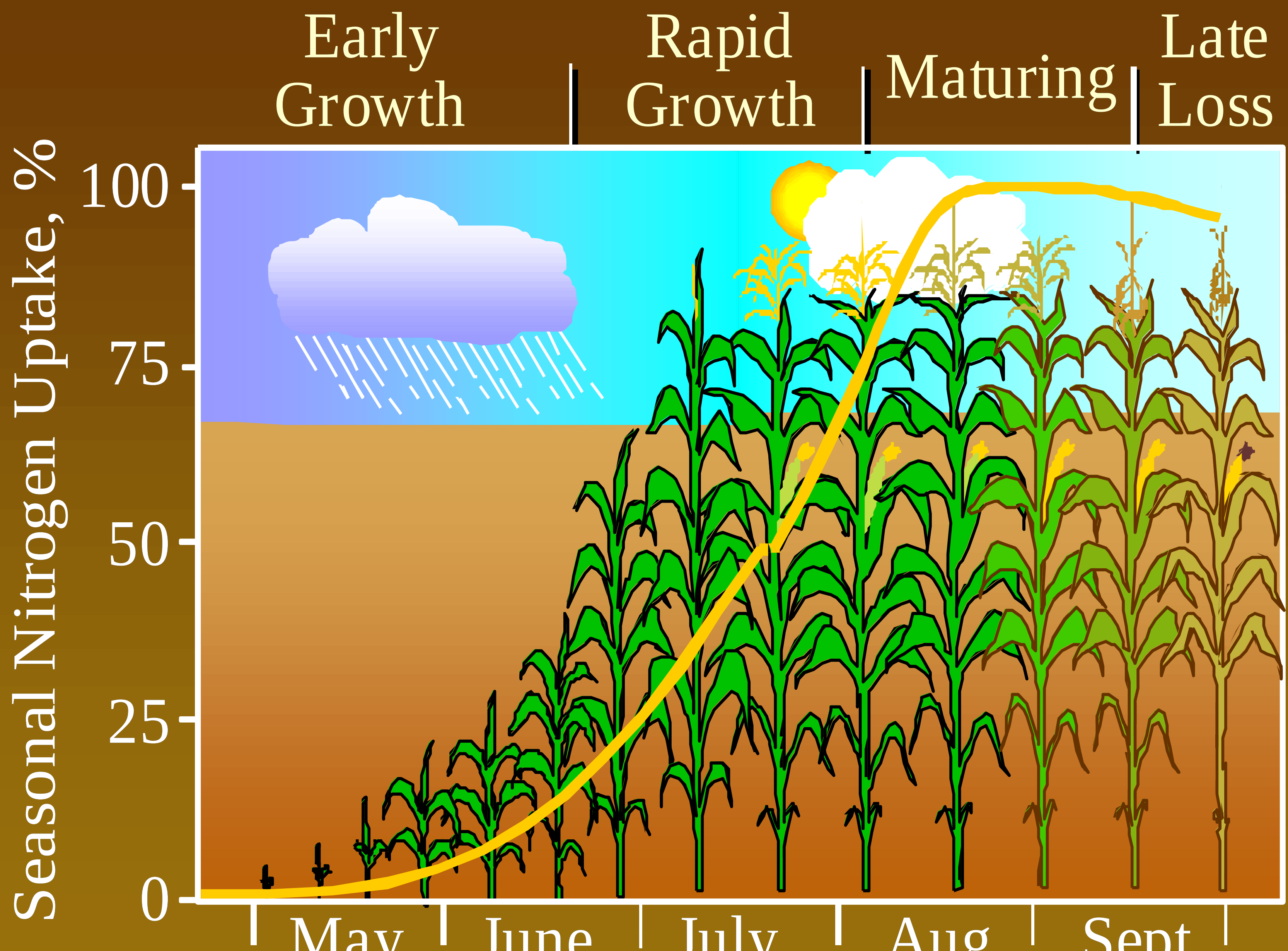
Water management and NUE

- Avoid excess water to minimize
  - Leaching of nitrate-N
  - Denitrification of nitrate-N
  - May require drainage or improved irrigation management
- Avoid crop stress due to soil water deficits
  - Supplement rainfall with irrigation to avoid stress
  - Prevention of stress allows vigorous crop to be efficient in
    - nutrient uptake
    - conversion of nutrients and carbohydrates to harvested product

N- Uptake Across The Growing Season



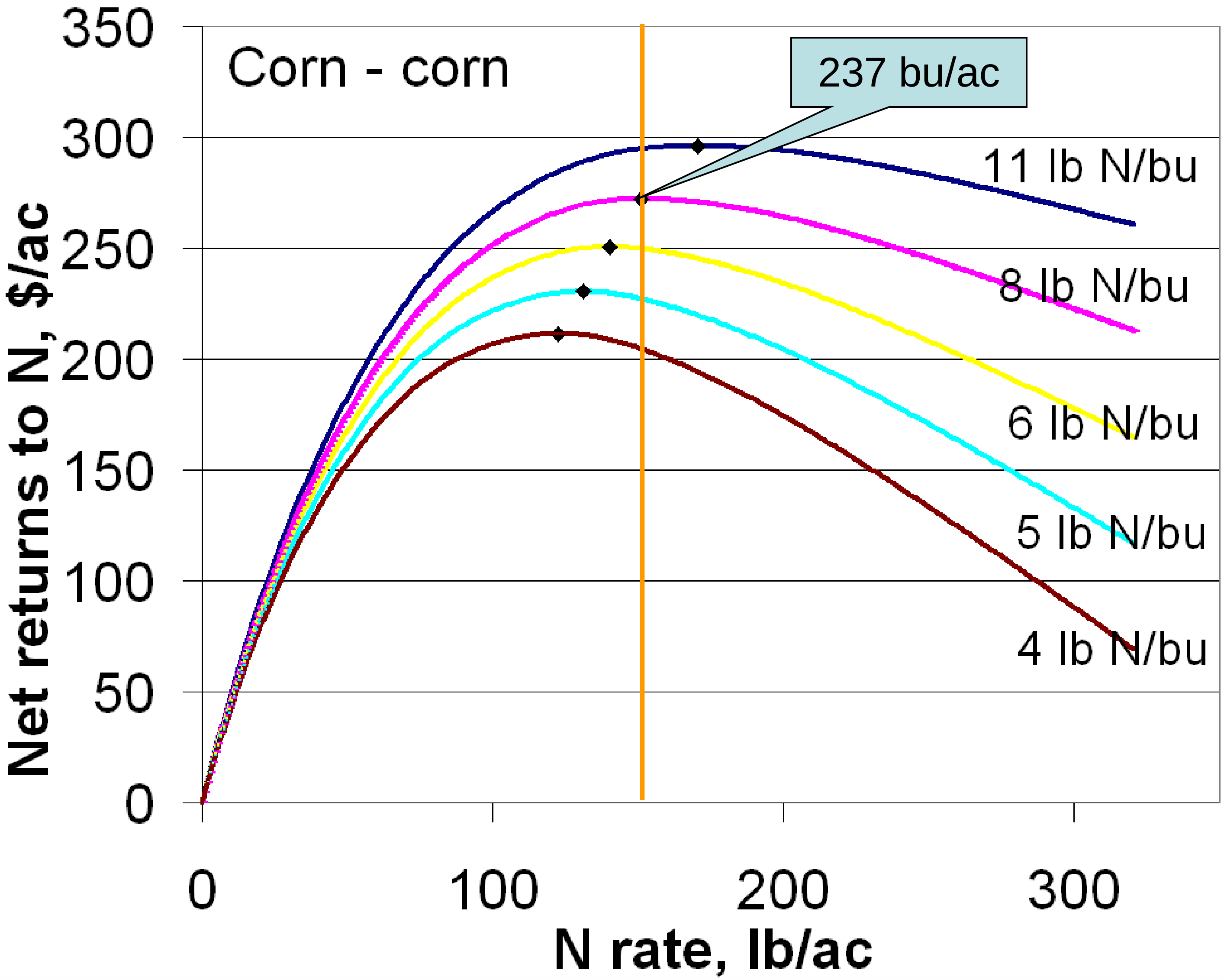
In-season determination of side-dress or fertigation N rate

- Pre-sidedress nitrate test (PSNT)
  - Most valuable with manure applied
  - Less valuable with cool spring or leaching conditions
- Canopy reflectance sensors/on-the-go adjustment of N rate

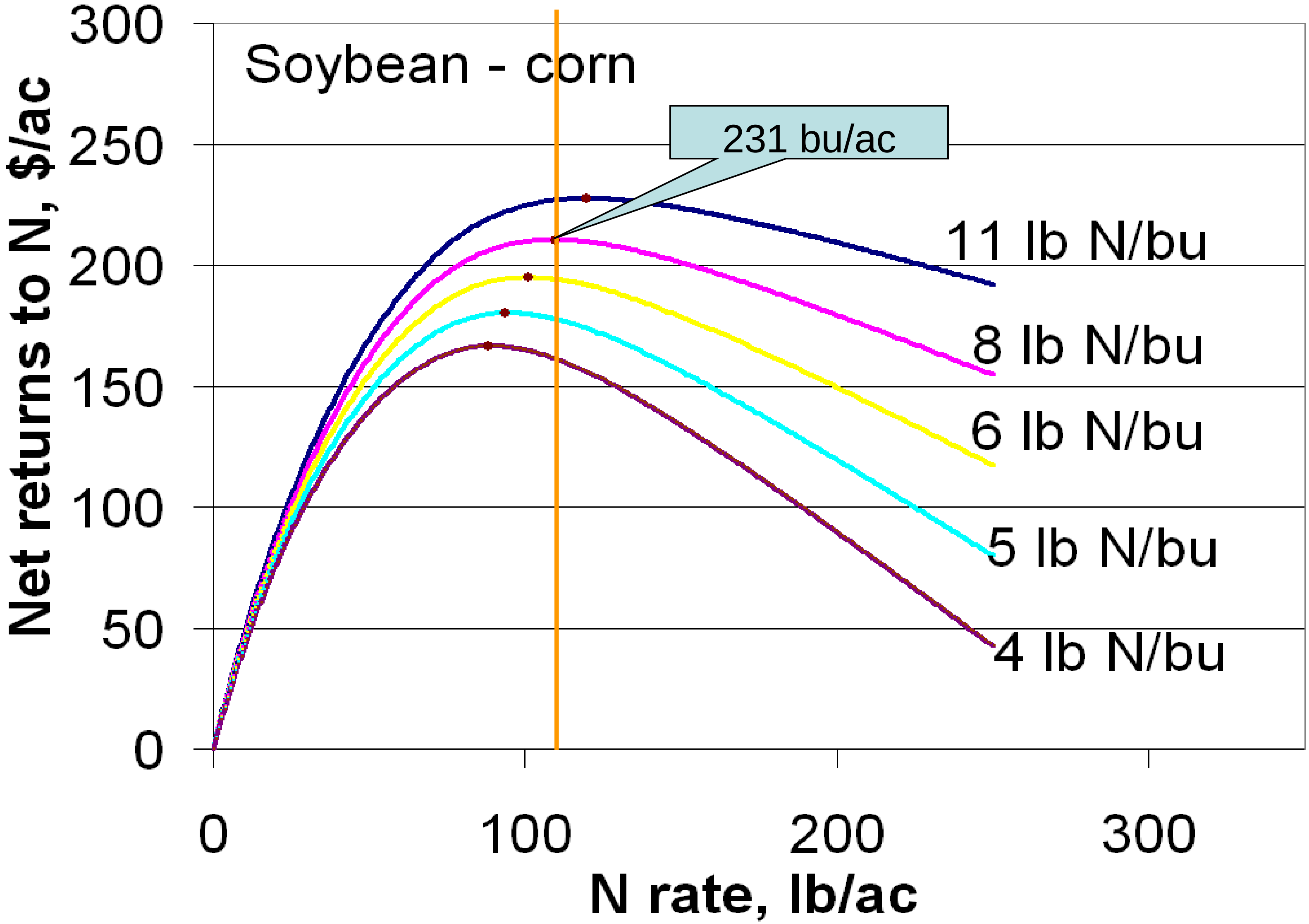
NUE and the economically optimal N rate (EONR)

