Why Nitrogen Won't Go Away: New Insights and the Continued Challenges with Corn Nitrogen Management

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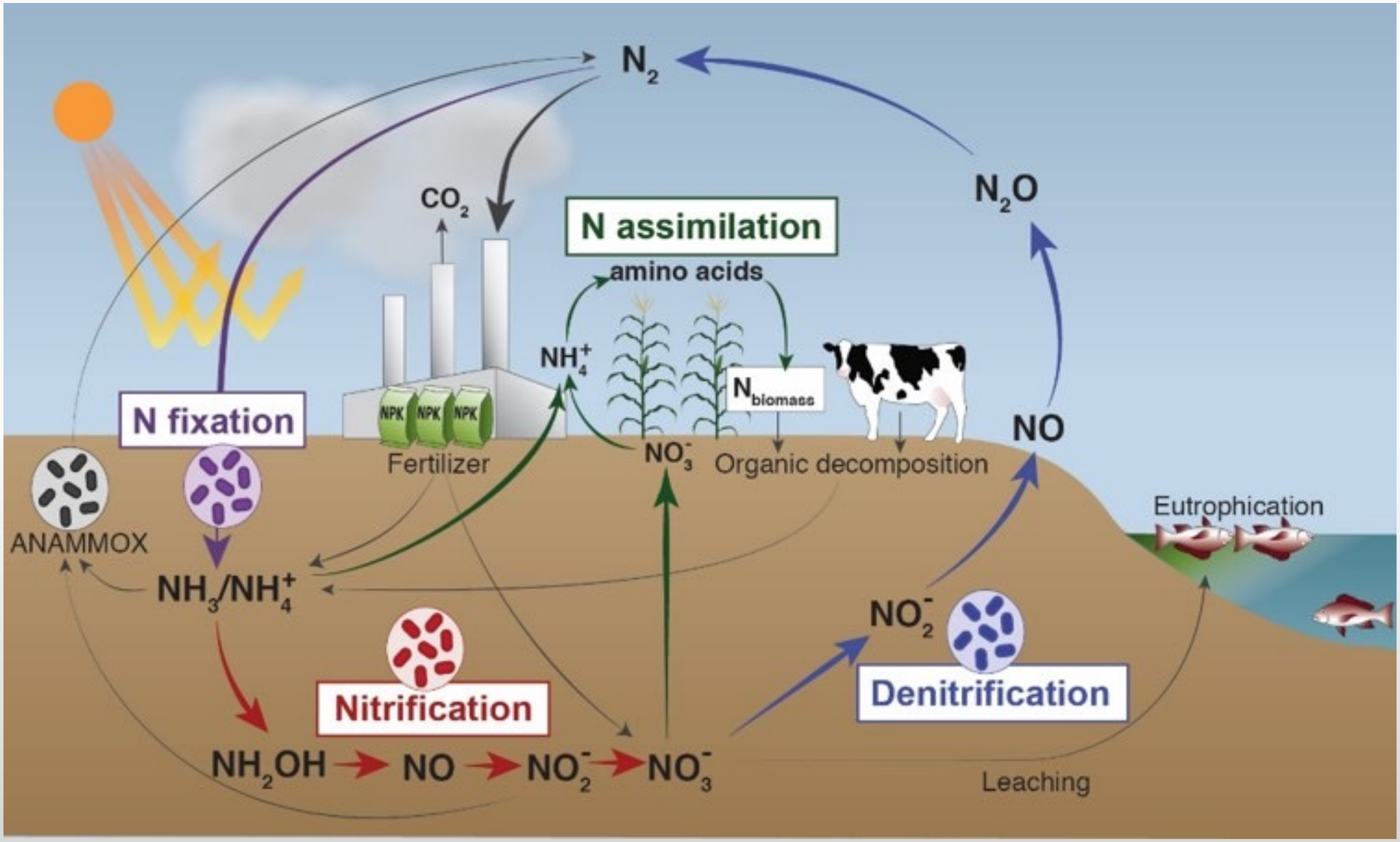


Source: http://websites.umich.edu/~lehnert/picts/N-cycle.jpg

- Nitrogen is **CHALLENGING**

- Weather is difficult to predict = N transformations, movement, and availability is difficult to predict

