Is Lost Nitrogen Really Lost (for Good?)

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(Yes) –Why the Question?

- Wet weather in May or June can cause crop yellowing:
- If the problem is root (and then plant) damage, adding more N often won't help
- If soil N is truly lost, we expect the response to N rate to be changed; adding N might pay
- If N is only moved deeper, it might still be available
- Today, we'll if consider "lost" N might be more available than we expect, and whether and how we might be able to tell

The N Cycle

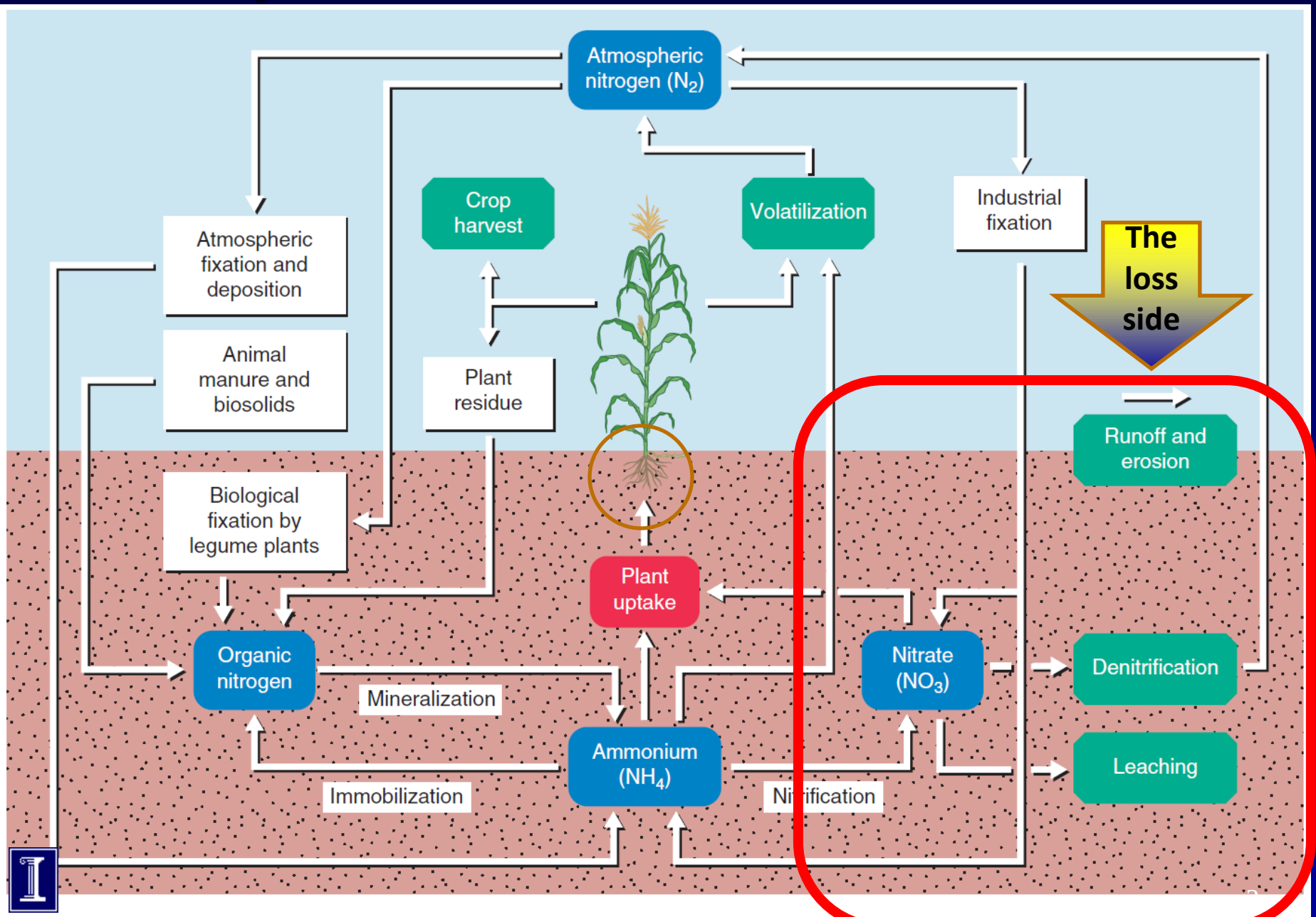


Figure 9.7. The nitrogen cycle.

N Getting Lost

- The only "losable" form (other than in sand, where urea can leach) is nitrate
  - Urea-N and ammonium-N need to be converted to NO_3 (nitrification) before they can be lost
  - Nitrification is a biological process and requires O_2; it's faster when soils are warm and aerated, with high microbial activity
- Leaching loss decreases as clay content increases, and increases with tile drainage
- Denitrification requires anaerobic (saturated = water in pore space and low O_2) conditions and is also biological, so faster when warm

Real Loss

- NO_3 leaching is not fast in medium or heavy-textured soils, but over time it can amount to substantial loss
- Denitrification can certainly play a role, but it's typically less than tile line loss in tile-drained fields
  - Requires at least 80% of pore space to be filled with water for O_2 depletion
  - Responds directly to soil temperature
  - Cool soils and cool weather lower denitrification: rainwater carries more O_2 at lower temps, and microbial activity is lower

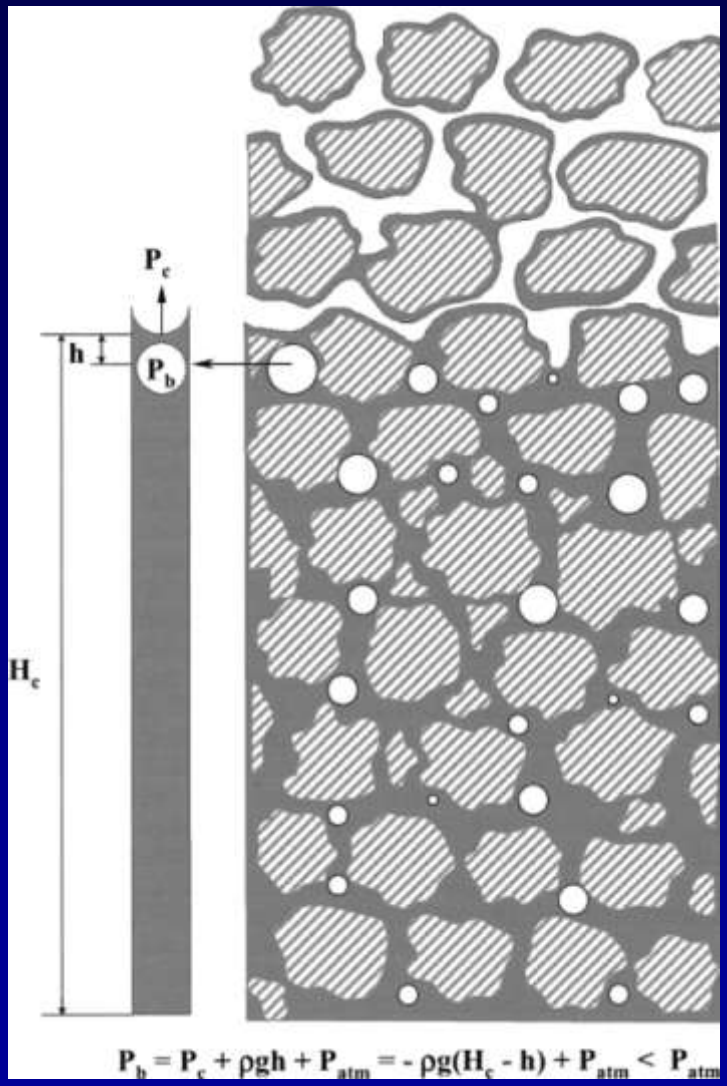
"Lost" N

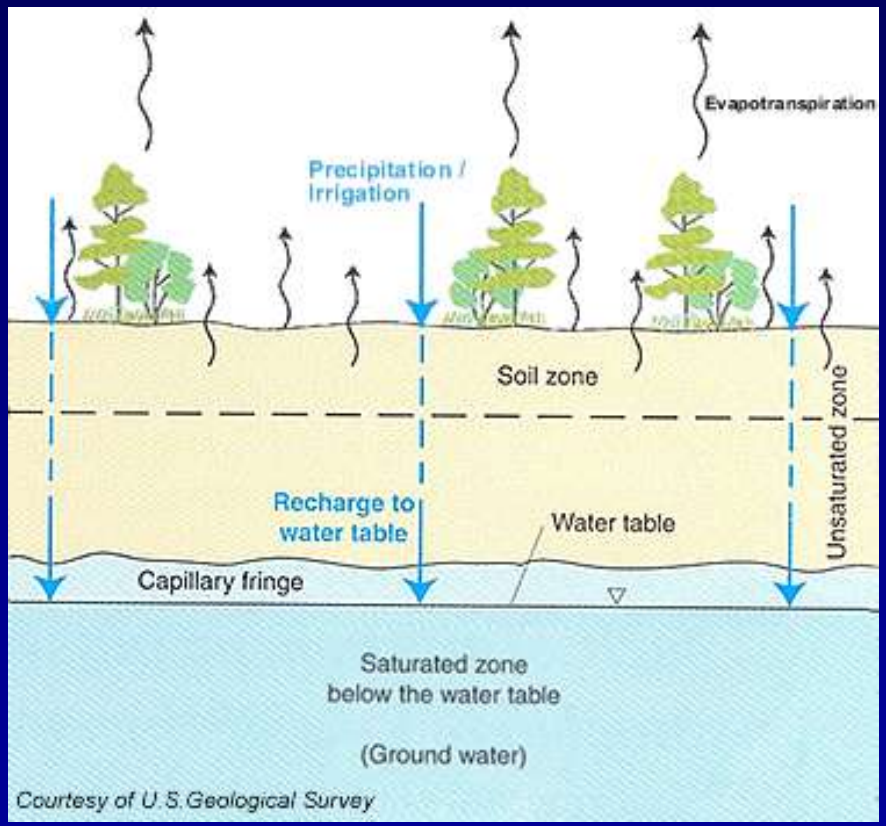
1. Not in the soil (at least not where and when we look)
   - We can't measure soil N very soon after a lot of rainfall
   - Measuring in the top foot or two may not tell us much about actual amounts present (deeper)
   - Tile line N outflow is a clue, but we don't know starting amounts in most cases
2. In the soil but not available to the **plant:**
   - Within the rooting depth, but roots not able to take it up
   - Deeper than the root "draw" (of water)

Using Plant Availability to Measure "Loss"

- Effective rooting depth (ERD) – the depth at which roots are active, with enough O_2 and energy supply to take up nutrients
  - This is usually more important than where (how deep) the N might be located
  - N beneath roots and in saturated soil is "lost", at least until roots can start to work again and move water
- ERD can include the depth from which water moves up through the combination of capillary action and root "draw"
  - Both of these require roots that are active, healthy, and well-connected to soil particles

As water is extracted by roots, more moves up from the capillary fringe, bringing NO_3 with it





If N "loss" is measured by plant availability:

- Water and N are closely linked, and water availability (amount and pattern) becomes a critical factor in N availability and "loss"
  - In 2012, subsoil water dried up by July, plants were highly stressed, pollination was damaged, and water/N accessibility after rains in August meant little
  - In 2013, wet conditions early following by drying (and good root health) meant upward movement of soil water to roots, along with N
- Root health also becomes a proxy for N availability
- Of course, actual N loss can be a factor
  - Water arriving at the root with low N means low uptake

Lost or Out of Reach – Can We Tell Which?

- Not easily, but there are clues:
  - Lack of access:
    - Stunting and early-onset drought stress usually mean compromised root systems
    - Fairly good yields without (or at low) N but flat response usually relates to lack of access
    - Failure of crop to green up after soils dry out usually means root damage
    - If later plantings escape yield loss, this is a good clue that it's a lack of access
  - Loss of N from soil:
    - Prolonged rainfall with standing water (or rapid movement down) and warm soil temperatures
    - Direct measurement from tile lines

Estimated N conversion, 2001-02 (warm winter, wet spring)

	NH_3 without N-Serve			NH_3 with N-Serve		
	DeKalb	Bond-ville	Browns-town	DeKalb	Bond-ville	Browns-town
	-------Percent of ammonia converted to nitrate-------					
Nov. 1 to Apr. 1	30	39	100	12	15	41
Dec. 1 to Apr. 1	14	20	61	5	8	22
Apr. 1 to Apr. 25	17	20		7	8	25

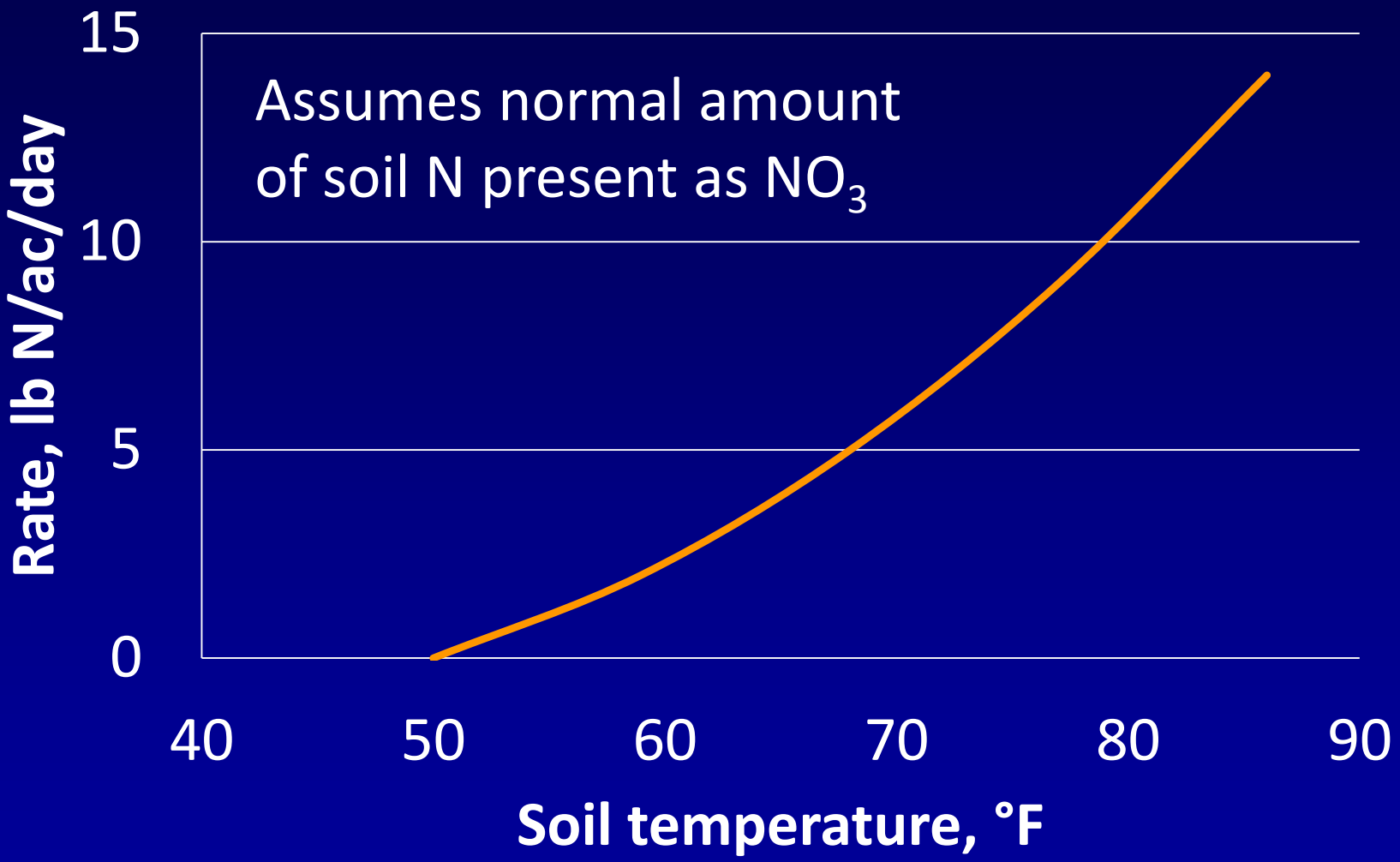
Source: Hoeft

Conversion to NO_3 is not "loss" – it only enables loss

Loss requires denitrification or leaching:

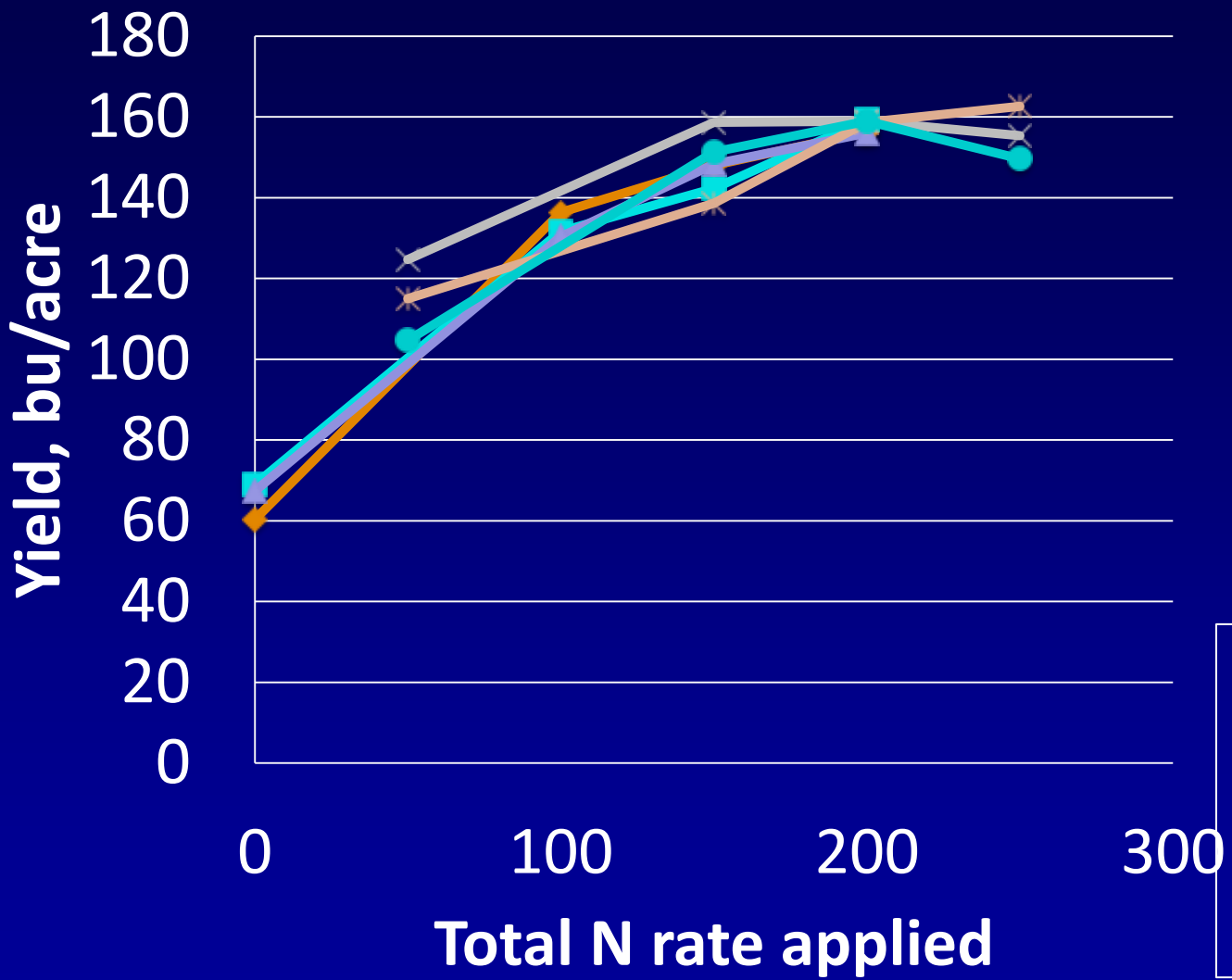
- denitrification estimated at 4 to 5%/day in saturated soils at 70°; <1%/day at 50°
- leaching measured by tile flow or deep sampling