- NUE is important to profitability and environmental production
- NUE was better when the previous crop was soybean compared with corn
- NUE was less, and residual soil nitrate–N was more, when N rates exceeded EONR
- EONR differs by field and year. Can we adequately predict EONR?

Most profitable mean N rates



Most profitable mean N rates



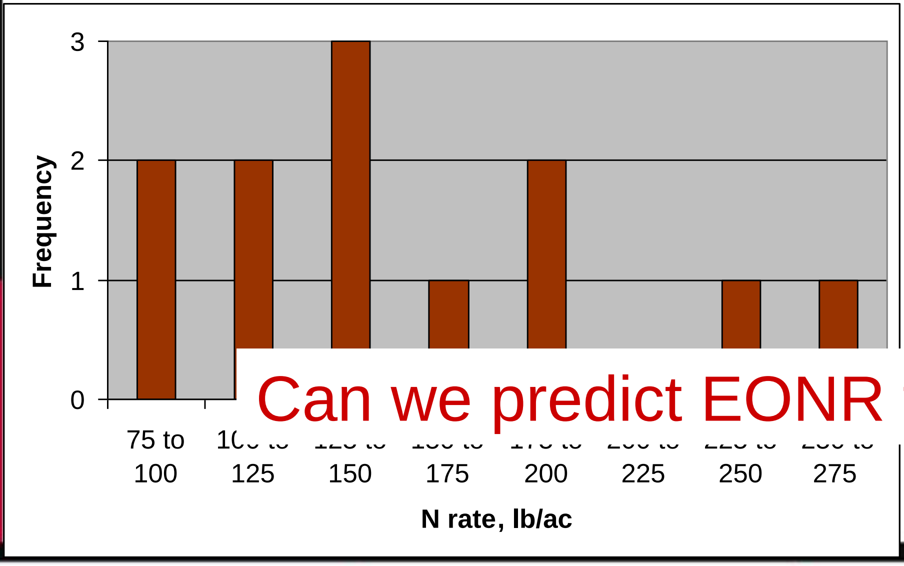
EONR distribution

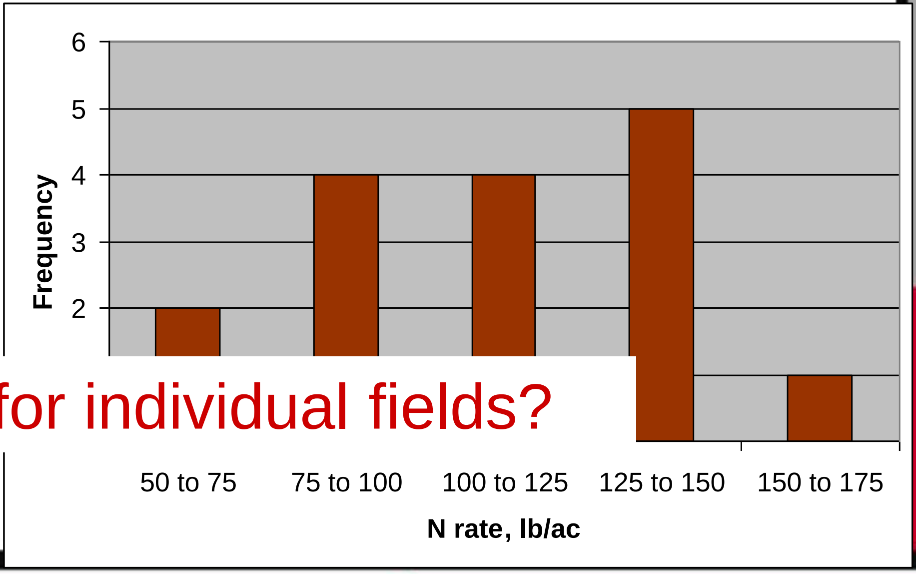
Corn-corn, 12 site-yr

- Mean = 155 lb/ac N
- Minimum = 91
- Maximum = 240
- Low 25% ≤ 114
- Top 25% ≥ 192

Soy-corn, 16 site-yr

- Mean = 111 lb/ac N
- Minimum = 72
- Maximum = 150
- Low 25% ≤ 93
- Top 25% ≥ 129





Can we predict EONR for individual fields?

University of Nebraska Nitrogen Corn Recommendation

N Rate (lb/acre) = 35 + (1.2 x EY) – (8 x NO_3-N) – (0.14 x EY x OM).

EY = Expected yield (bu/acre)
NO_3-N = Root zone residual nitrate-N (ppm)
OM = Soil organic matter (%)

Additional credits for legumes, manure and irrigation water subtracted from basic algorithm.

Adjustment for fertilizer:grain price
Adjustment for time of application

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How good is the UNL equation for N rate at high yield?

- On average, relative to mean EONR
  - 15 lb/ac over-estimate for corn:corn
  - = EONR for soybean:corn
  - 36 lb/ac over-estimate for drybean:corn;
    - definitely need to increase the N credit for drybean from 25 lb/ac to 50 lb/ac.

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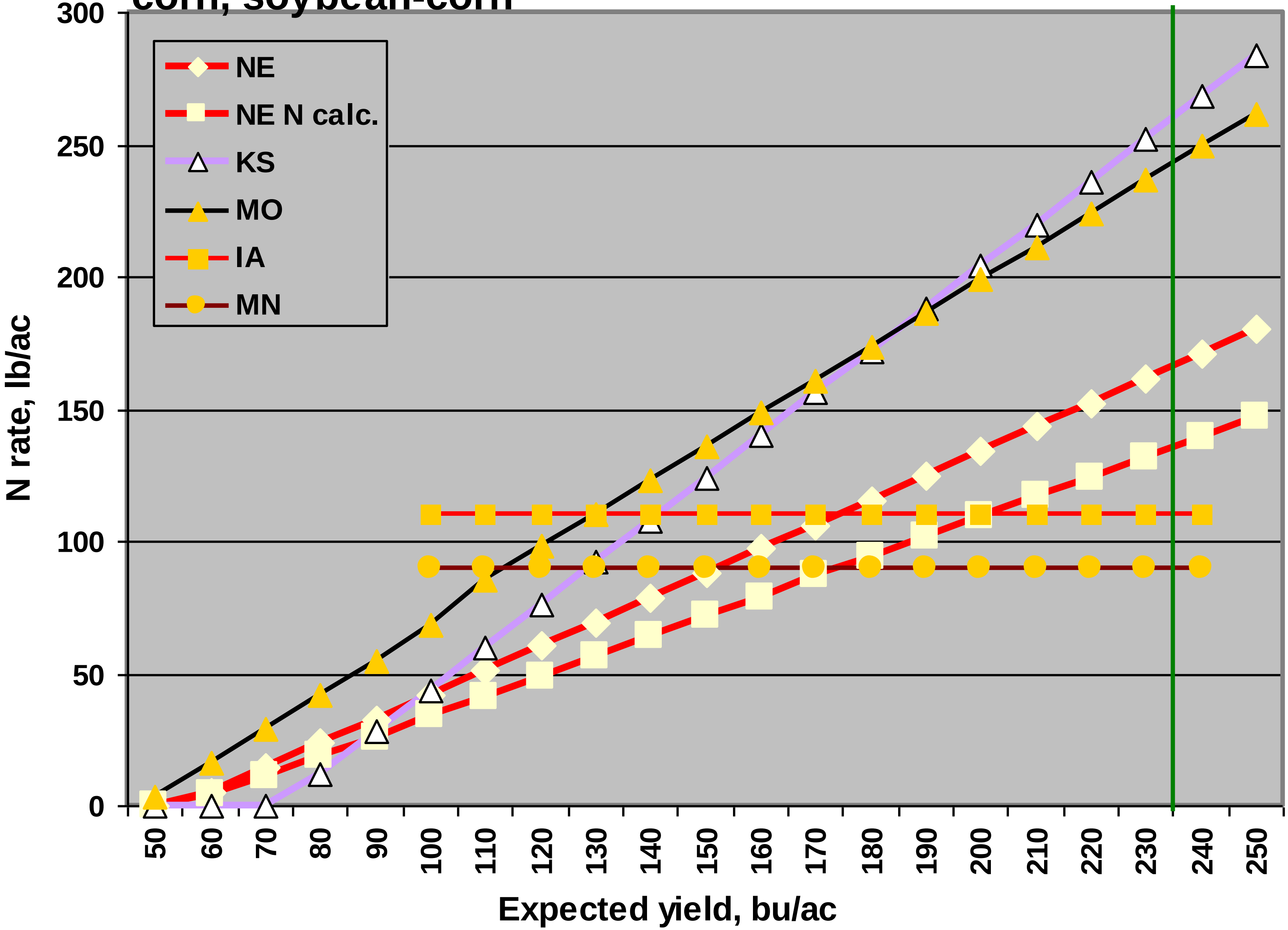
Does the UNL equation for N rate account for variation in EONR at high yields?

- The previous crop and price components are well justified.
- However, it did not account for much variation in EONR within cropping system, especially for corn-corn
- The UNL equation is better over a wider yield range, e.g. 50 to 270 bu/ac.

N rates with 2% SOM, 5 ppm NO3-N, $0.33 N, $2.20 corn, soybean-corn



"….belongs in every bathroom of every home" – Joseph Jenkins, author of the "*Humanure Handbook*".

"….This is the book to read if you give a crap about crap" – Sim van Der Ryn, author of the "*The Toilet Papers*".