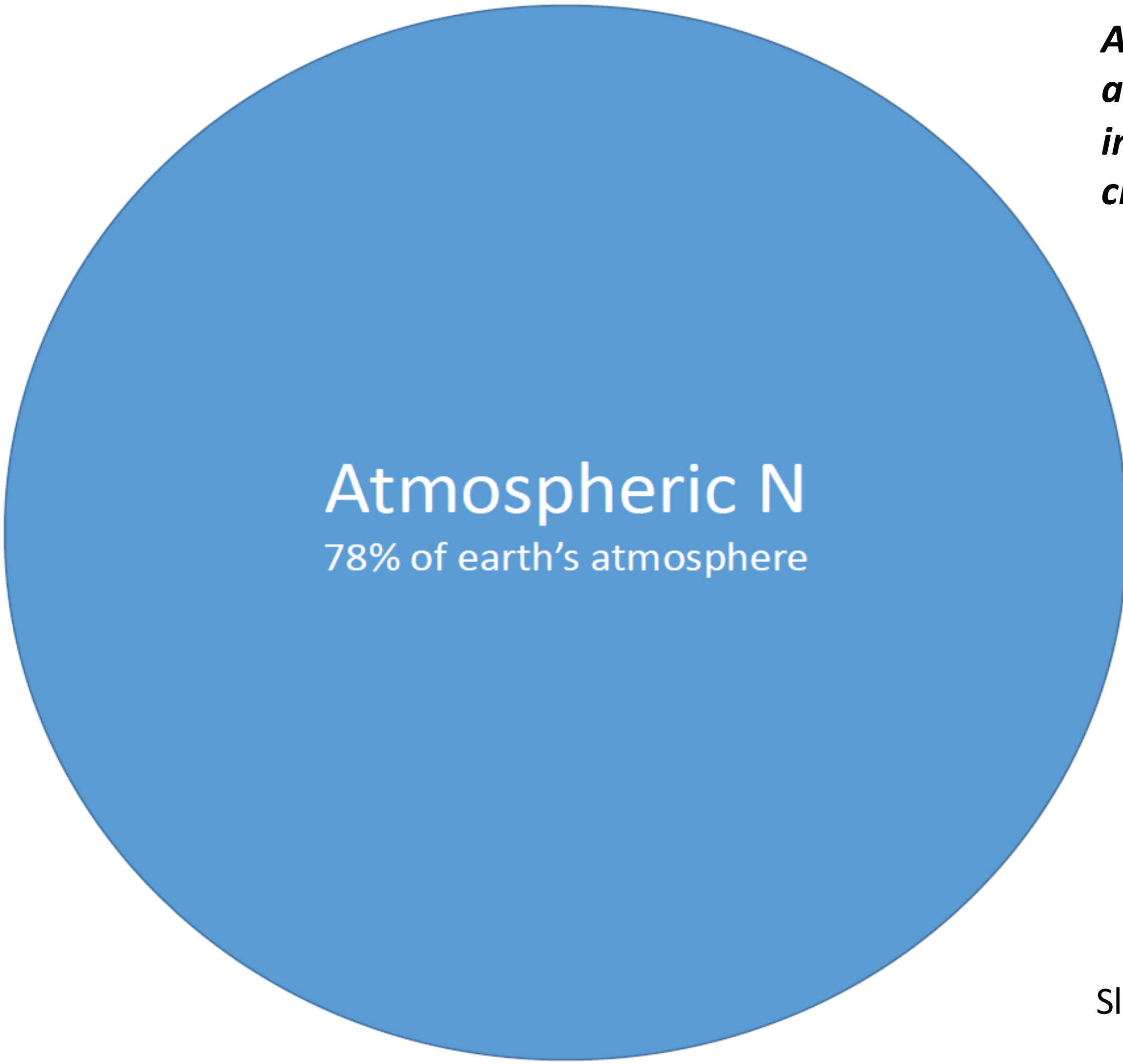
- Too much rainfall, ponding = leaching and denitrification

- Too hot and dry = volatilization, insufficient mineralization, poor plant uptake

- High residue carbon = immobilization

Source: https://www.agric.wa.gov.au/soil-carbon/immobilisation-soil-nitrogen-heavy-stubble-loads.