Denitrification in saturated soil



Estimated from lit. sources

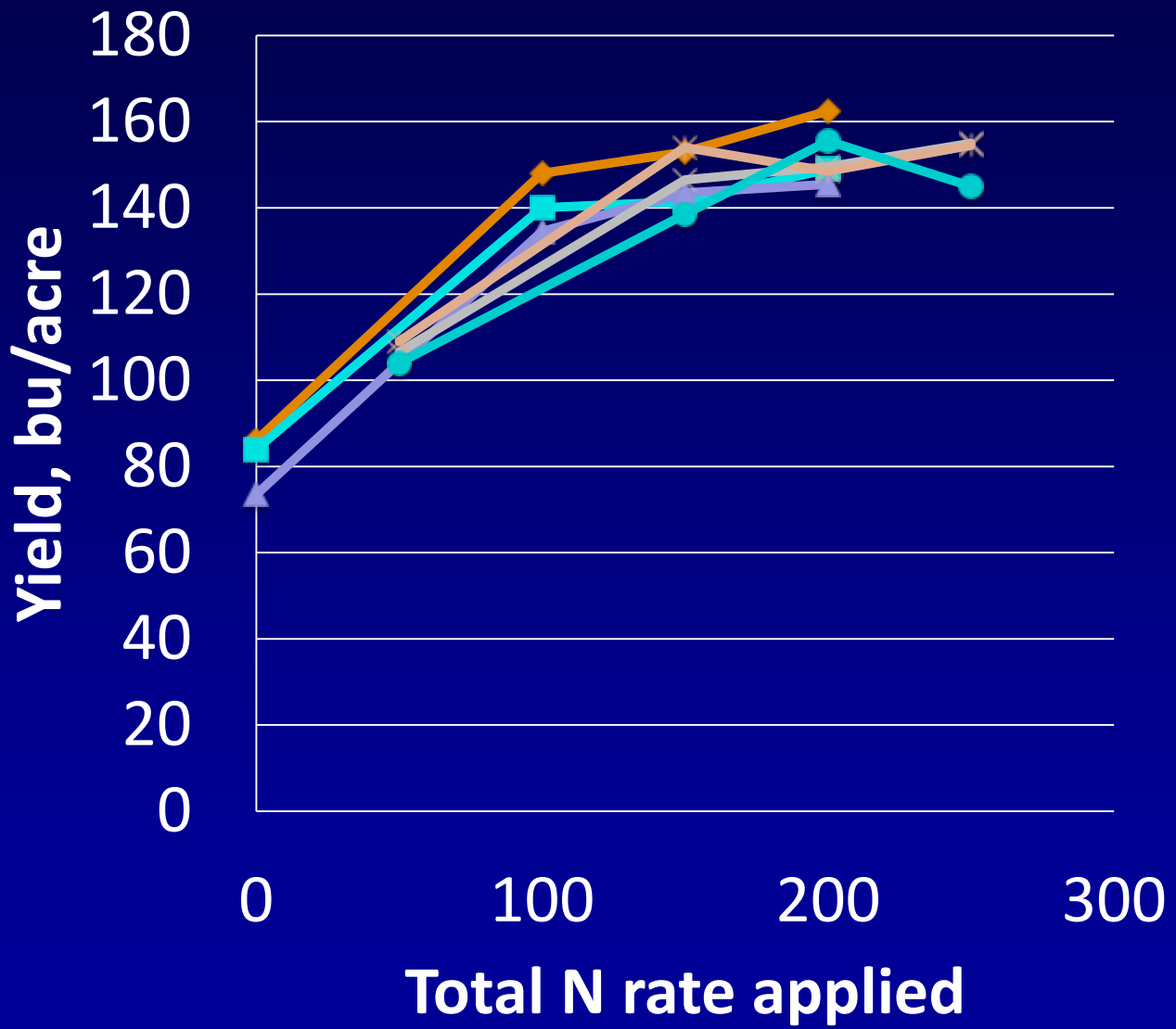
Cisne, 3-yr avg



s = 50 lb supplemental N after flooding

Source: Torbert et al., 1993

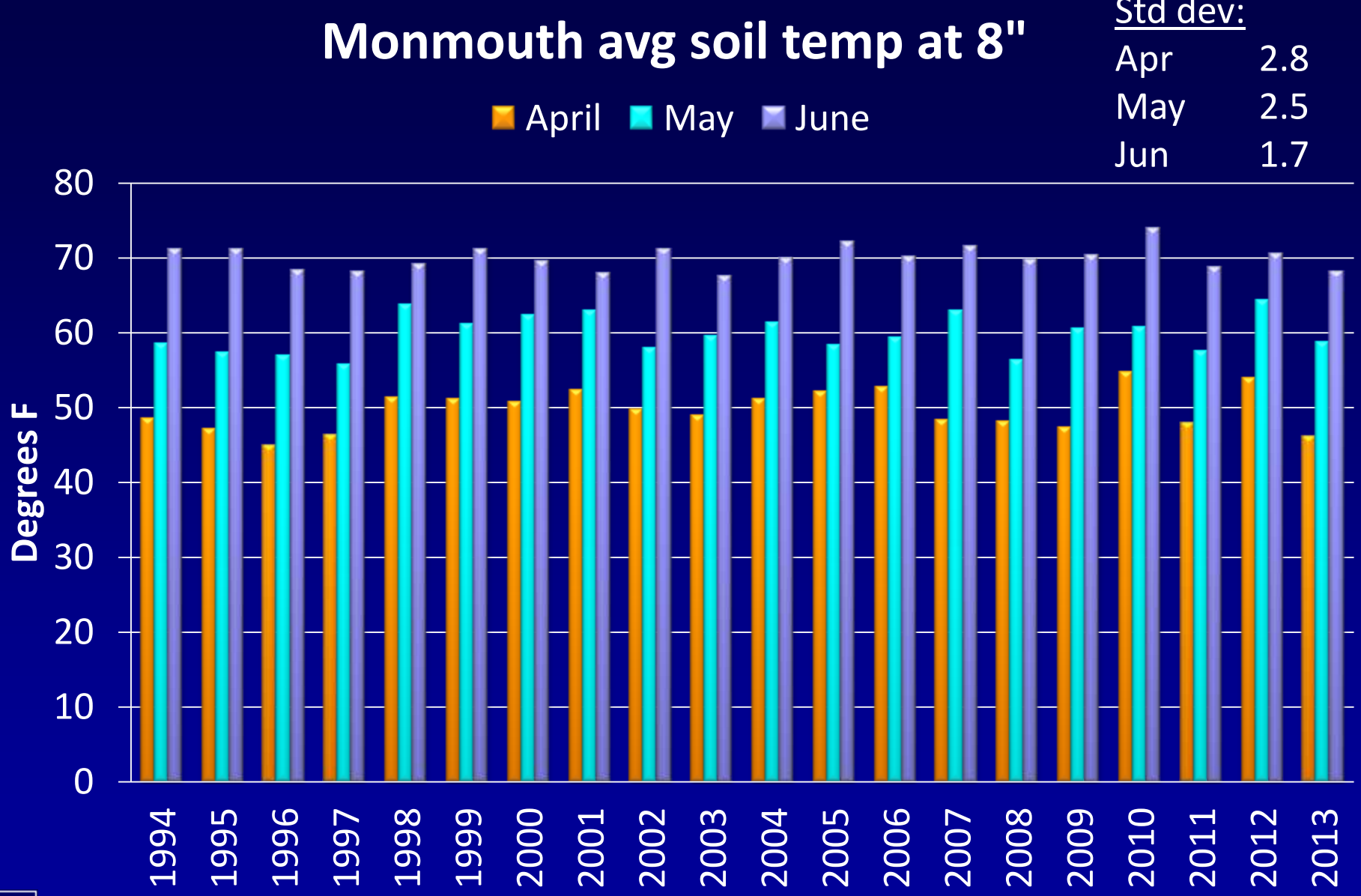
Drummer, 2-yr avg



s = 50 lb supplemental N after flooding

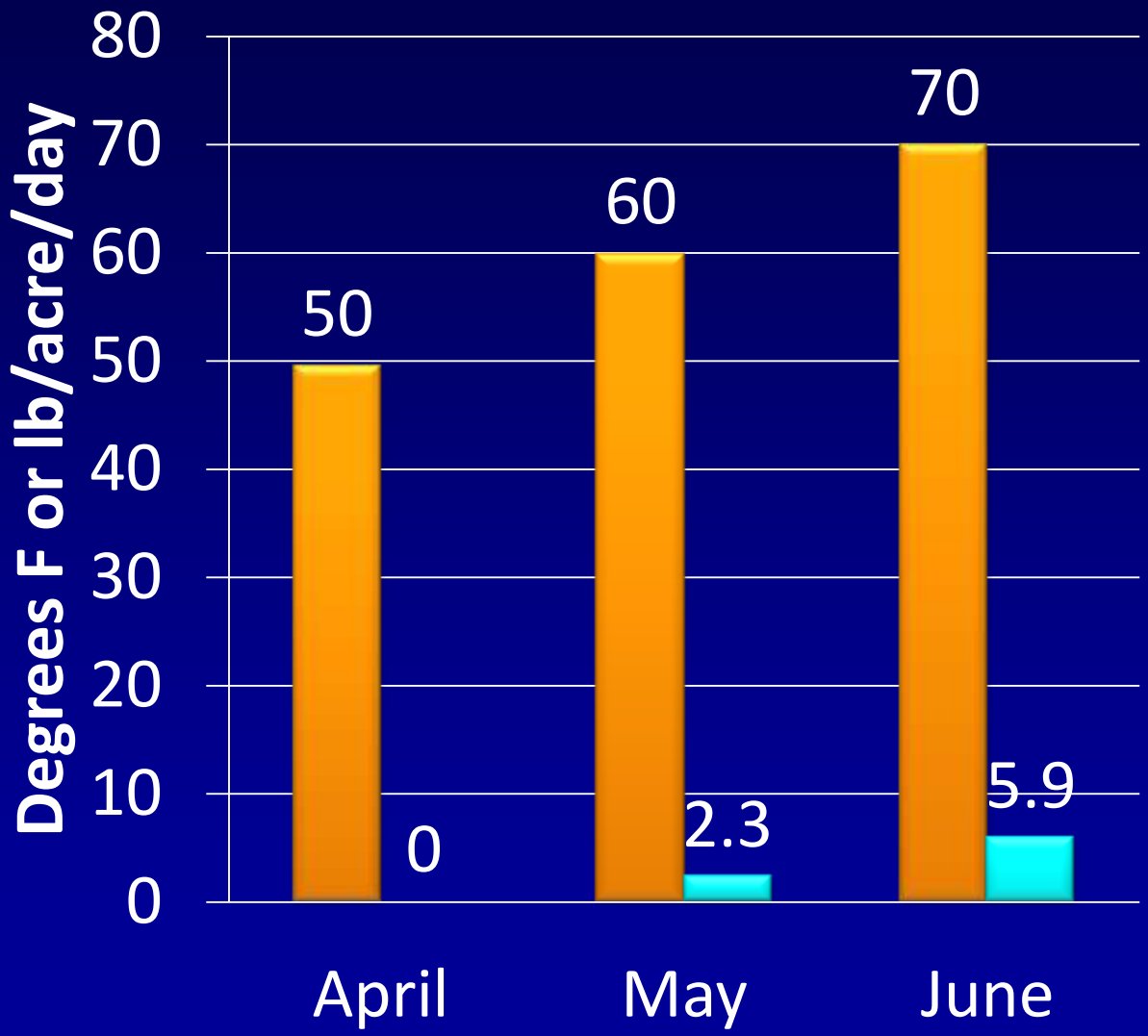
Source: Torbert et al., 1993

Monmouth avg soil temp at 8"



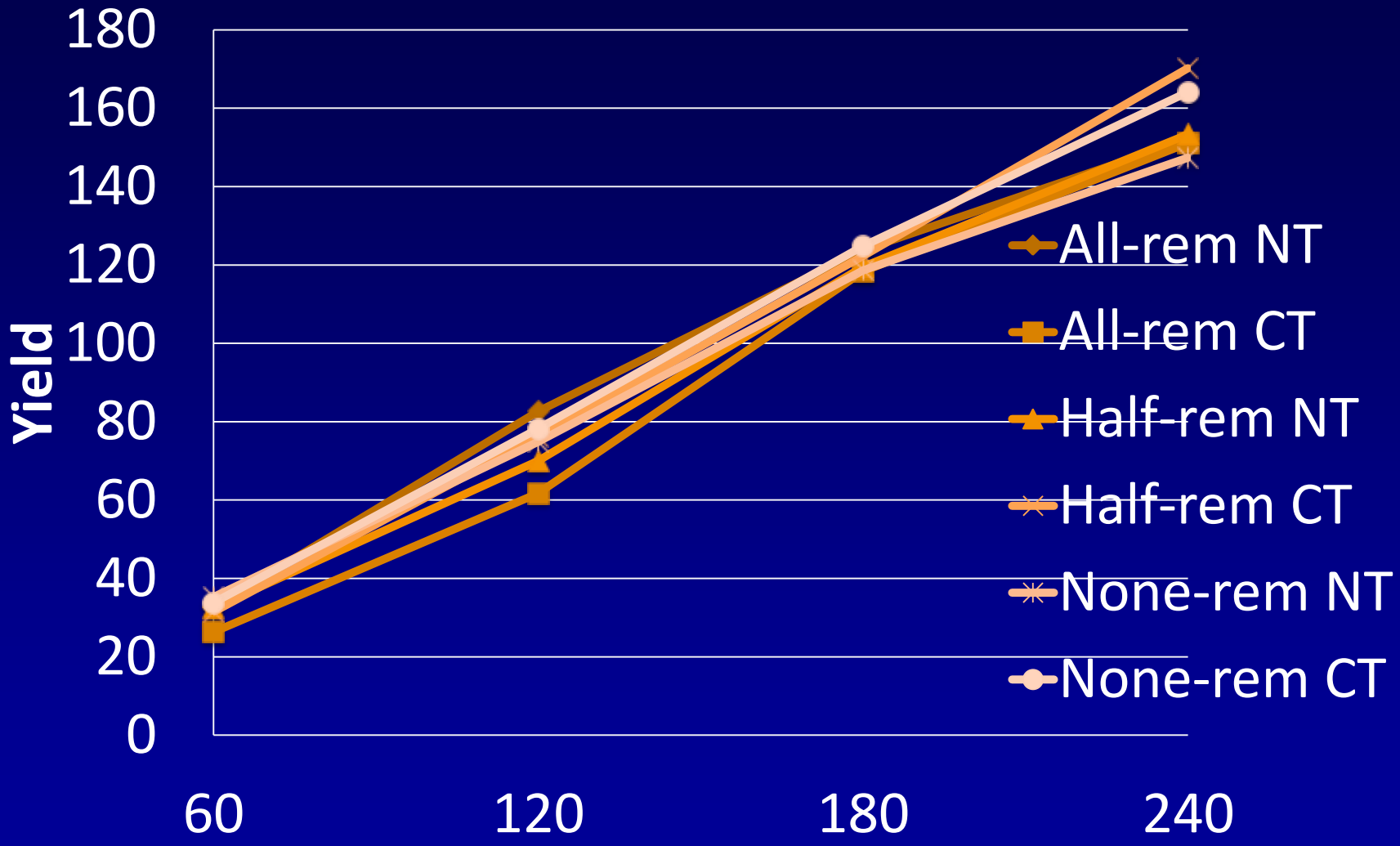
Std dev:	
Apr	2.8
May	2.5
Jun	1.7

Monmouth, 8", 20-yr avg

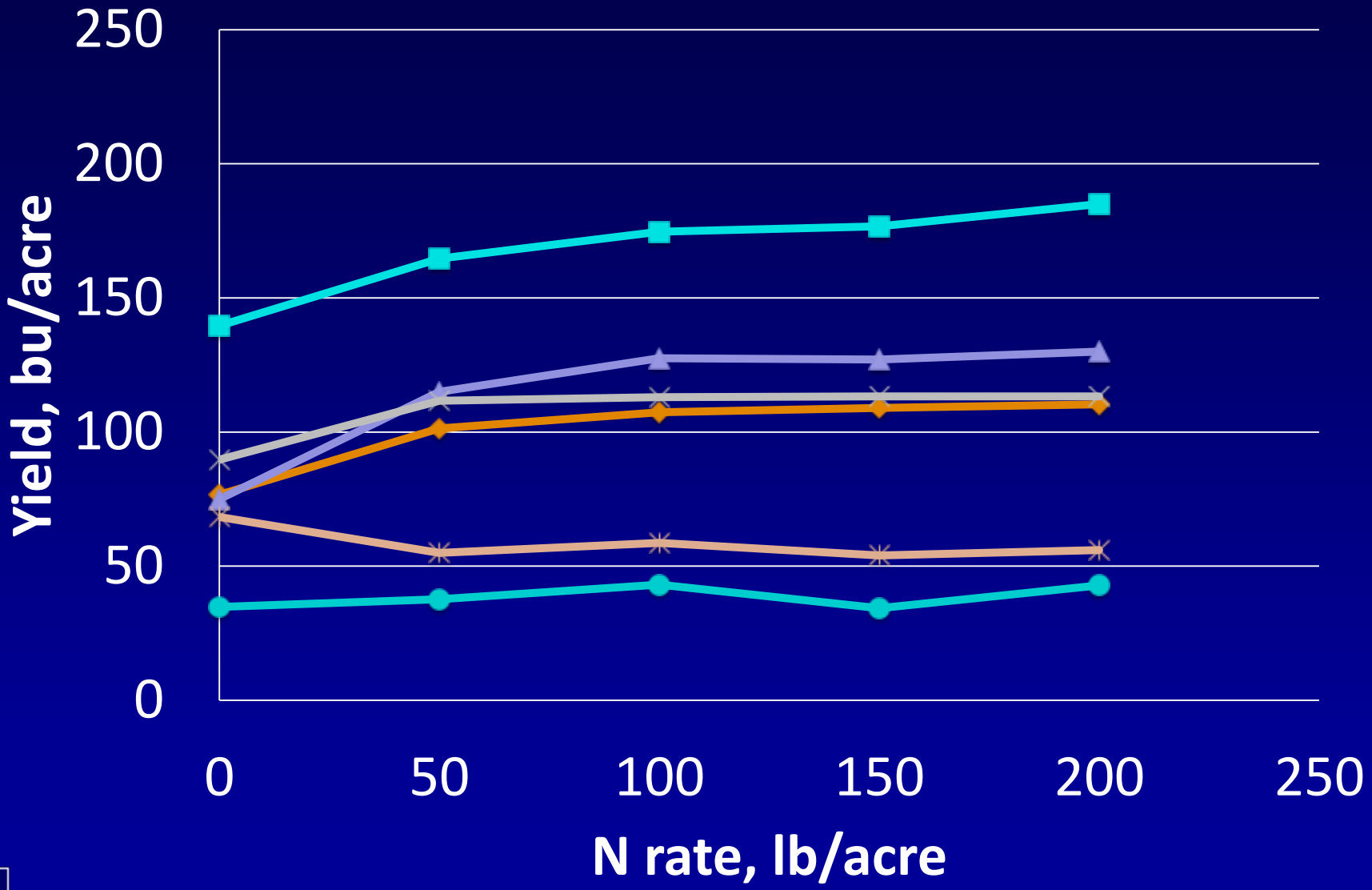


"Loss": In saturated soils with N as NO_3

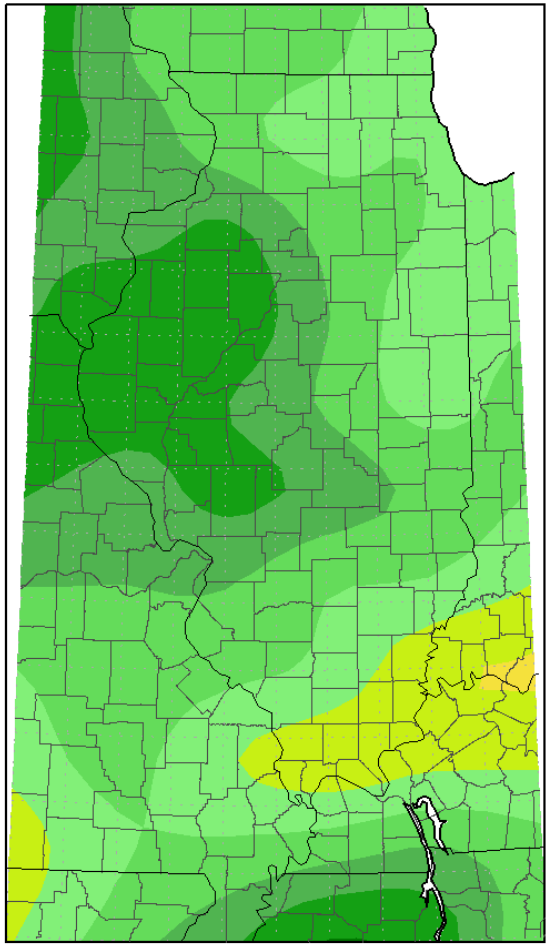
Urbana Cont C 2010 – Root problem

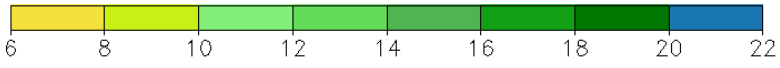


On-Farm N Rate, 2012 – Drought stress



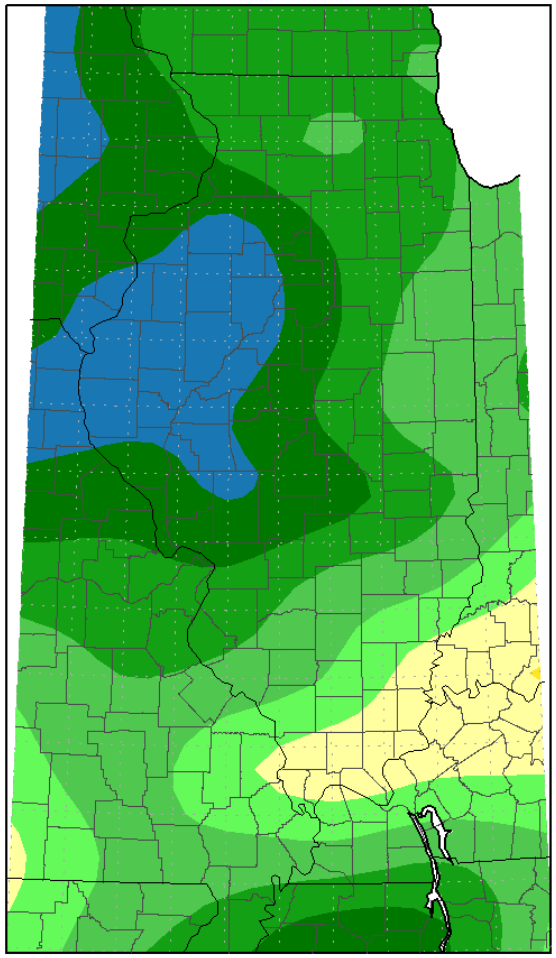
Accumulated Precipitation (in)
April 1, 2013 to May 31, 2013