"….in his naughty and inimical style, ………….. Read and heed." – Joel Salatin, author of the "*The Sheer Ectasy of Being a Lunatic Farmer*".

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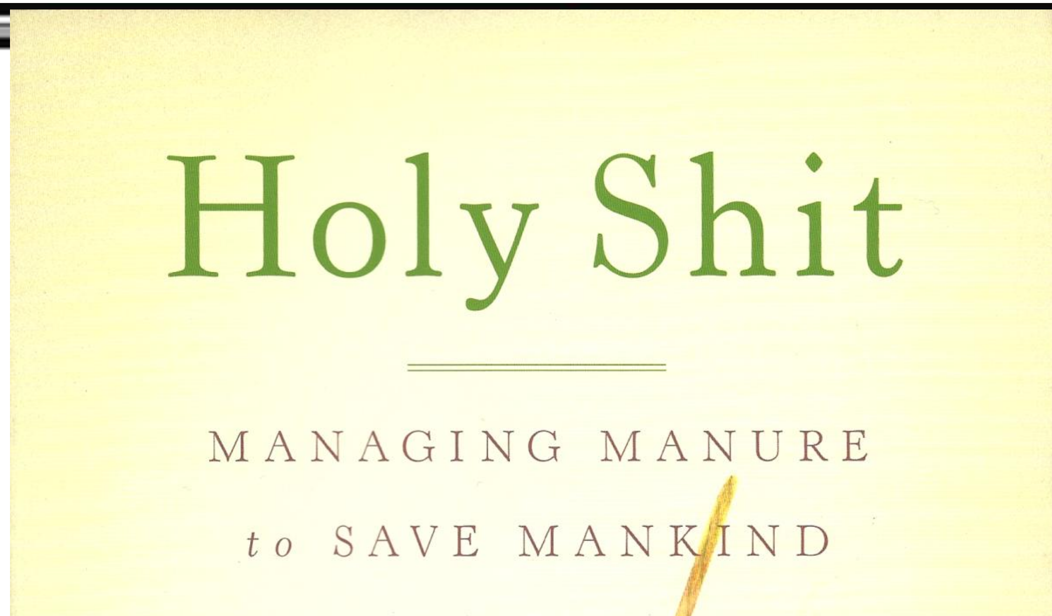

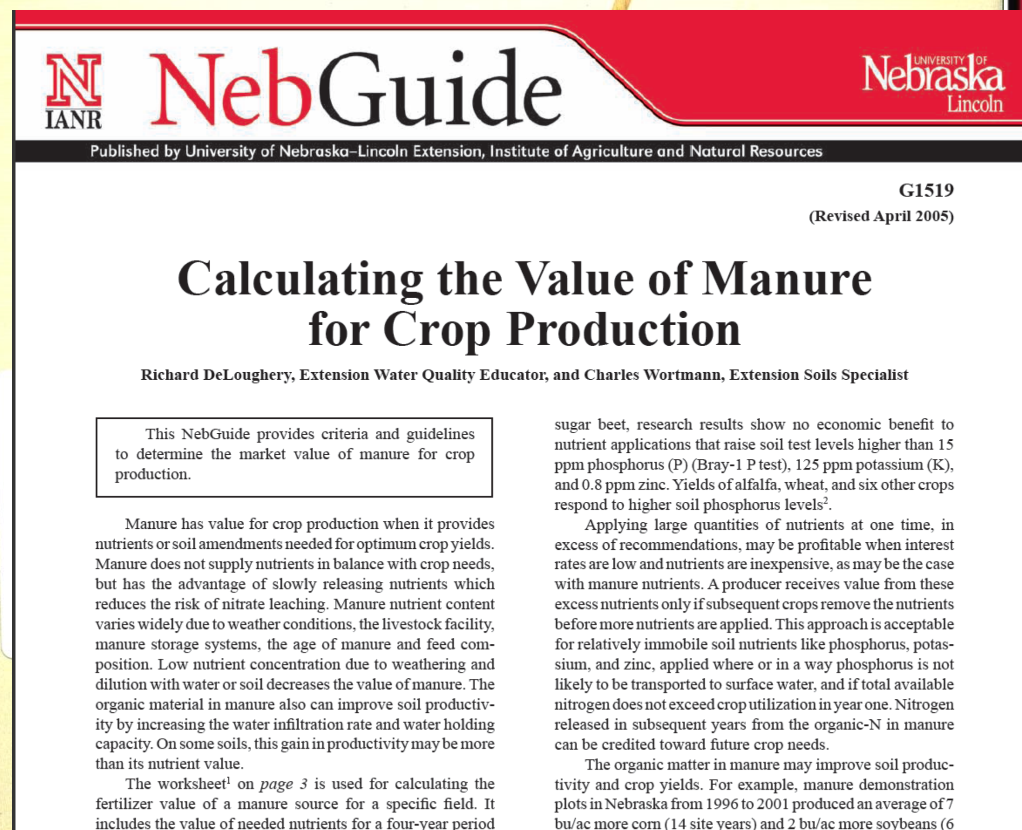

NebGuide

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Calculating the Value of Manure for Crop Production

Richard DeLoughery, Extension Water Quality Educator, and Charles Wortmann, Extension Soils Specialist

This NebGuide provides criteria and guidelines to determine the market value of manure for crop production.

Manure has value for crop production when it provides nutrients or soil amendments needed for optimum crop yields. Manure does not supply nutrients in balance with crop needs, but has the advantage of slowly releasing nutrients which reduces the risk of nitrate leaching. Manure nutrient content varies widely due to weather conditions, the livestock facility, manure storage systems, the age of manure and feed composition. Low nutrient concentration due to weathering and dilution with water or soil decreases the value of manure. The organic material in manure also can improve soil productivity by increasing the water infiltration rate and water holding capacity. On some soils, this gain in productivity may be more than its nutrient value.

The worksheet[1] on *page 3* is used for calculating the fertilizer value of a manure source for a specific field. It includes the value of needed nutrients for a four-year period

sugar beet, research results show no economic benefit to nutrient applications that raise soil test levels higher than 15 ppm phosphorus (P) (Bray-1 P test), 125 ppm potassium (K), and 0.8 ppm zinc. Yields of alfalfa, wheat, and six other crops respond to higher soil phosphorus levels[2].

Applying large quantities of nutrients at one time, in excess of recommendations, may be profitable when interest rates are low and nutrients are inexpensive, as may be the case with manure nutrients. A producer receives value from these excess nutrients only if subsequent crops remove the nutrients before more nutrients are applied. This approach is acceptable for relatively immobile soil nutrients like phosphorus, potassium, and zinc, applied where or in a way phosphorus is not likely to be transported to surface water, and if total available nitrogen does not exceed crop utilization in year one. Nitrogen released in subsequent years from the organic-N in manure can be credited toward future crop needs.

The organic matter in manure may improve soil productivity and crop yields. For example, manure demonstration plots in Nebraska from 1996 to 2001 produced an average of 7 bu/ac more corn (14 site years) and 2 bu/ac more soybeans (6

Will higher fertilizer rates be needed for 300-bu corn & 100 bu soybean?

- Probably, because of greater nutrient removal
- However, recent and current high yield research results indicate
  - Increases will be moderate and consistent with increased yields and nutrient removal
  - Nutrient use efficiency increases with increased yield potential if nutrient application is at most profitable rates
  - Recommendations may require minor revision; on-going research is needed

Soybean N

Early yellow leaves with cool wet conditions

N fixation begins with 2-3 open trifoliate leaves

Starter N?

1. Yes in northern latitudes, including Brookings SD, and High Plains
2. No yield advantage for most of the Corn Belt
3. What about heavy residue situations?

2011 SMFD starter N/foliar trials

- Funded by the Nebraska Soybean Board
- Treatments
  - Row cleaning
  - Starter N as diluted UAN with split emitters
    - Different rates and placements
  - Foliar application at V4 and R2
    - Nachurs N-Rage: 23-4-2 with 0.05% Mn; the N is 67% triazone; rate = 2 gal/Ac (lb/Ac 5.1-0.9-0.4).
    - Nachurs SoyGrow: 0.36% Fe, 0.5% Mg, 2.6% Mn, and 1.5% Zn (~1/3 oz Zn/A); rate = 1 pt/Ac (lb/Ac 0.005-0.007-0.036-0.021).
    - ~$20 to $21/Ac

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Average grain yield

Treatment	Means for 4 locations (bu/Ac)
Control	**64.8**
Row cleaning	65.0
5 lb N in-furrow	65.9
10 lb N in-furrow	**66.3**
10 lb N inject 2” to side	65.9
10 lb N over the row	64.1
Foliar V4	64.8
Foliar R2	67.2
Foliar V4 and R2	65.9
Starter plus Foliar V4 and R2	67.1
Significance	ns

What is the risk?

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Average grain yield

Treatment	Means for 4 locations (bu/Ac)
Control	**64.8**
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Foliar V4	64.8
Foliar R2	**67.2**
Foliar V4 and R2	**65.9**
Starter plus Foliar V4 and R2	**67.1**
Significance	ns

Mean for R2 foliar = 66.7***. Which nutrients had the effect?

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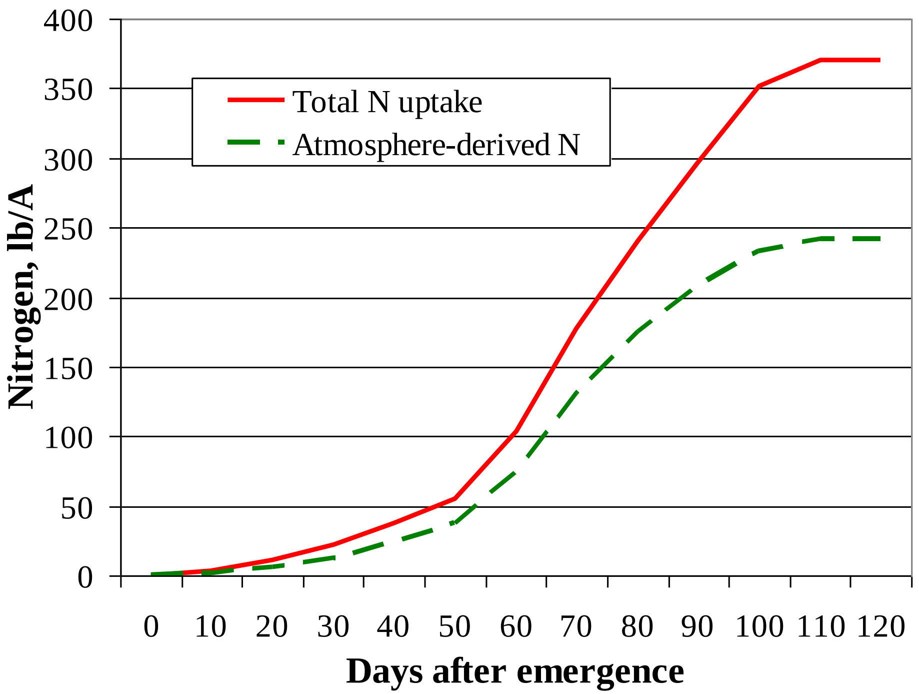
Oil and protein

Location	Protein	Oil
Bancroft	33.2	19.8
Cortland	34.7	18.8
Elba	33.9	19.2
SCAL	33.8	19.2

No starter N or foliar effects on oil or protein. Mean of 6.7% moisture.