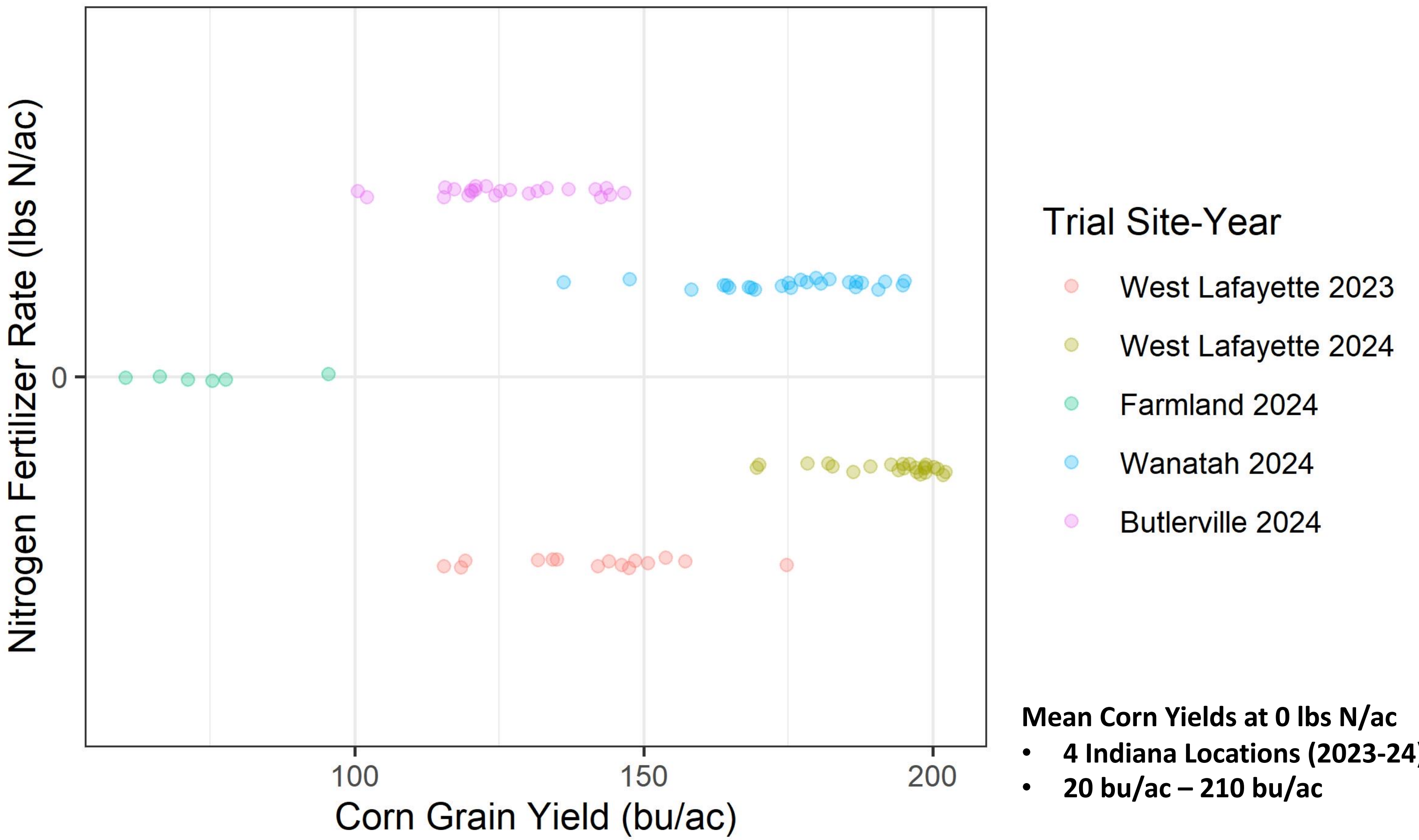
A lot of N in the atmosphere, not a lot of N in the available form for crops