Midwestern Regional Climate Center
cli-MATE: MRCC Application Tools Environment

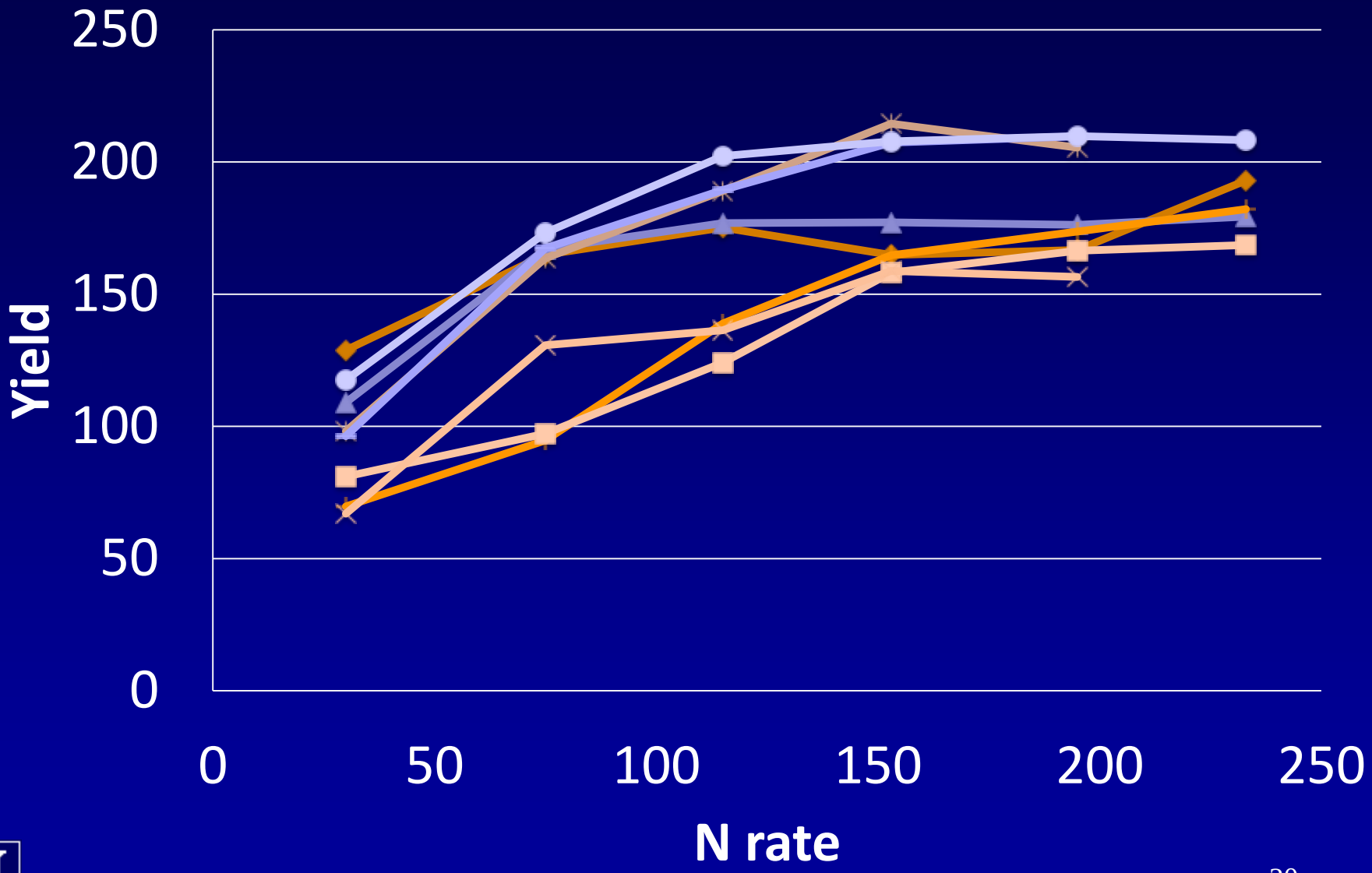
Accumulated Precipitation (in): Departure from Mean
April 1, 2013 to May 31, 2013



Mean period is 1981-2010.

Midwestern Regional Climate Center
cli-MATE: MRCC Application Tools Environment

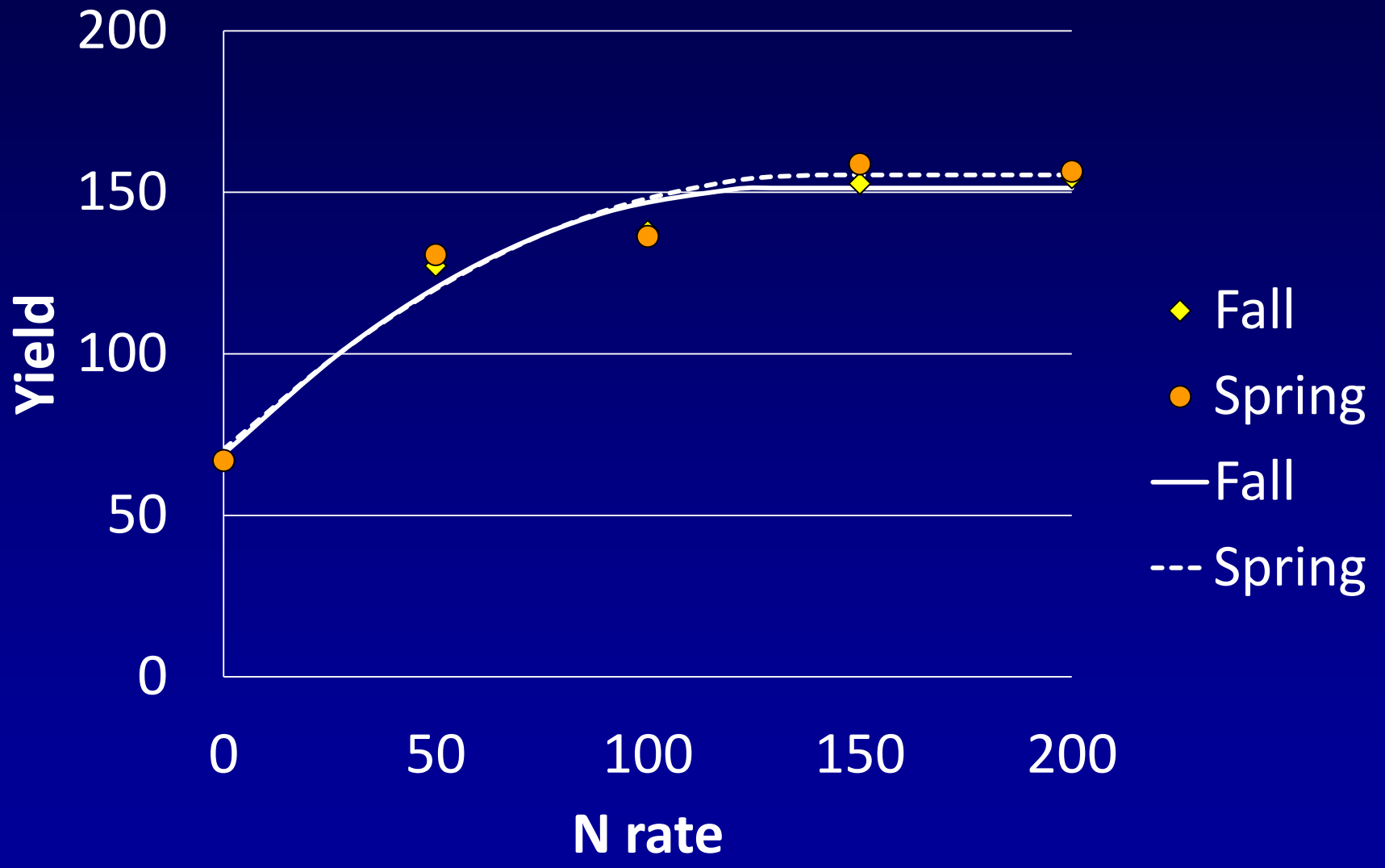
On-Farm N rates 2013



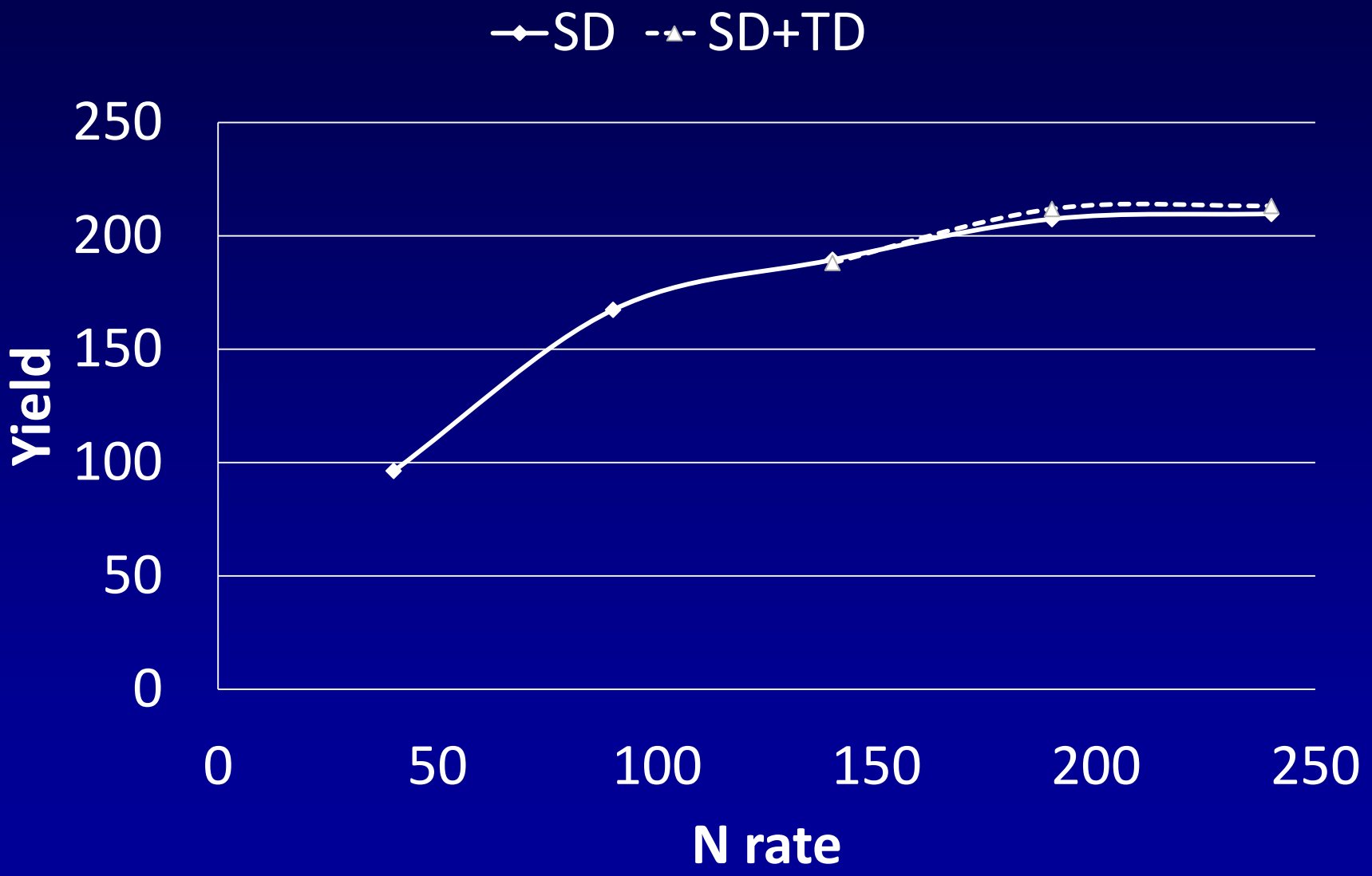
N "Loss" in 2013

- Some N was applied in fall 2012 (adding to lots of leftover soil N if following corn) or in early spring 2013
- Rainfall in March to April and May 2013 was up to 2X normal in parts of Illinois
- Tile line flow started in February 2013 with very high measured NO_3 levels – mostly from leftover (not fall-applied) soil N, but suggesting high loss levels
- Tile line N flow was heavy in spring 2013 as well, suggesting ongoing loss – including applied N(?)
- As a result, some "rescue" applications took place, even though sampling to measure "loss" was not possible in most fields