N application at early pod development



Nebr. 2009-2010: 56 trials conducted.

With 27 lb/A N applied, >60 bu/A	Yield increase, bu/A
South-central	**2.5**
Northeast	**1.5**
Southeast	**0.3 ns**

No more gain with 54 lb N or N+4.5 lb S.

A "High Yield" trial: Treatments

- Clipping, or Cobra (Lactofen) applied @ 12 oz/A, at V2 to break apical dominance for more branching and pods
  - Not a new idea
  - Increased risk of lodging
  - Soybean produces excess flowers and pods; aborts according to the crop's potential until R3

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“High yield” trial

Effect of practices was mostly consistent across sites; no treatment x site interaction.

Clipping and Cobra resulted in reduced yield.

Other practices did not affect yield.

Treatment	Yield bu/A
Full package (FP)	58.1
FP with Cobra	61.8
FP – starter N	60.1
FP – foliar	59.5
FP – Bioforge	61.3
FP – Optimize 400	60.0
FP – clipping	65.6
Minus all	65.7
Significant	***

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Thank you!

Questions?

SMFD High Yield: treatments

- Bioforge
  - Non-regulated growth promoter for increased stress tolerance
  - Seed treatment, 4 oz/cwt
- Optimize 400
  - elite *Bradyrhizobium japonicum* inoculant
  - "LCO *(Lipo-chitooligosaccharide) Promoter Technology*"
  - Earlier and increased nodulation?
  - Increased root growth?

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Treatments

- 5 lb starter N in-furrow
- Foliar NPK + micro-nutrients at R2

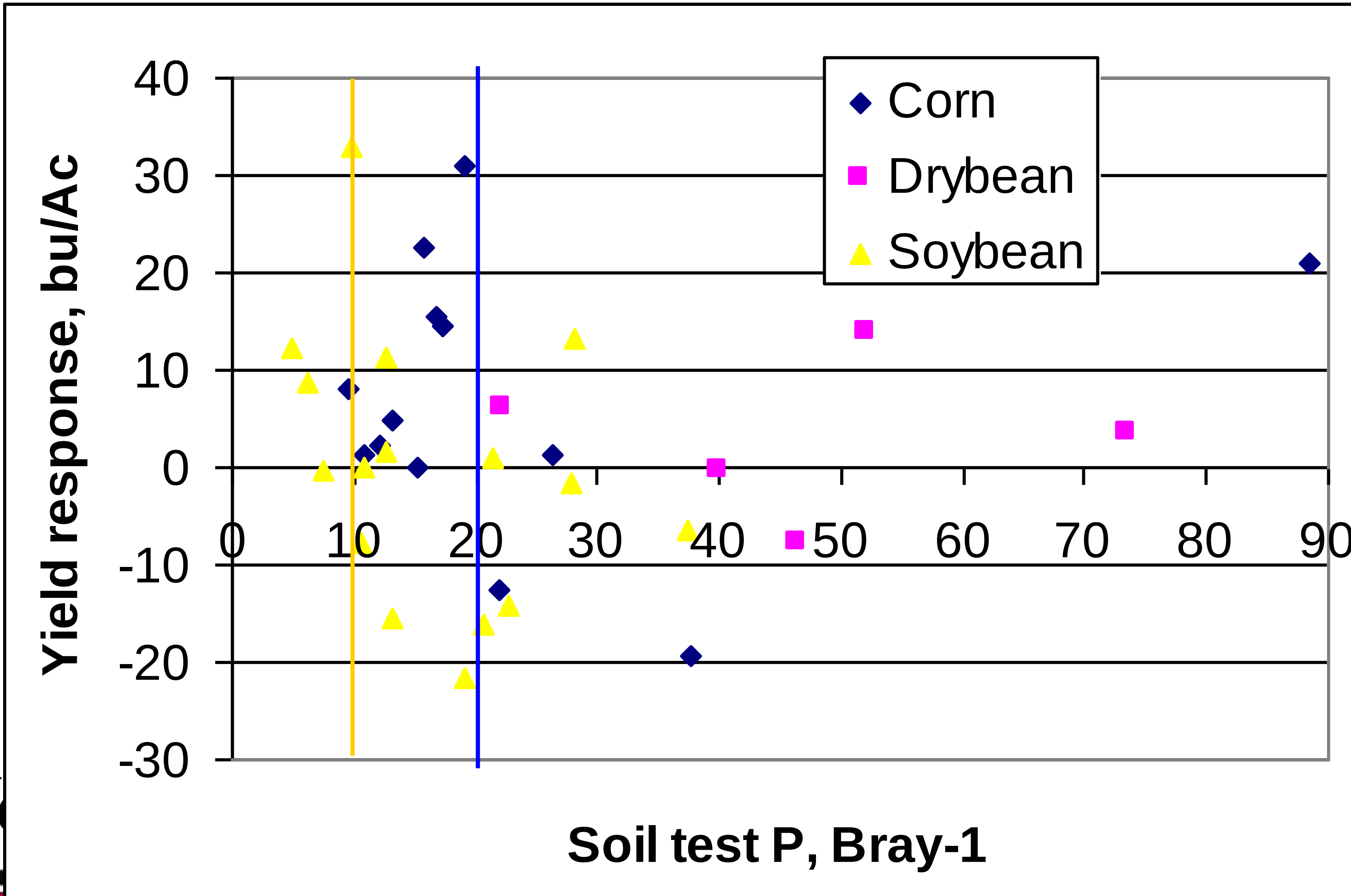
Treatment configuration

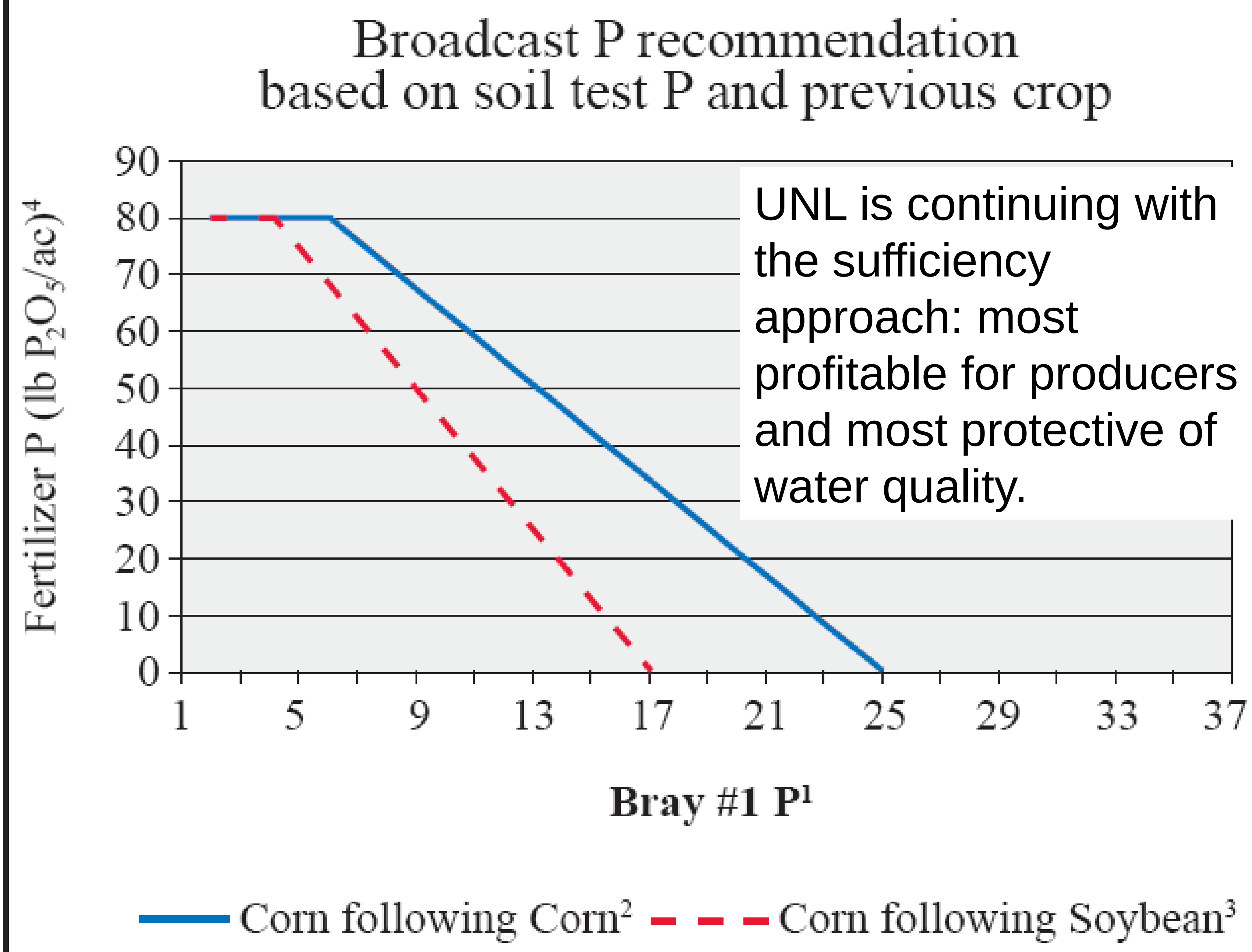
- Minus-one, omission, or 'kitchen sink minus one' trial
  - The full package of treatments is compared to the full package minus one practice

High Yield Soybean Trial

	5 lb. Starter N in Seed Furrow	Foliar NPK + Micro at R2/3	BioForge Seed Treatment	Optimize 400 Seed Treatment	Clipping at V2
1. Full					
2. Full With Cobra					Cobra at 12.5 oz/Ac at V2
3. Minus Starter N					
4. Minus Foliar					
5. Minus BioForge					
6. Minus Optimize 400					
7. Minus Clipping					
8. Minus All					