Soil + crops

Slide by H. Poffenbarger, 2019

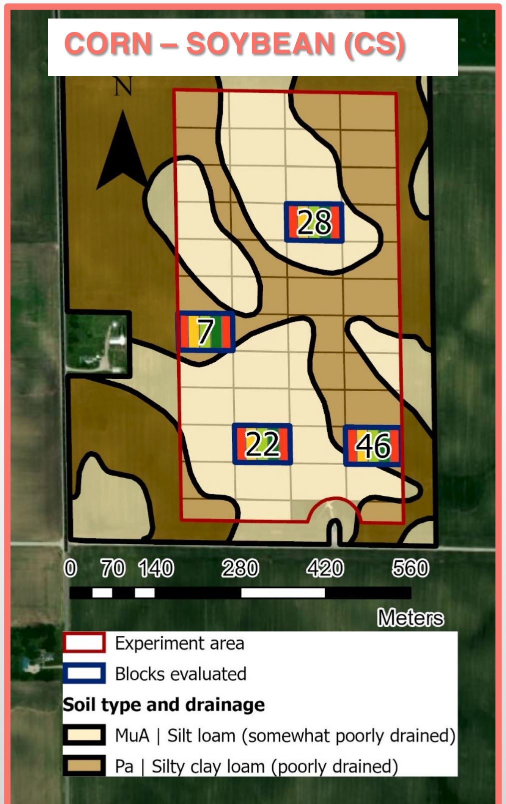
Variability of Corn Yields at 0 lbs N/ac by location

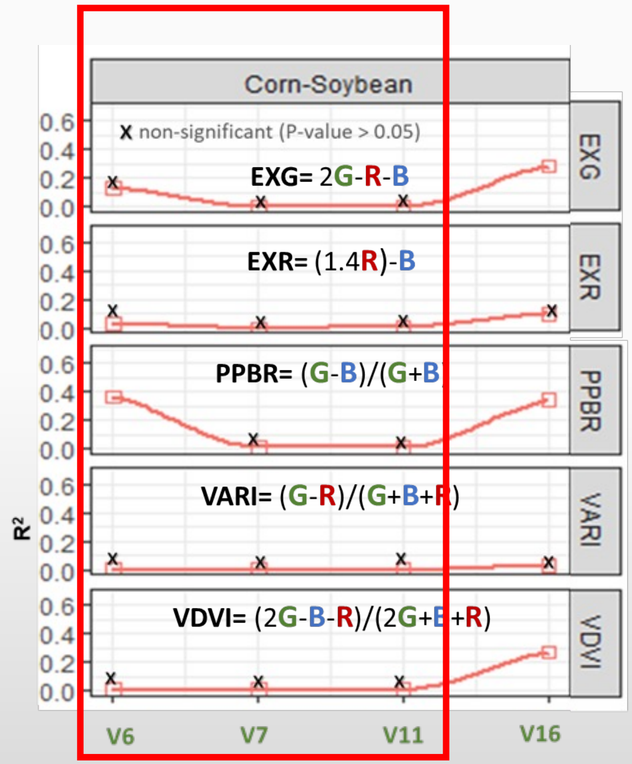


Mean Corn Yields at 0 lbs N/ac

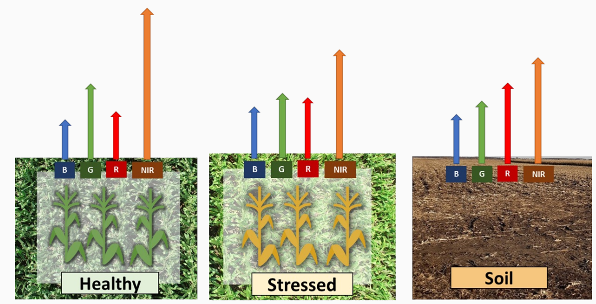
- **4 Indiana Locations (2023-24)**
- **20 bu/ac – 210 bu/ac**