On-Farm N Timing Trial 2013



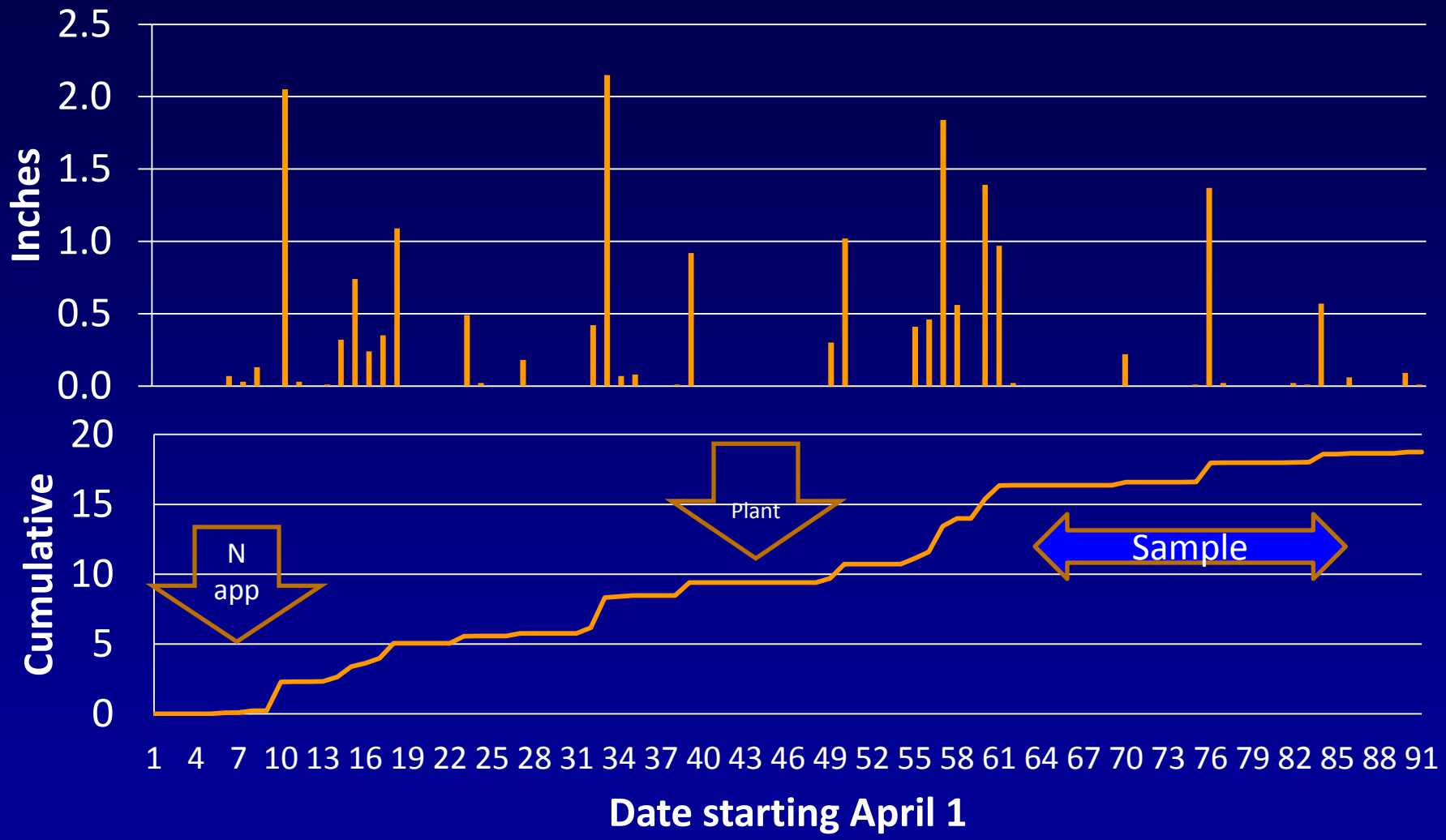
Sidedress v late topdress, 2013



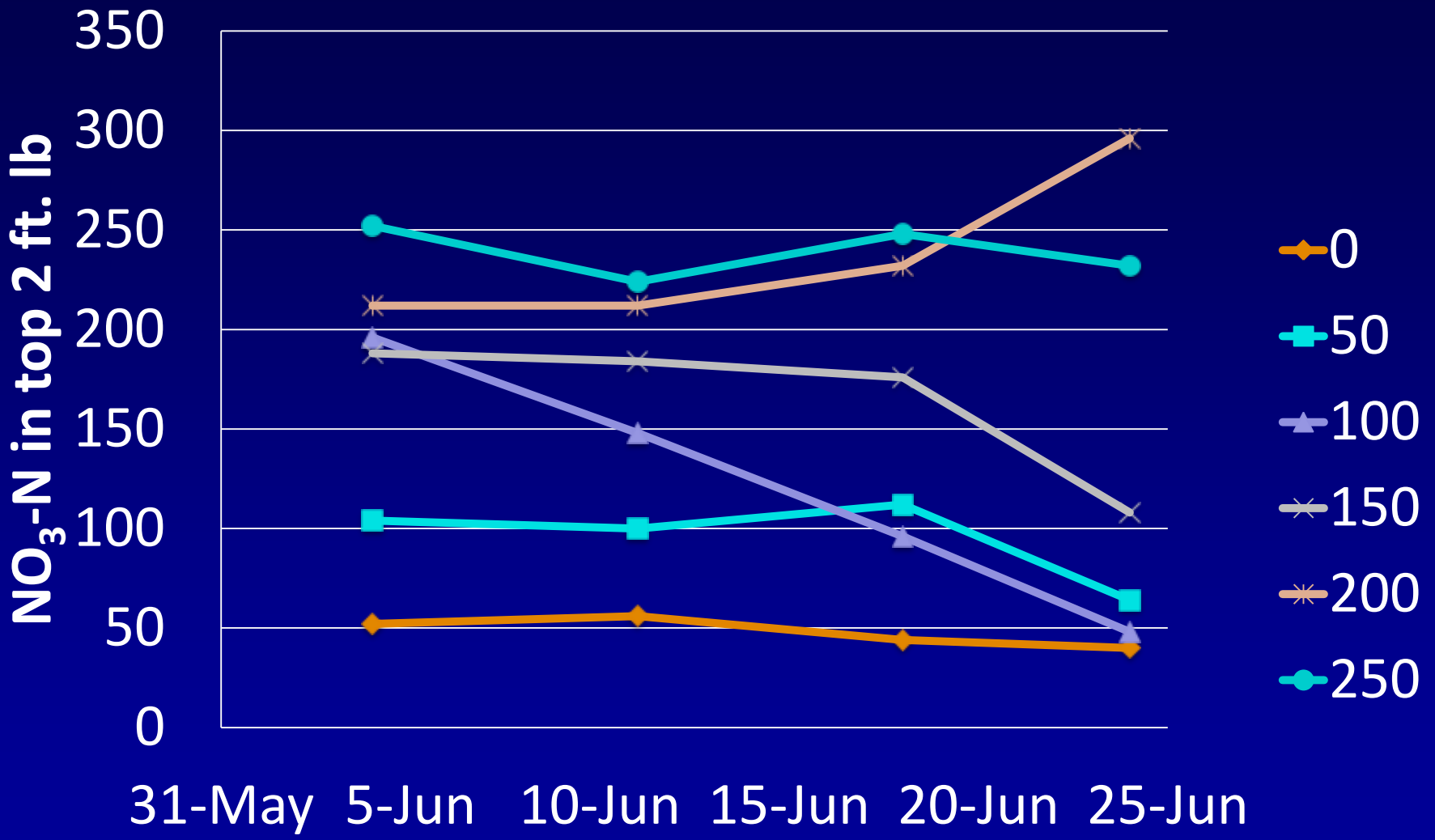
Tracking N at Perry

- We had two N rate studies at Orr Center (NE Pike County):
  - Continuous corn (yr 9) with residue, tillage, and N rate treatments
    - UAN (rates) injected April 4
    - Planted May 15
  - Corn following soybean
    - UAN rates applied April 5
    - Planted May 13

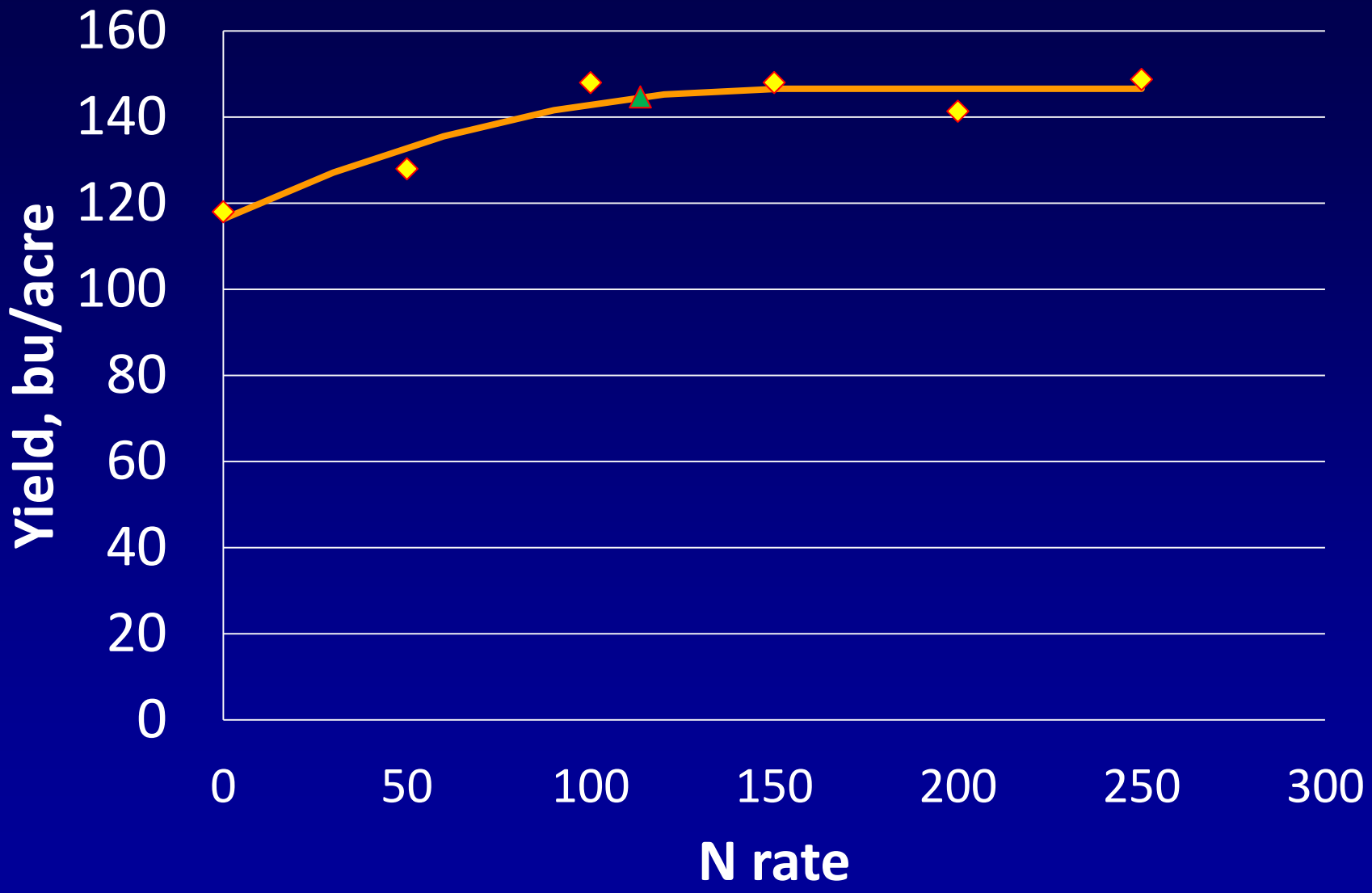
Spring rainfall, Perry 2013



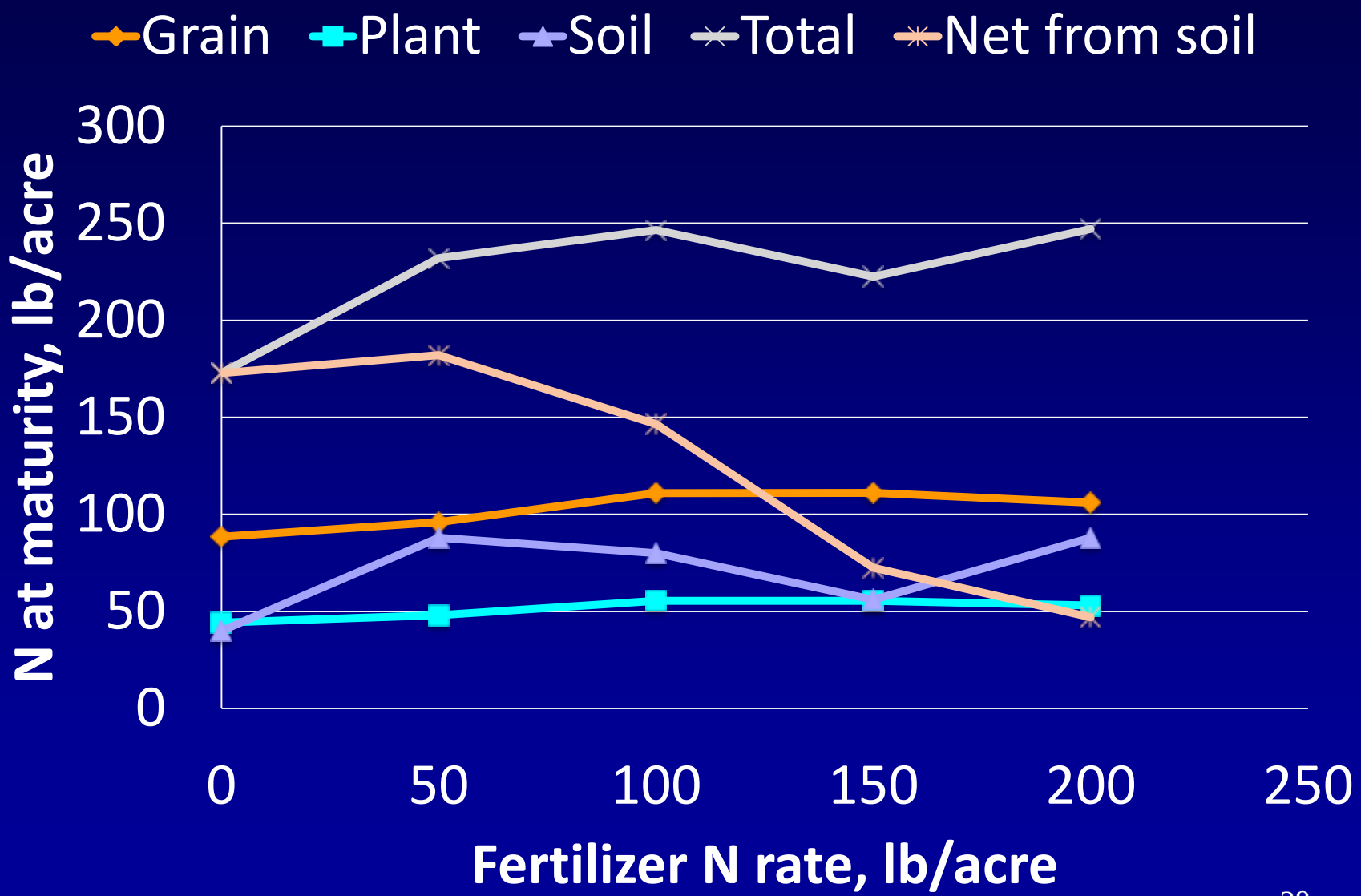
Perry 2013


350
300
250
200
150
100
50
0
NO_3-N in top 2 ft. lb
31-May
5-Jun
10-Jun
15-Jun
20-Jun
25-Jun
Sampling date
0
50
100
150
200
250