Corn response to 40 lb applied P_2O_5

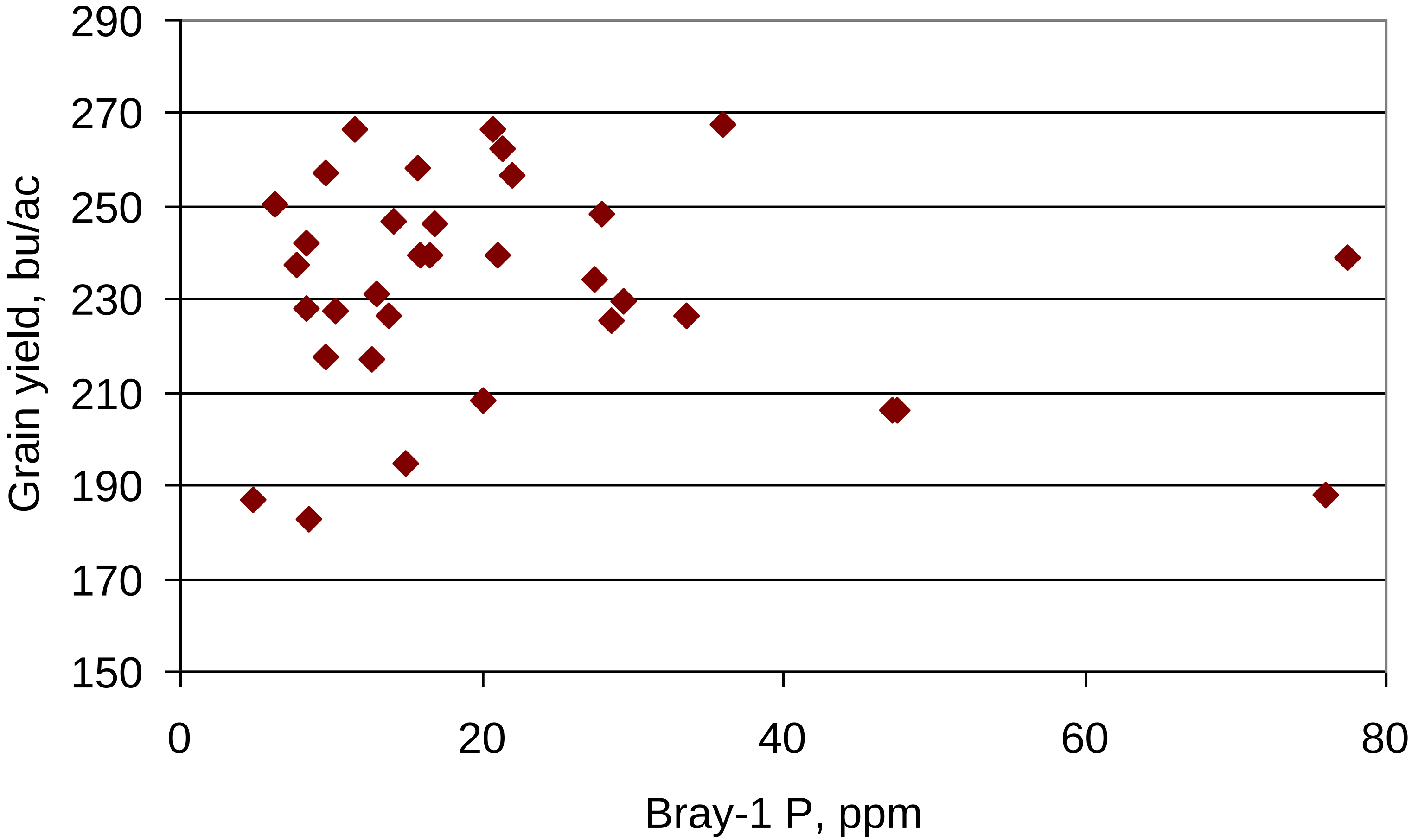




UNL is continuing with the sufficiency approach: most profitable for producers and most protective of water quality.

From: Shapiro et al., 2009.

Is high soil test P needed for high yield corn?



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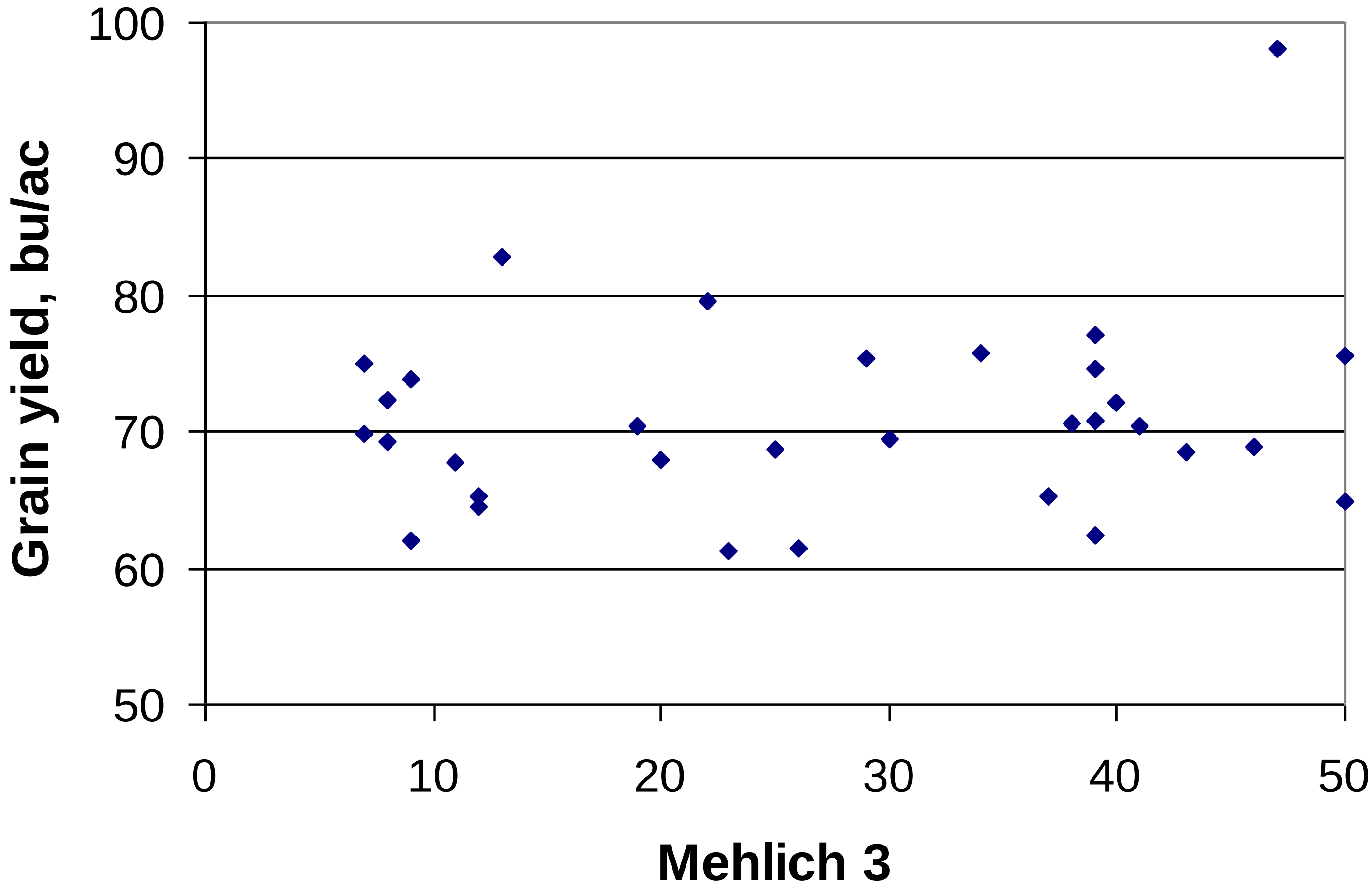
STP and soybean yield, 32 trials on different sites in Nebraska with >60 bu yield



Slow-to-warm soils issue

- MN results show that high STP may be important in cases of slow to warm soils
  - Latitude dependent issue
  - High priority for research

STP levels and high yield

- South Central Ag Lab
  - STP levels from <10 to 65 ppm Bray-1
  - No effect on ridge-till yield
- Research to begin in 2011; until 2016
  - ARDC, HAL, WCREC
  - STP: <15, 25, 35 ppm
  - Continuous corn, with and without tillage
  - Funded by IPNI
  - Corn-soybean: funding?

Soil test levels

- Will 300/100 bu yields need relatively high soil test levels?
  - Nutrient removal will increase
  - But high yield crops are expected to have healthy, well-developed roots systems efficient in nutrient uptake

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Reasons to consider maintaining high soil test levels

- Soil test levels vary across field; maintaining higher levels reducing risk of having low level areas
  - Minimize risk with site-specific management
- Applications can be withheld for one or two years in cases of unusually high costs
  - Depends on rental arrangements

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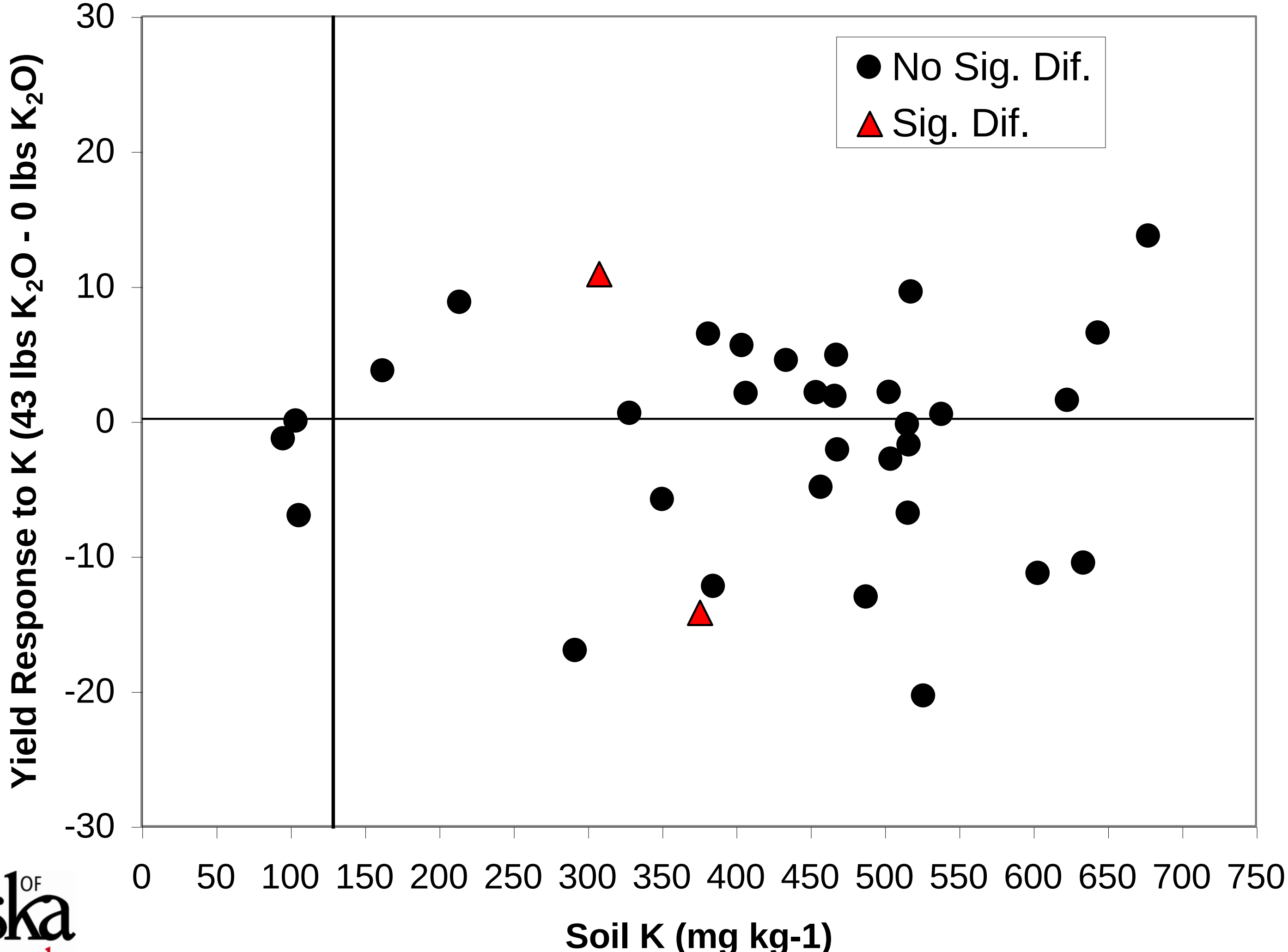
Potassium Responses