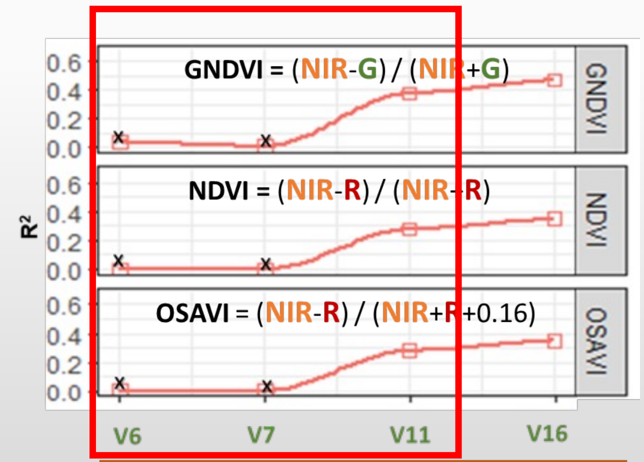
Relationship between multiple vegetative indices (extracted from UAV imagery) and corn grain yield response to N fertilizer rate





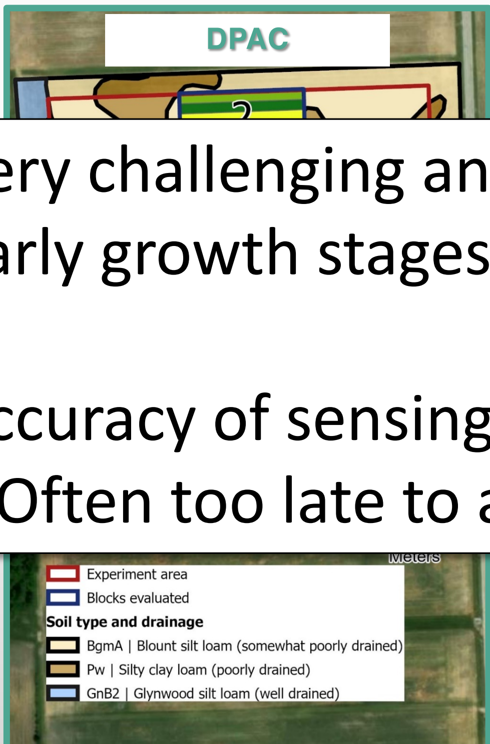
RGB-Based VI

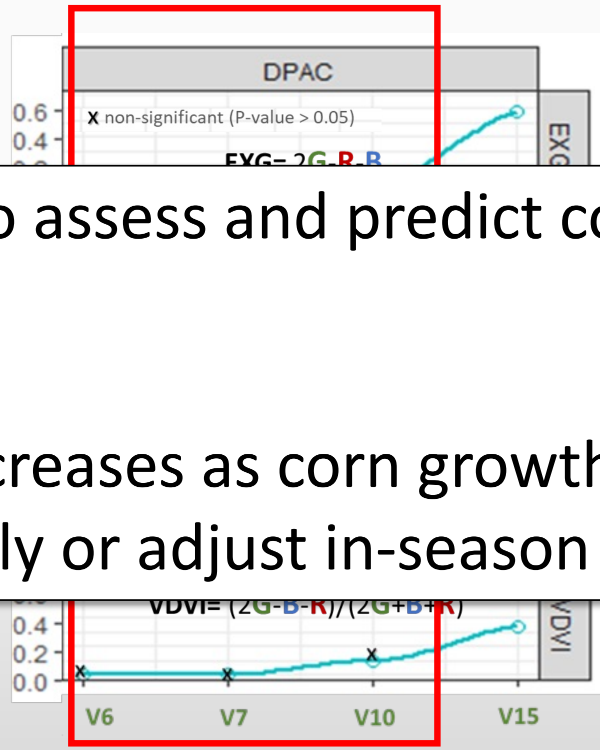




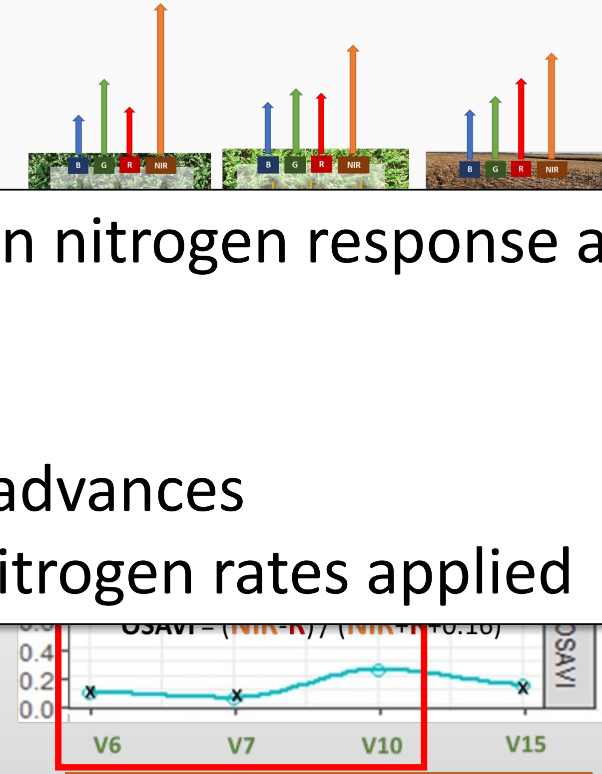
R-G-NIR-Based VI

Relationship between multiple vegetative indices (extracted from UAV imagery) and corn grain yield response to N fertilizer rate