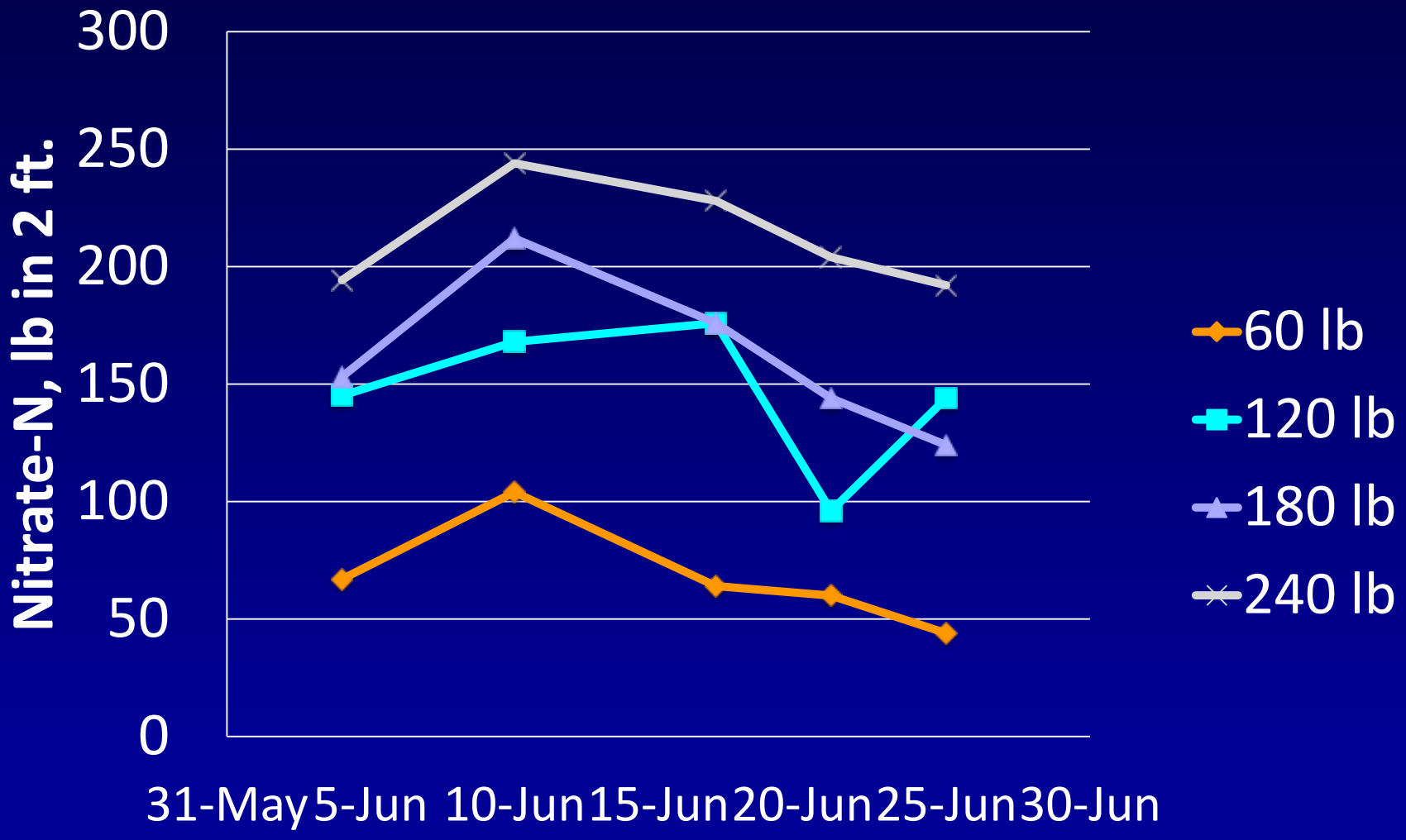
Perry 2013, SC



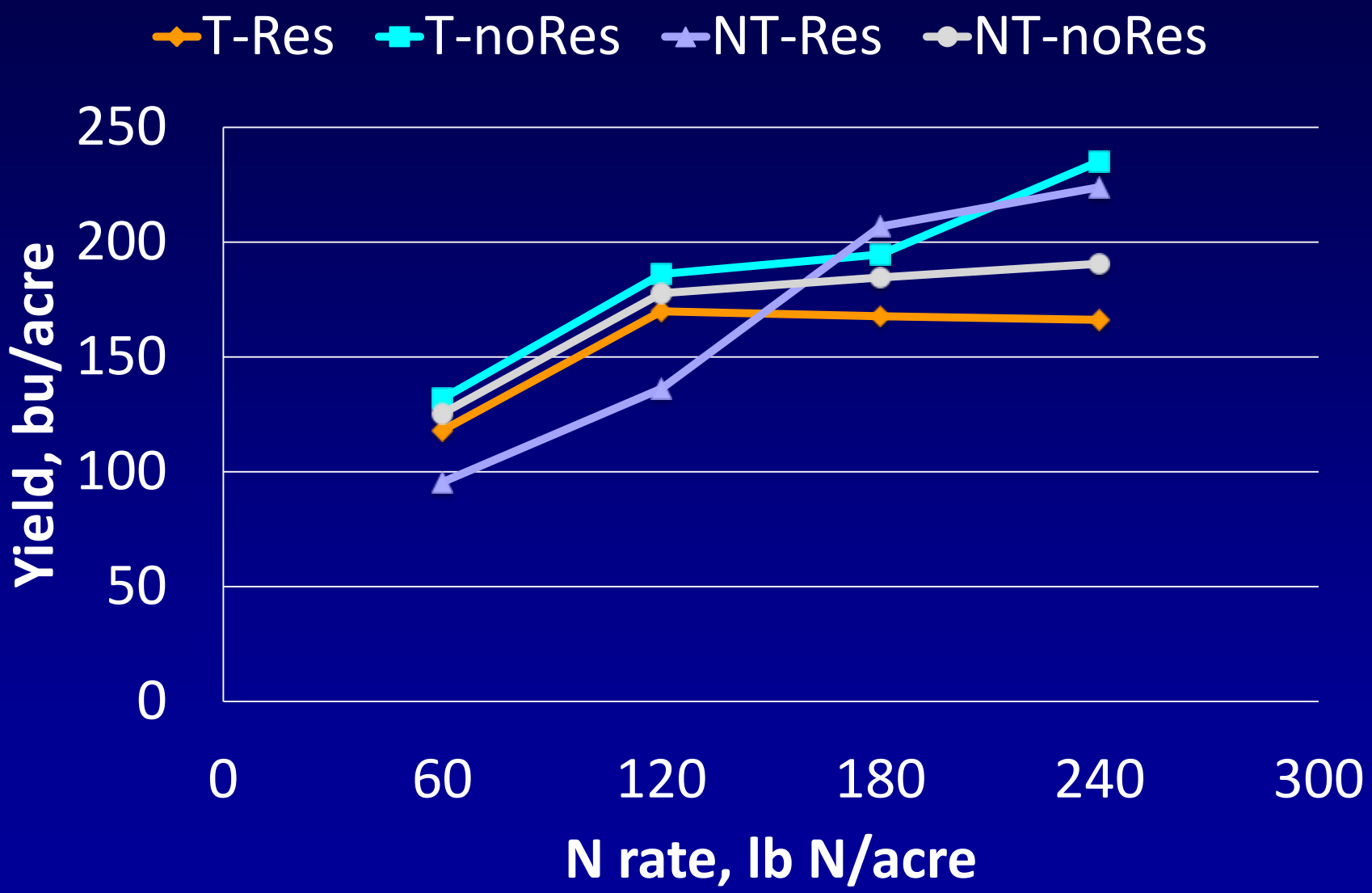
Perry N rate, SC 2013



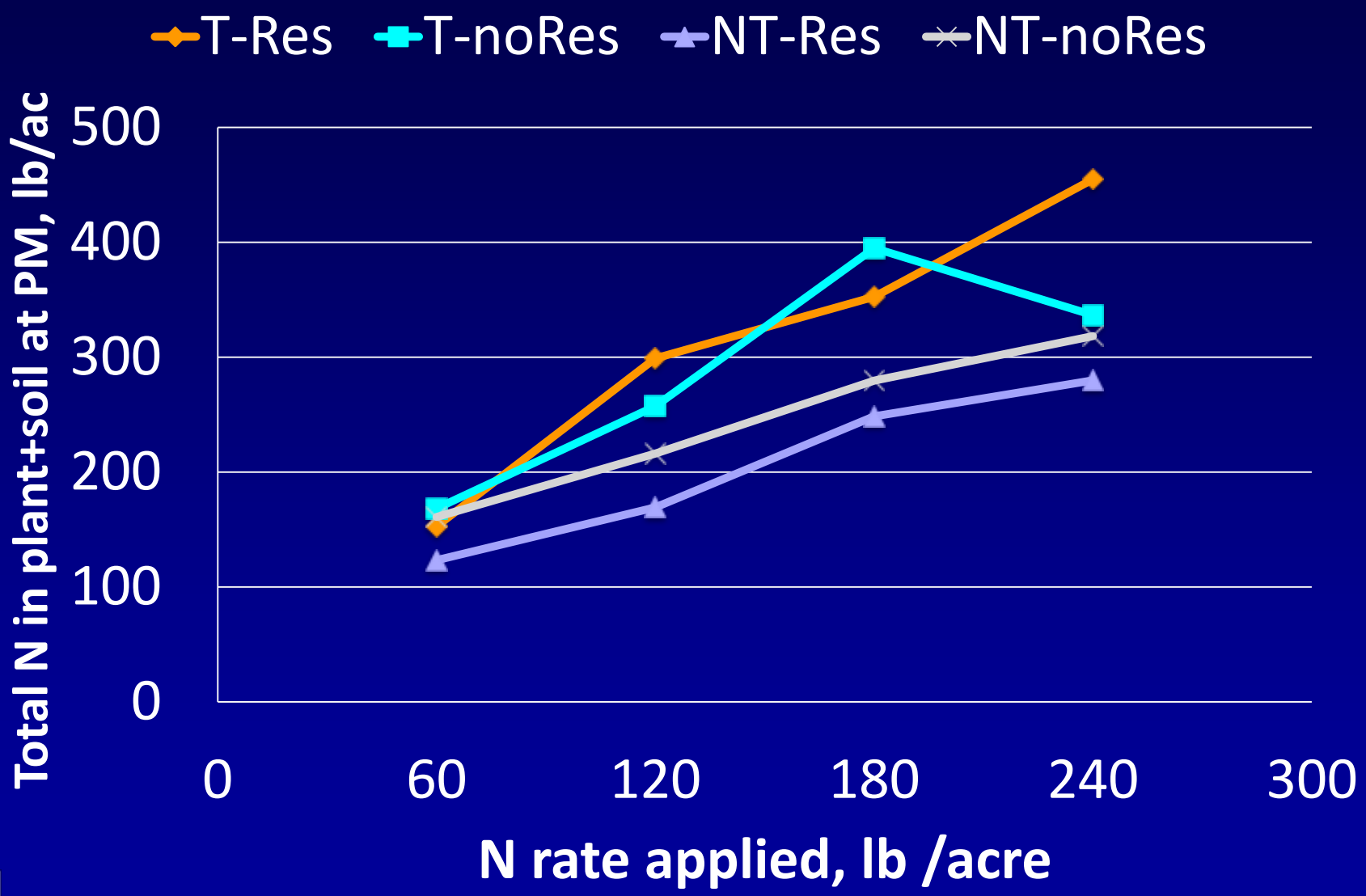
Perry Cont C 2013



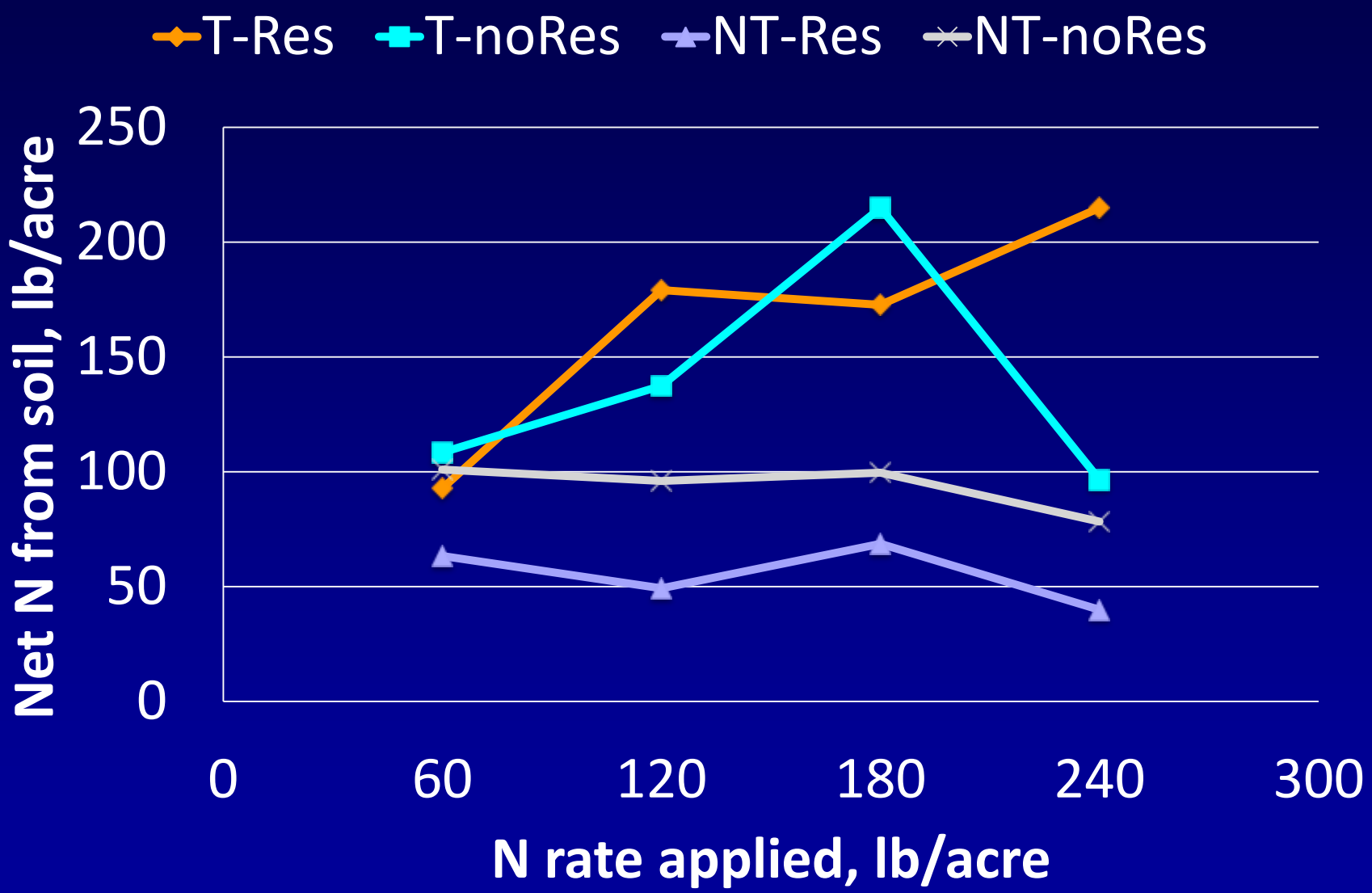
Perry Cont C 2013



Perry Cont C 2013



Perry Cont C 2013

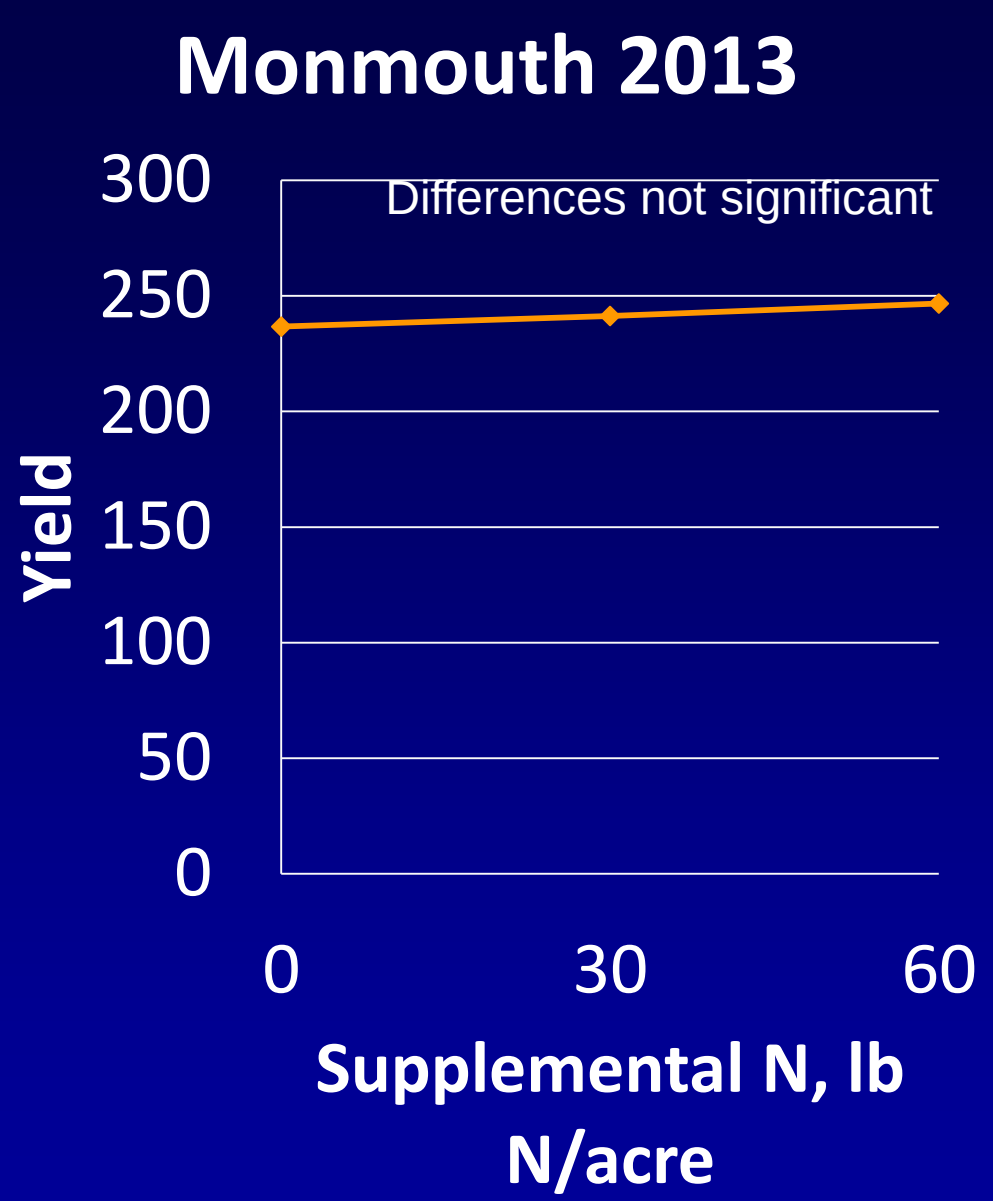


Lessons learned:

- Even with a lot of rain, soils in these studies were probably not saturated, and not all rain entered the soil
- 10 inches of rain on top of UAN didn't make it all (or even much of it) go away: any guess that more needed to be added was probably incorrect (though 240 was not enough to maximize yield in continuous corn)
- Soil contributions to N supply were substantial – in the 150 lb N/acre range – though the "net" may be lower in no-till

N “loss”?

At Monmouth in 2013, 165 lb N on corn after soybeans applied early April, corn planted early May, supplemental N applied in early June, with 18 inches of rain in previous 2 months



N from soil organic matter