K application often results in reduced grain and biomass yield in Nebraska

Previous crop	0 kg/ha K	40 kg/ha K
Soybean	229	222*
Corn	235	232
Drybean	235	225
All	230	226*

Supported by findings of Miany and Olson (Miany, 1980) at UNL-ARDC and by McCallister et al. (1988) across numerous site-years.

Table VI. Potassium fertilizer suggestions.

Potassium Soil Test, ppm K	*Relative Level*	*Amount to Apply Annually (K_2O), lb/ac*		
		Broadcast[1]		**Row**[2]
0 to 40	Very Low (VL)	120	plus	20
41 to 74	Low (L)	80	plus	10
75 to 124	Medium (M)	40	or	10
125 to 150	High (H)	0		0
Greater than 150	Very High (VH)	0		0

From: Shapiro et al., 2009.

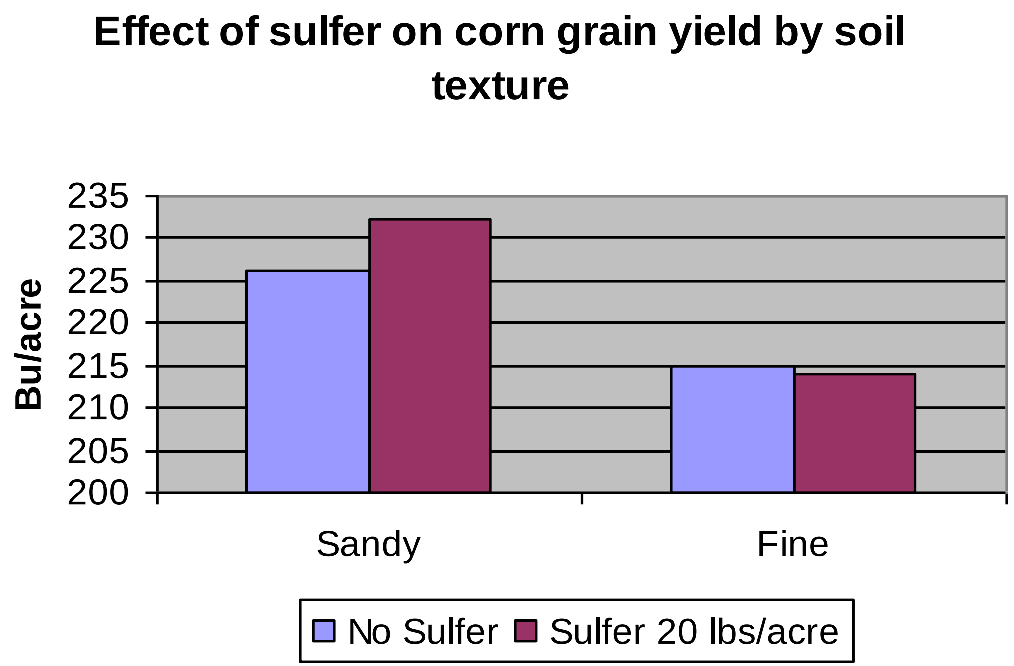
Effect of 20 lb S/Ac, irrigated NSFP trials

5 trials each for sandy and medium/ fine textured soil.

No additional response to 40 lb S/Ac.

Supported by results from 28 UNL starter S trials in past 10 years

Dakota Dirt: 11 S trials in SD in 2010; no significant responses; Mean 135 bu/ac. Also, 78 trials over the years with <40lb S in 2’ depth; 15% had a yield increase.



Lincoln

Does Bt rootworm resistant corn need more fertilizer?

- 6 of the varieties used in the 34 high yield trials were Bt RR resistant
  - Not a good test, but informative
  - Average EONR was lower with Bt Rr; N recovery efficiency was greater
  - P uptake was less and S uptake was more with Bt RR; uptake of Ca, Mg, K not affected
- No, Bt RR does not need different fertilizer management
- Adjust N rate for increased yield

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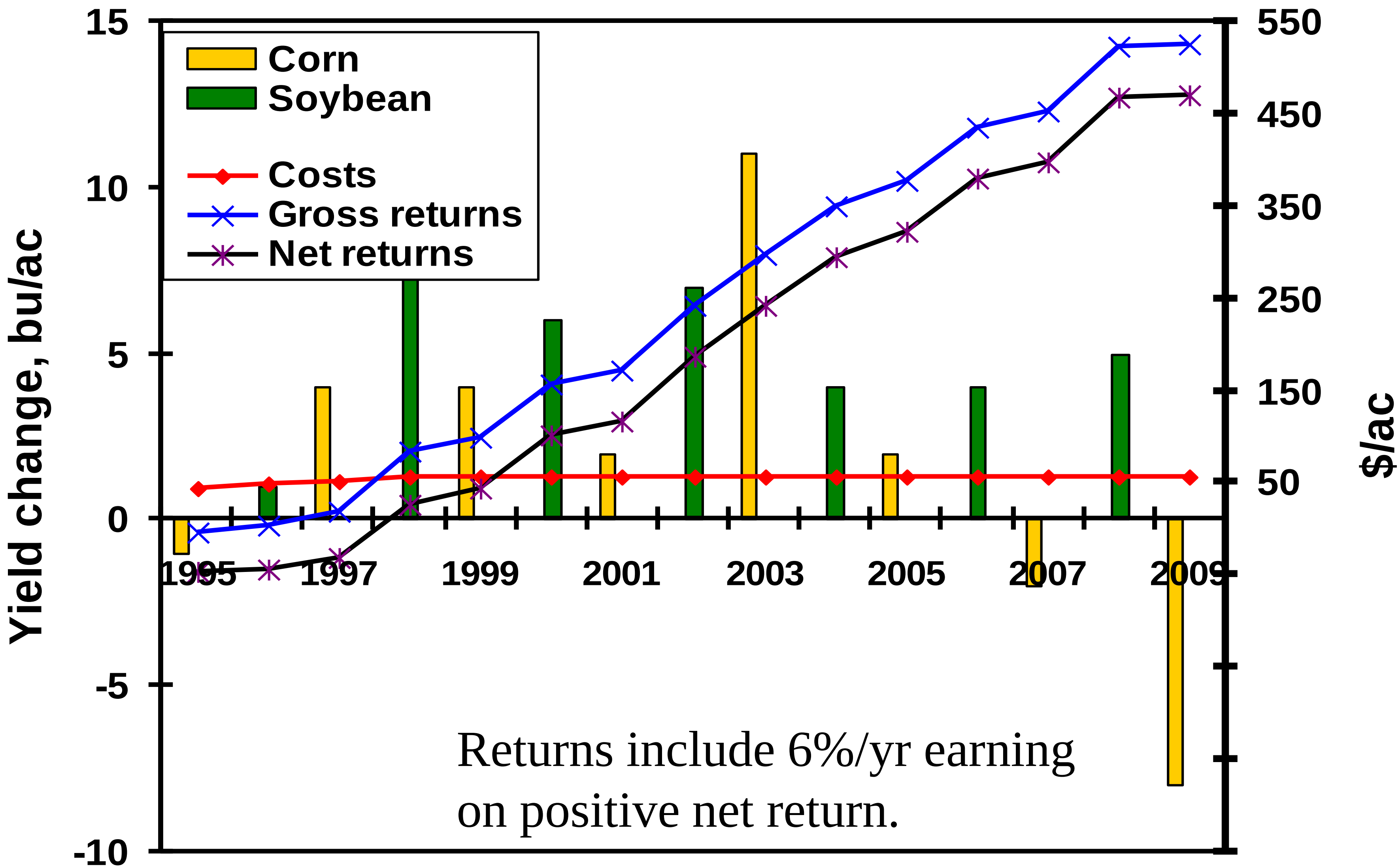
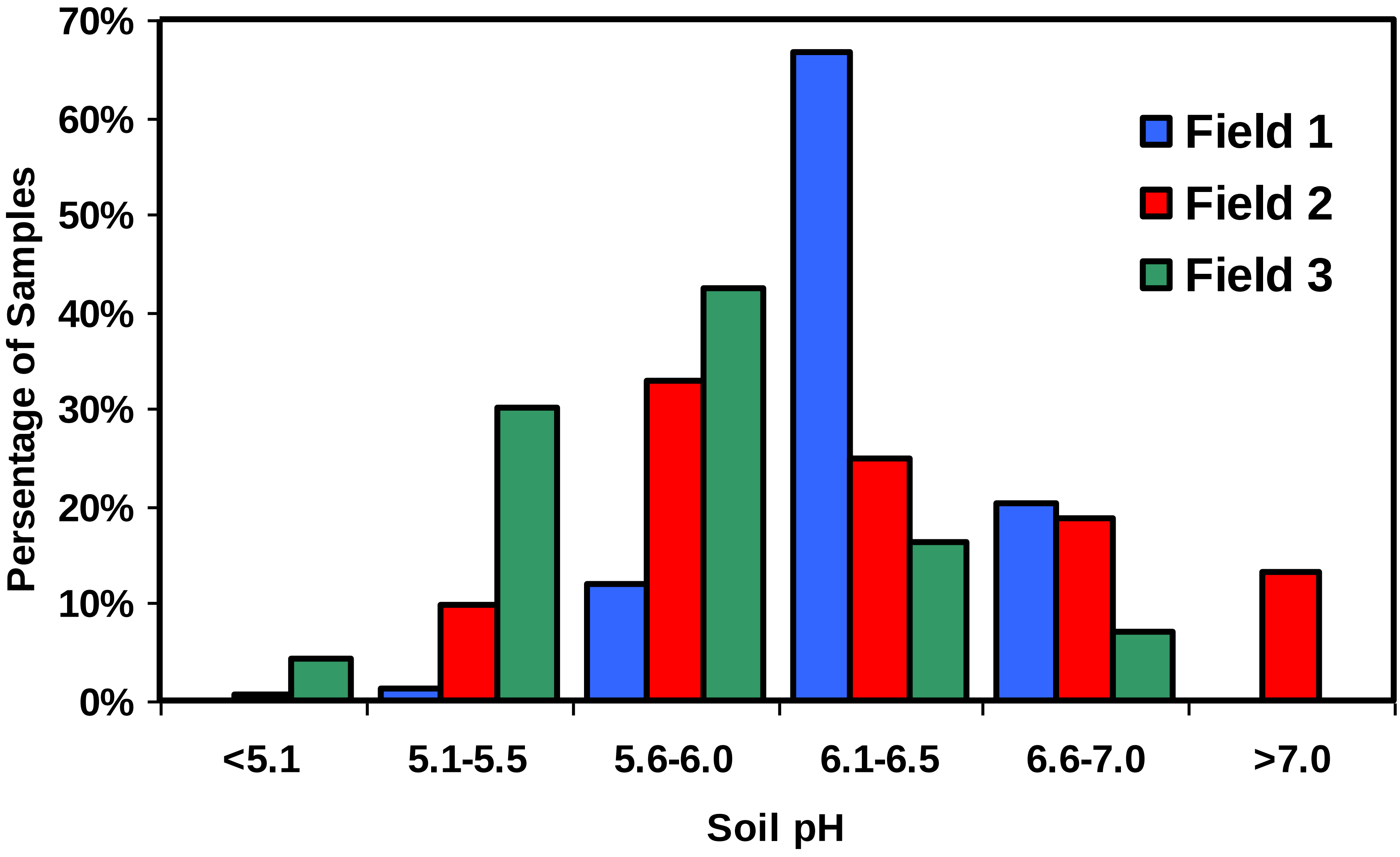
IANR