RGB-Based VI

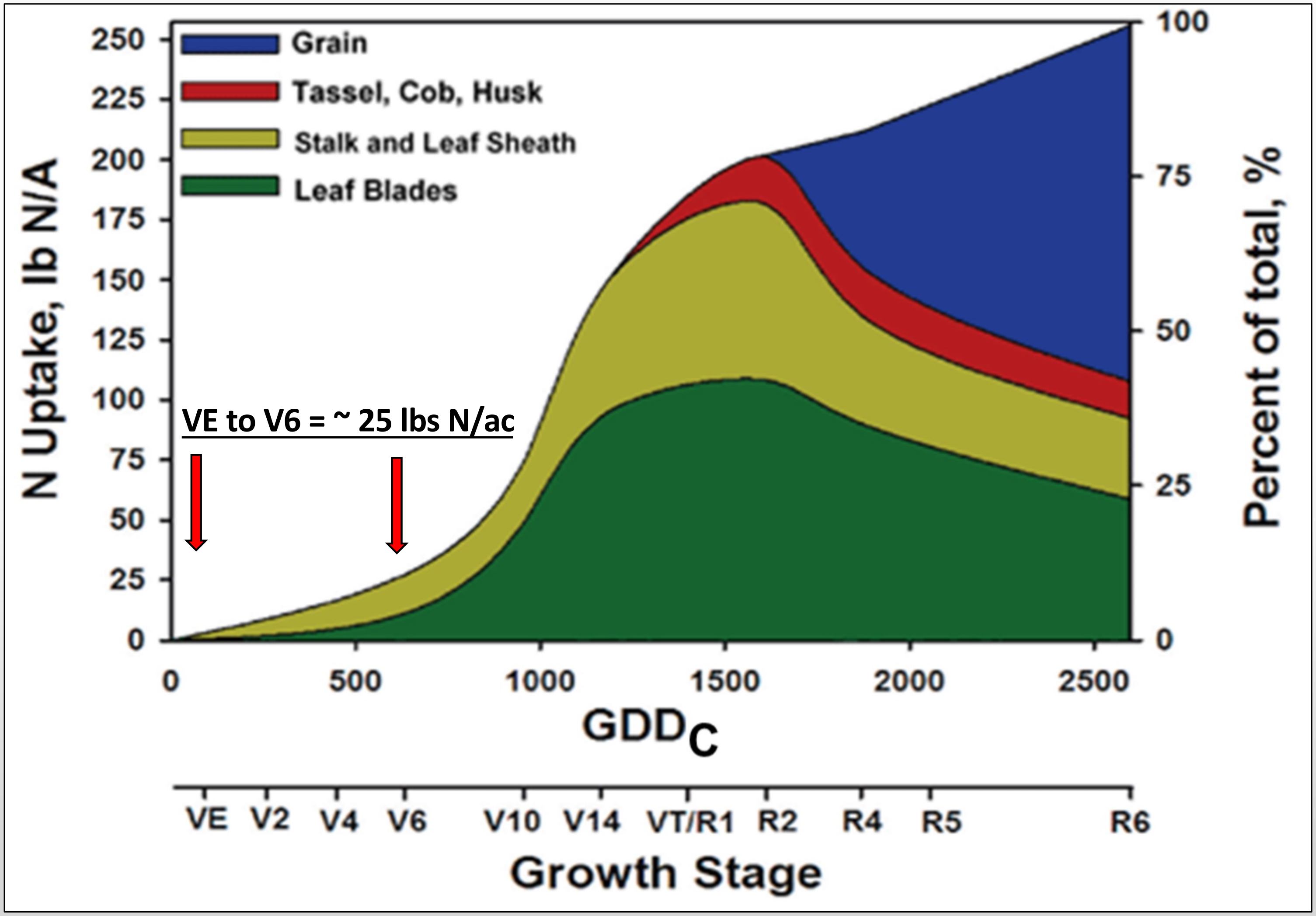


R-G-NIR-Based VI

Very challenging and to assess and predict corn nitrogen response at early growth stages.

Accuracy of sensing increases as corn growth advances