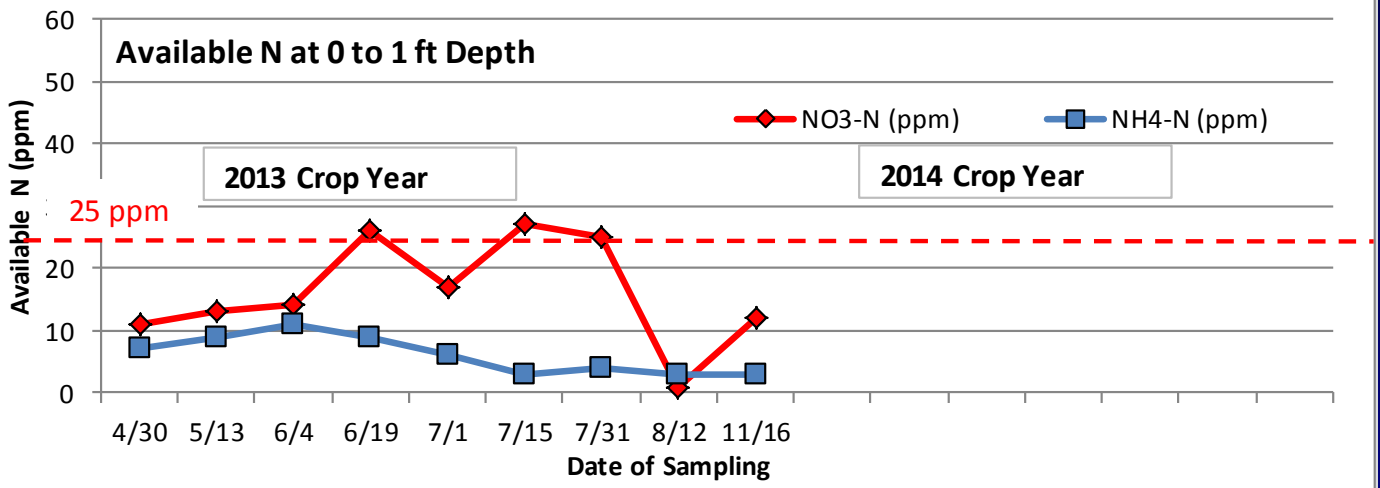
- General estimate is 2% of SON per growing season:
  - Say a soil has 3.5% OM in top 12 inches: 2,000,000 lb in 7 in. x 3.5% = 120,000 lb SOM/acre
  - SOM is ~5% N: = 6,000 lb SON/acre
  - 2% of 6,000 = 120 lb N mineralized per year
- Time course of release follows soil temp and moisture at depth
  - Similar to crop/root growth dynamics
  - Declines as soils dry, as will uptake of N
  - Increases with late rainfall, even if crop uptake slows or stops

N from soil organic matter

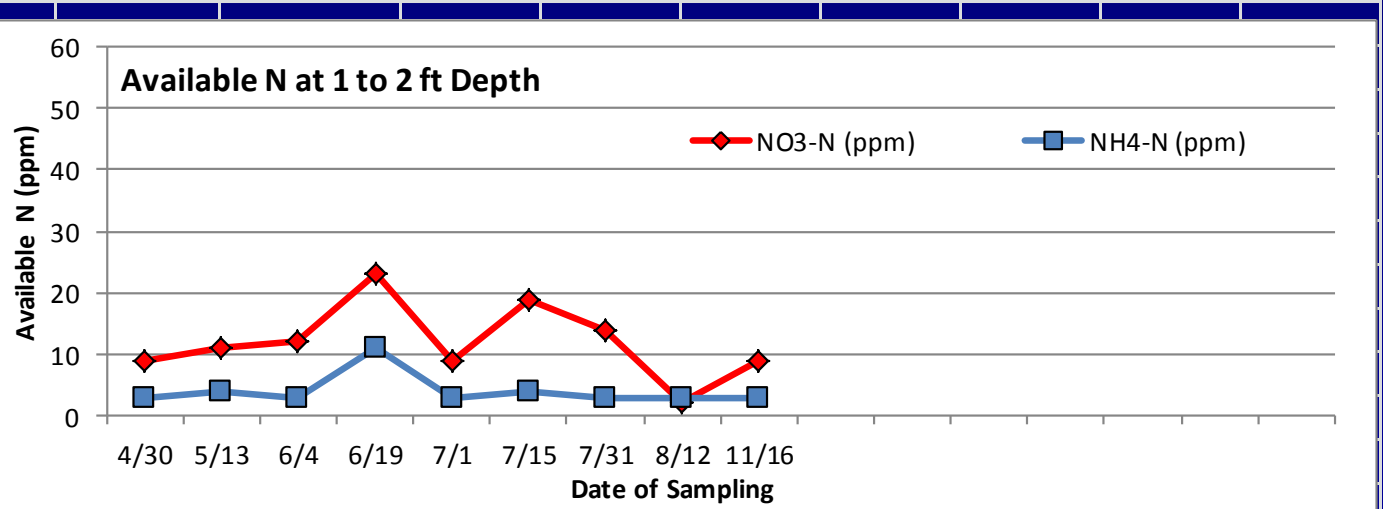
- Produced as NH_4 first, conversion to NO_3 is rapid
- Distribution will be similar to that for organic matter, modified by temperature and moisture
- Rate of formation could be 1 to 2 lb/acre/day in mid- to late June, maybe half the crop uptake rate
- Saturated soils will stop mineralization, and can "reverse" it through denitrification
- But like all N, the root system has to be active for it to be able to take up mineralized N