Lime use to amend acid soils



Variable rate lime application



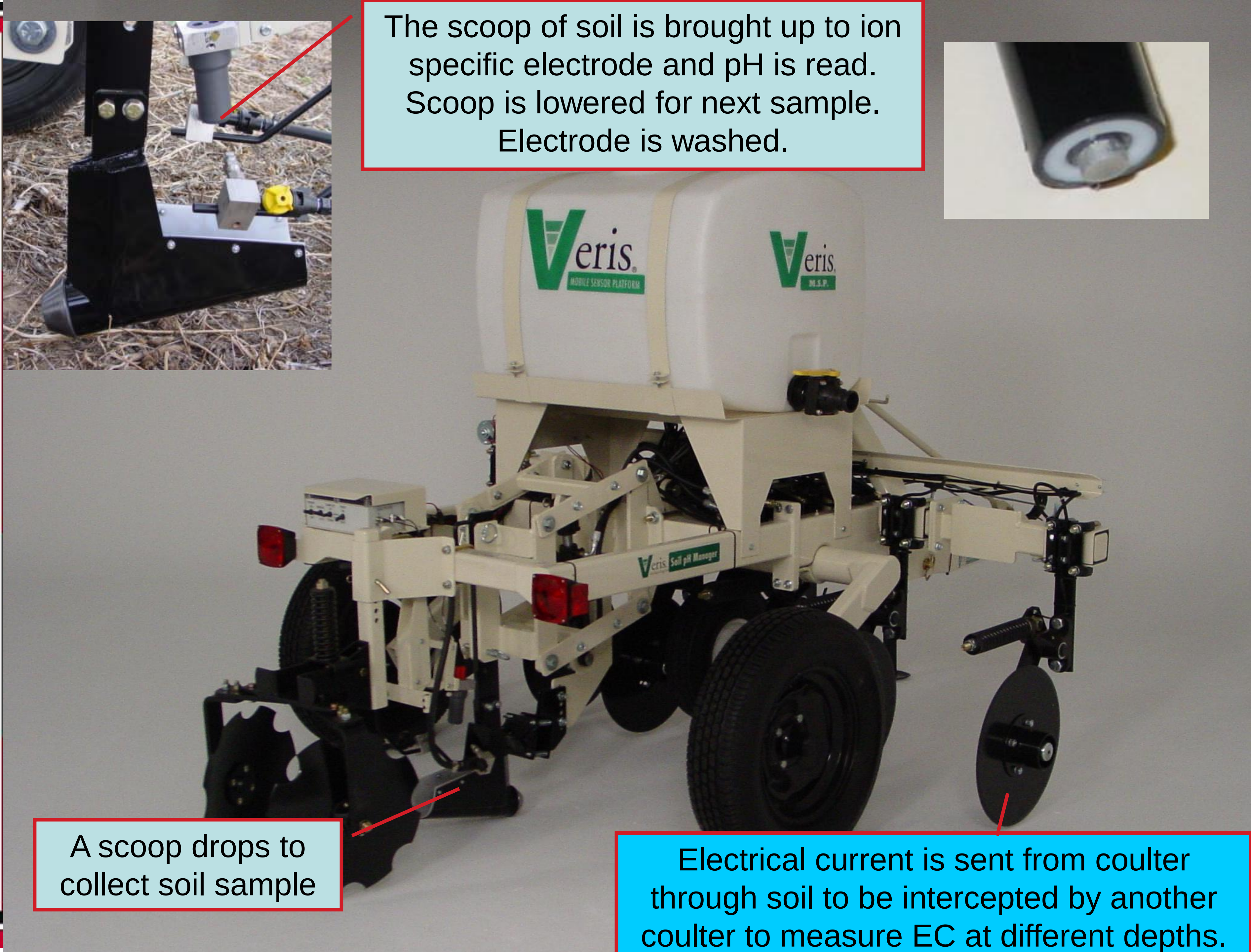
70%
60%
50%
40%
30%
20%
10%
0%
Persentage of Samples
Field 1
Field 2
Field 3
<5.1
5.1-5.5
5.6-6.0
6.1-6.5
6.6-7.0
>7.0
Soil pH

Management zones or targeted soil sampling

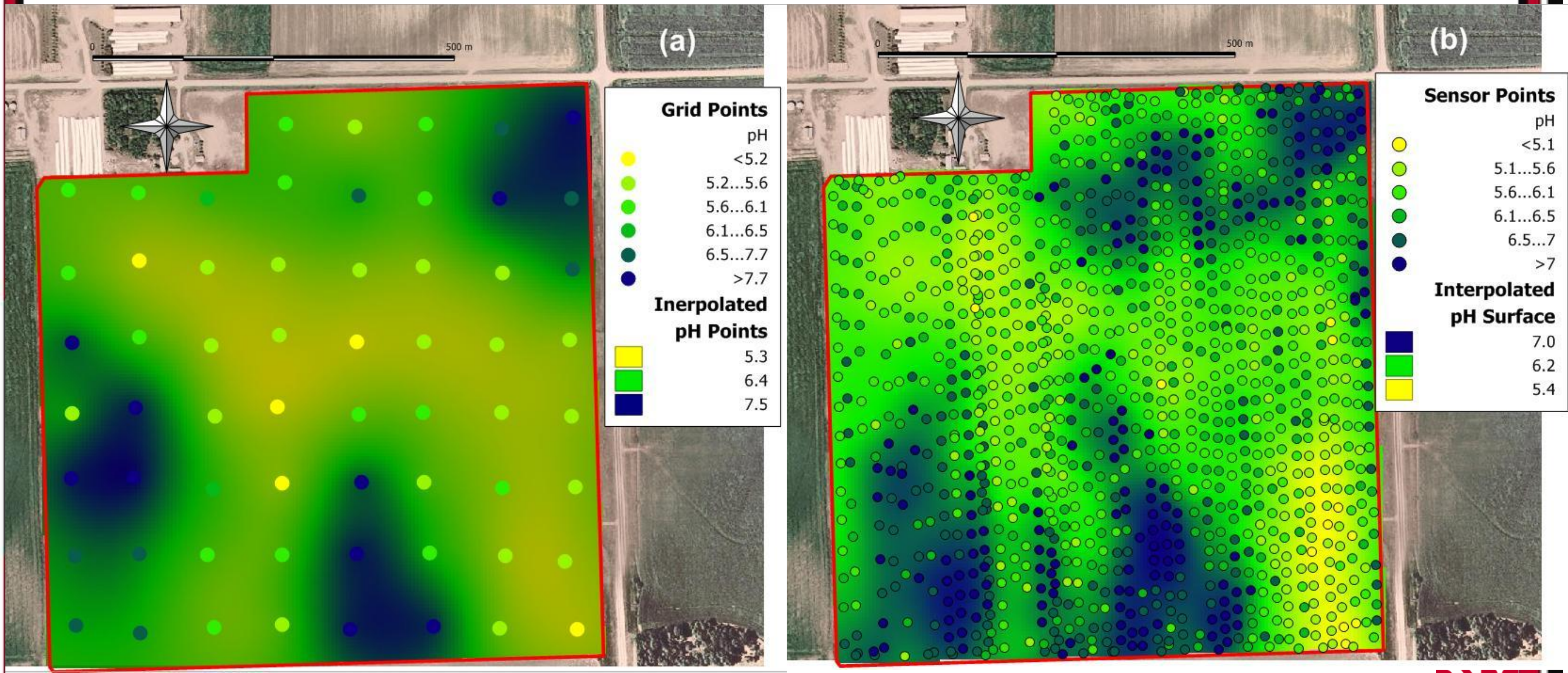
- Zones may be 1 (e.g. an old farm place or feedlot) to 40 acres
- Samples should be composites of ≥10 cores
- Check for variation in soil pH
  - Can be done in the field
  - Send to lab
- Do the results confirm zonation? Is there much difference in pH and does it differ by zones? Is more detailed mapping justified?
- Learn from your fields.

Grid sampling for lime requirement


Veris
M.S.P.
Veris
MOBILE SENSOR PLATFORM
368A


The scoop of soil is brought up to ion specific electrode and pH is read. Scoop is lowered for next sample. Electrode is washed.
Veris
MOBILE SENSOR PLATFORM
Veris
M.S.P.
Veris
Soil pH Manager
A scoop drops to collect soil sample
Electrical current is sent from coulter through soil to be intercepted by another coulter to measure EC at different depths.