NH3 150# w/N-Serve 11/28/2012

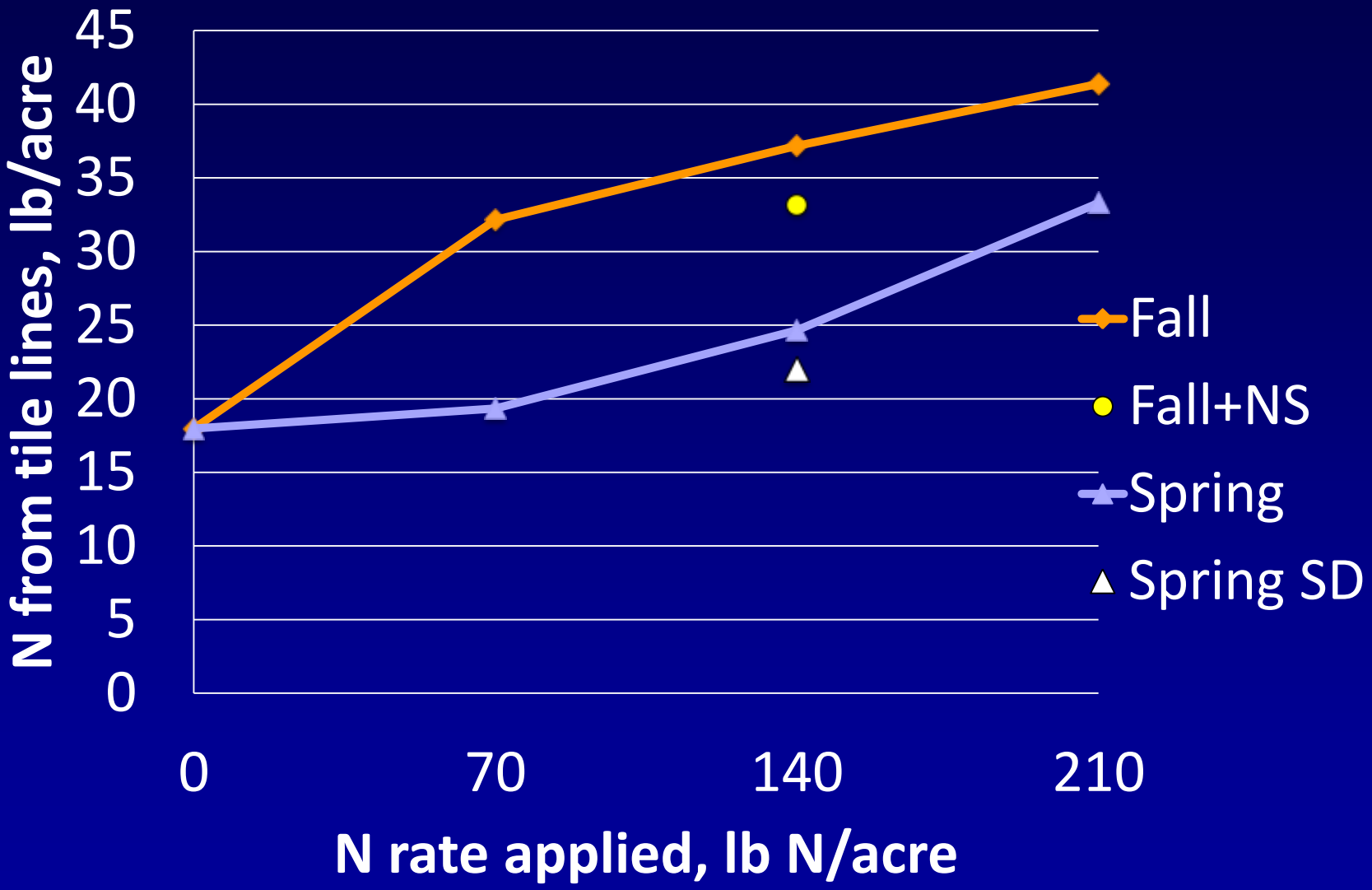
Surface



Subsurface

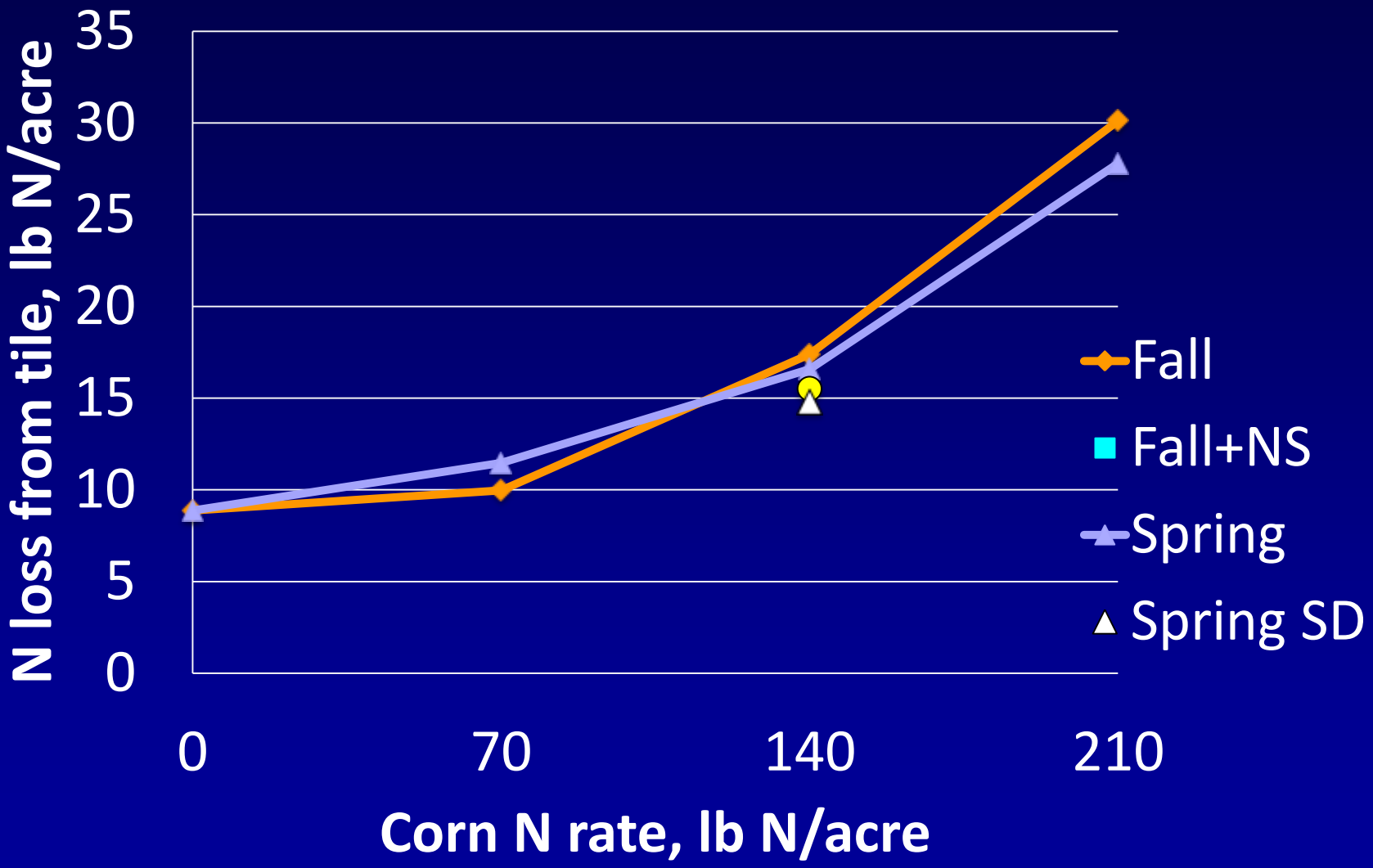


Tile line NO_3 Loss in Corn, 2002-04

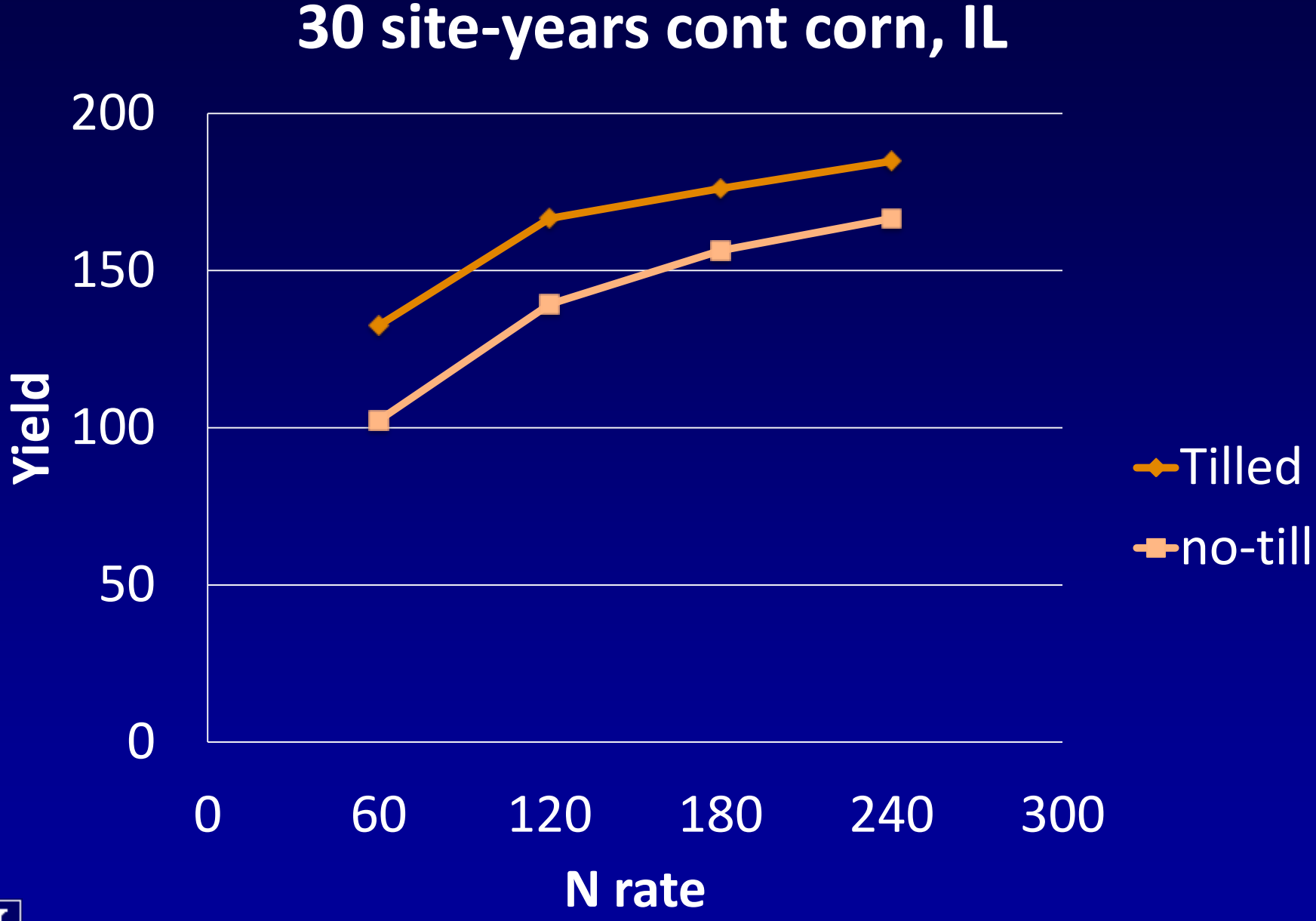


Source: Clover & Hoeft, unpublished

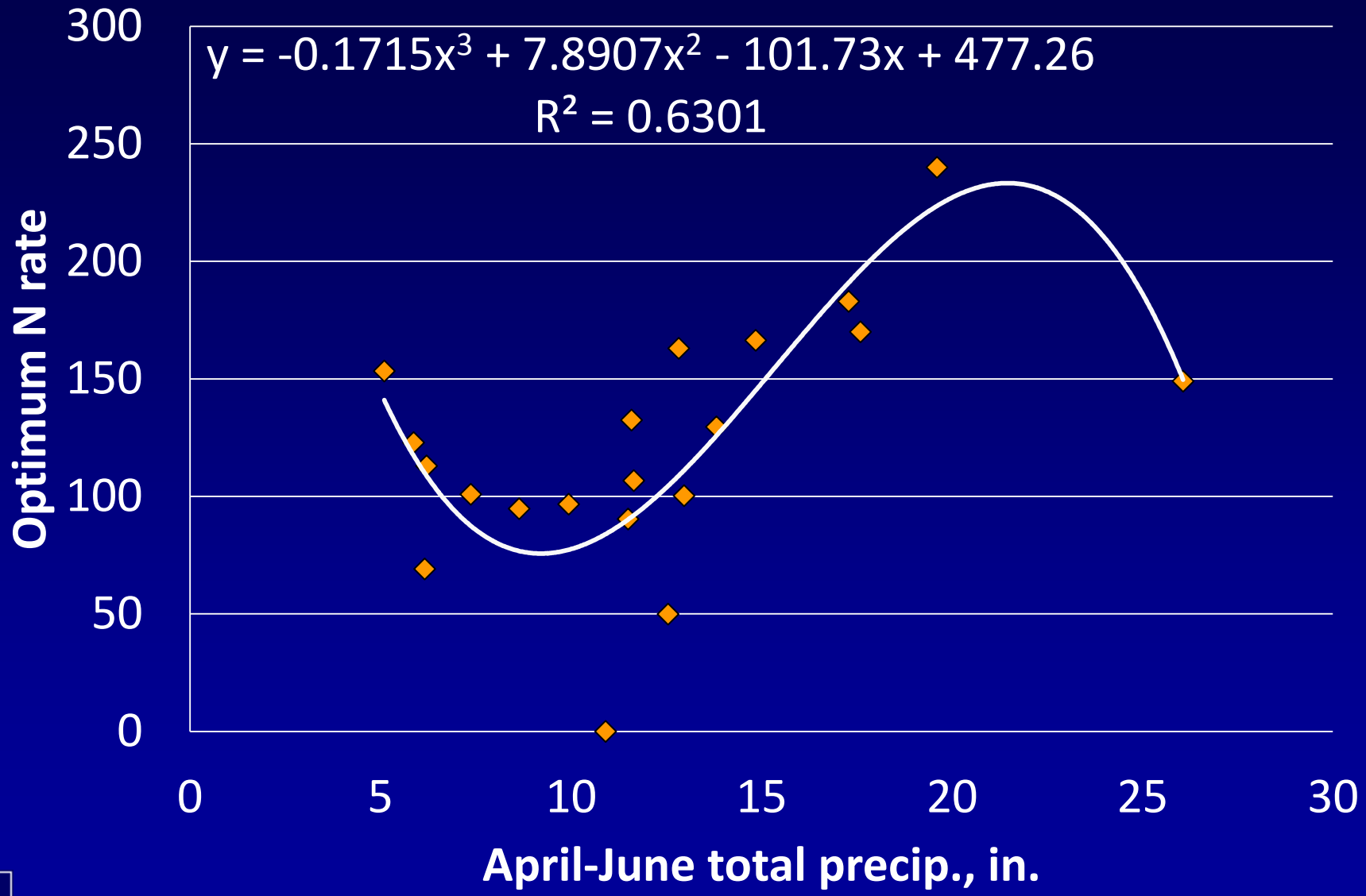
Tile N loss, soybean following corn



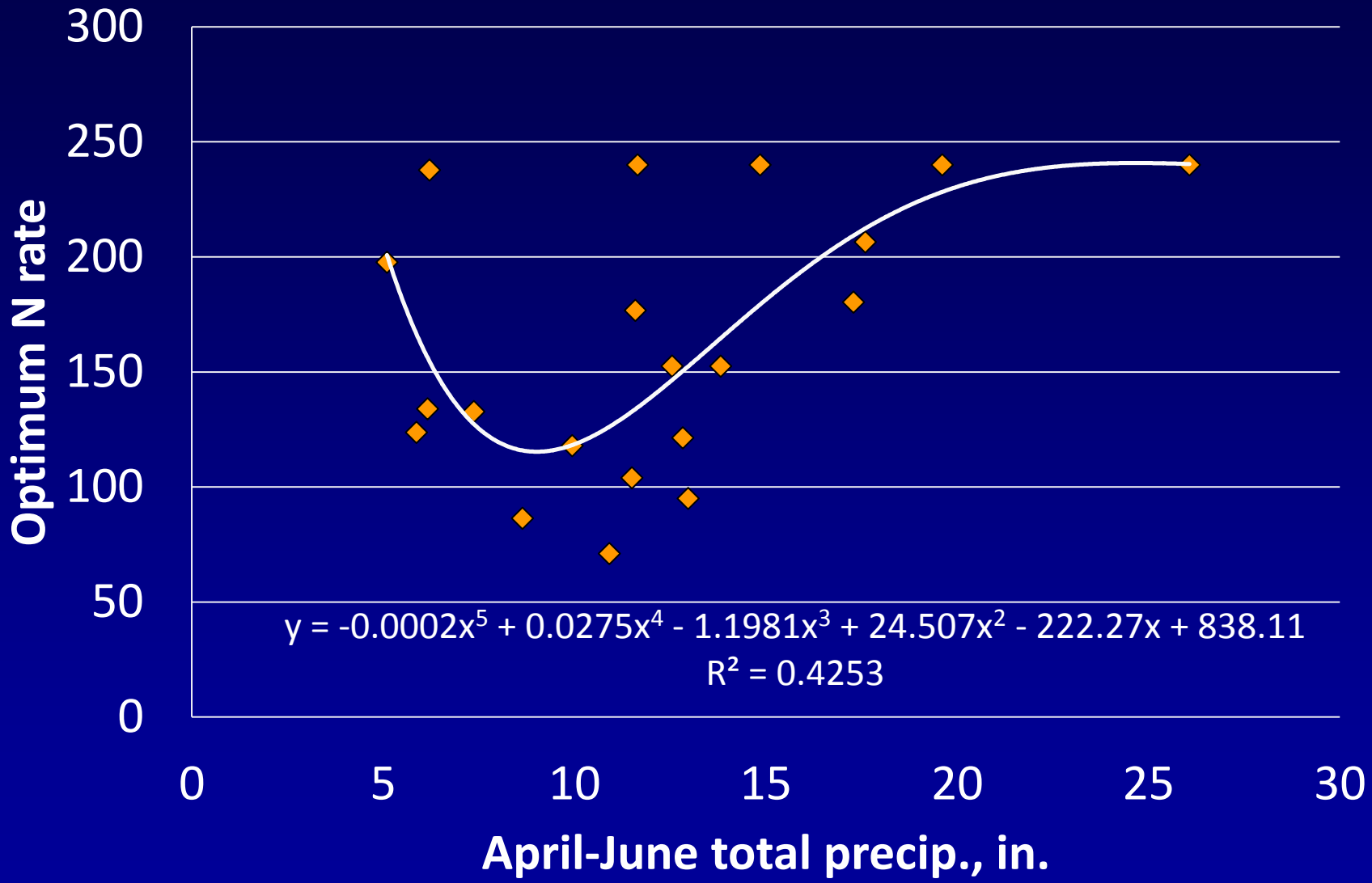
Source: Clover & Hoeft, unpublished


30 site-years cont corn, IL
200
150
100
50
0
Yield
0
60
120
180
240
300
N rate
Tilled
no-till

Monmouth SC, 1994-2013



Monmouth Cont C, 1994-2013



N: Lost or Unavailable to the Plant?

- The result is the same – N-deficient corn and/or responsiveness to higher N rates
- Damage to roots/unavailability of N usually follows flooding with yellowing visible earlier than we'd expect N loss to be taking place
- Drying soils and increased mineralization will help both, but less if roots are damaged
- Applying additional N will fix either problem only if it reaches roots for uptake
- Dry conditions late and increased uptake of water from depth will bring N up if it's there, and if the roots (and plants) can get and use it


THANK YOU