Grid sampling vs sensor mapping of soil pH: JL field



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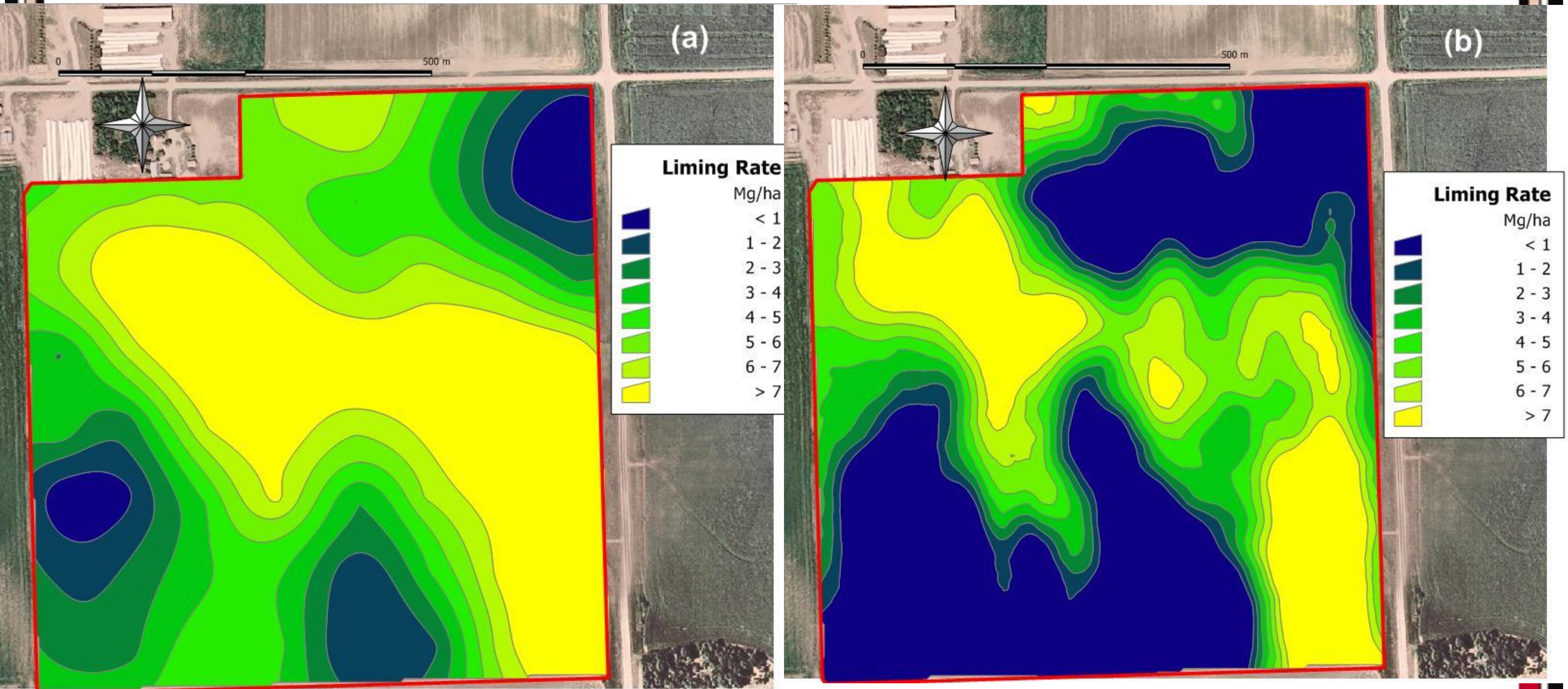
Contour liming rate by grid sampling and by sensor, JL



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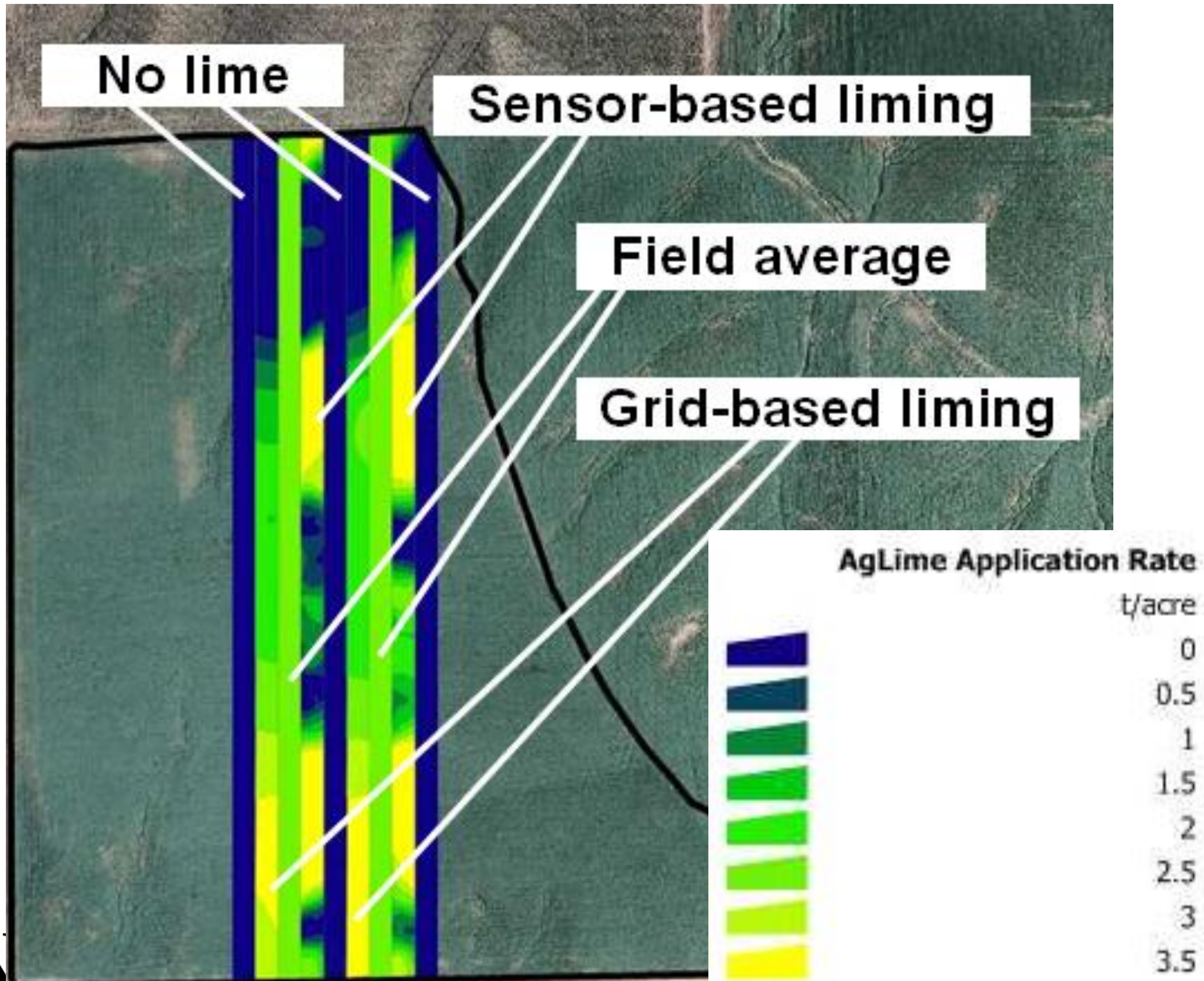
The agronomics and economics of variable rate liming



Nance, Saunders, and Wayne Counties

4 treatments

2 reps

Continue 2010 to 2014

Nebraska UNIVERSITY OF Lincoln EXTENSION

Know how. Know now.

EC117

Fertilizer Suggestions for Corn

Charles A. Shapiro, Richard B. Ferguson, Gary W. Hergert, and Charles S. Wortmann, Extension Soils Specialists; Daniel T. Walters, Professor of Agronomy and Horticulture

Fertilizer nutrient requirements for corn are based on expected yield and nutrient levels in the soil. This revision contains slight changes to the nitrogen (N) recommendation equation

depth of 0 - 8 inches every three to five years in the fall. Most Nebraska soils supply adequate amounts of K, sulfur, zinc, and iron, but on some soils the corn crop will benefit from applying

CropWatch: Soil Management

Soils and soil management recommendations

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CROPWATCH

Soil Management to Optimize Crop Production in Nebraska

Nutrient Deficiencies

- Key to Nutrient Deficiencies in Soybean -**NEW**
- Key to Nutrient Deficiencies in Wheat and other Small Grains -**NEW**
- Key to Nutrient Deficiencies in Corn and Sorghum

Plant symptoms can be used to differentiate and identify crop nutrient disorders. Symptoms of

Soil Test

Soil Test Nebraska

University of Nebraska Department of Agronomy and Horticulture site for fertilizer recommendations.

Calculate fertilizer recommendations for all crops produced in Nebraska:

1. Directly enter crop and soil test information, or,
2. Upload files with test information from ...cal laboratories.

http://cropwatch.unl.edu/web/soils/home/

New

Free Slide Rule Offers Quick Calculation for Nitrogen Rates

Click here for more information on how to

Featured Pubs

UNL Publication:

Fertilizer suggestions for

http://cropwatch.unl.edu/web/corn/home

CropWatch: Corn

Nebraska Corn Production, Pest Management, and Research Information

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CROPWATCH

Nebraska Corn

The lastest information on corn production and management practices from the University of Nebraska-Lincoln.

Corn Planting Depth, Date, and Population Information

With these nice spring days, you may be eager to start planting, even in wet soils where planting may be difficult. Remember that many agronomic problems that occur later in the season start with how things were done at planting, particularly the planting depth you use. For more information on problems related to planting depth, click here. You can also check out the April 2, 2010 Market Journal segment on this topic by clicking here.

As corn hybrid genetics and seed treatments continue to improve, producers

Upcoming Events

Please check the Crop Watch Calendar for Upcoming Events!

Corn Facts

Corn is an economically important crop to Nebraska resulting in $5.8 billion in 2009 from 8.9 million acres harvested according to USDA National Agricultural Statistics Service.

1. Nebraska ranks 3rd in U.S. corn production
2. Nebraska has 8.5 million irrigated acres
3. Ethanol plants utilized 38% of Nebraska's grain (2007)
4. Nebraska ranks 1st in U.S. popcorn production

Summary

- The mean economically optimal N rates (EONR) for irrigated corn: 155, 111, and 83 lb/ac, resp., when the previous crop was corn, soybean, and drybean, and the fertilizer N to corn price ratio was 8 lb N per bu.
- The respective yields at EONR were 237, 231, and 218 bu/ac
- At mean EONR, the recovery efficiency was 62, 76, and 21% for CC, CS, and CD.

Summary

- The UNL algorithm predicted mean EONR 16 lb/ac high for corn:corn, was right on for soybean:corn, but greatly over-recommended N for drybean:corn.
- Grain: N price factor is important
- Difficult to predict $EONR_{site\text{-}year}$ for corn after corn
- P recommendation revised in 2009.
- K and S recommendations well validated.

Thank you!

Questions?