- Often too late to apply or adjust in-season nitrogen rates applied



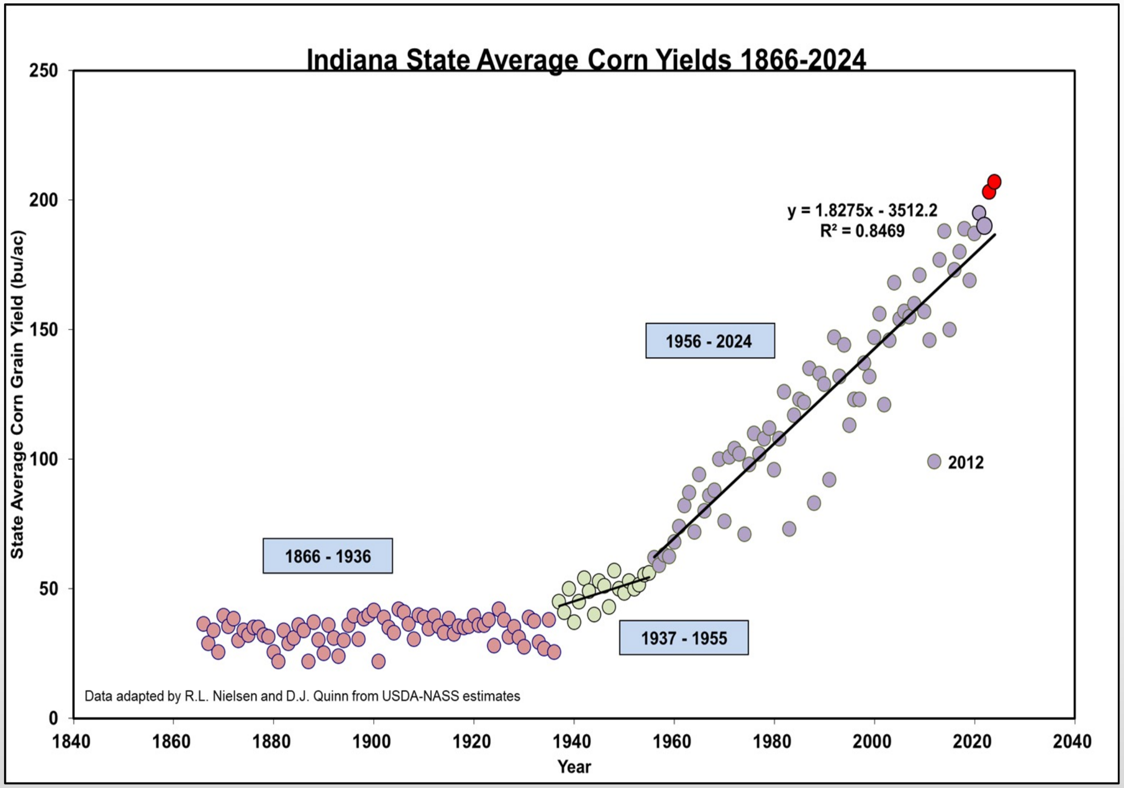
Bender et al., 2013

Do hybrids today require higher N rates?

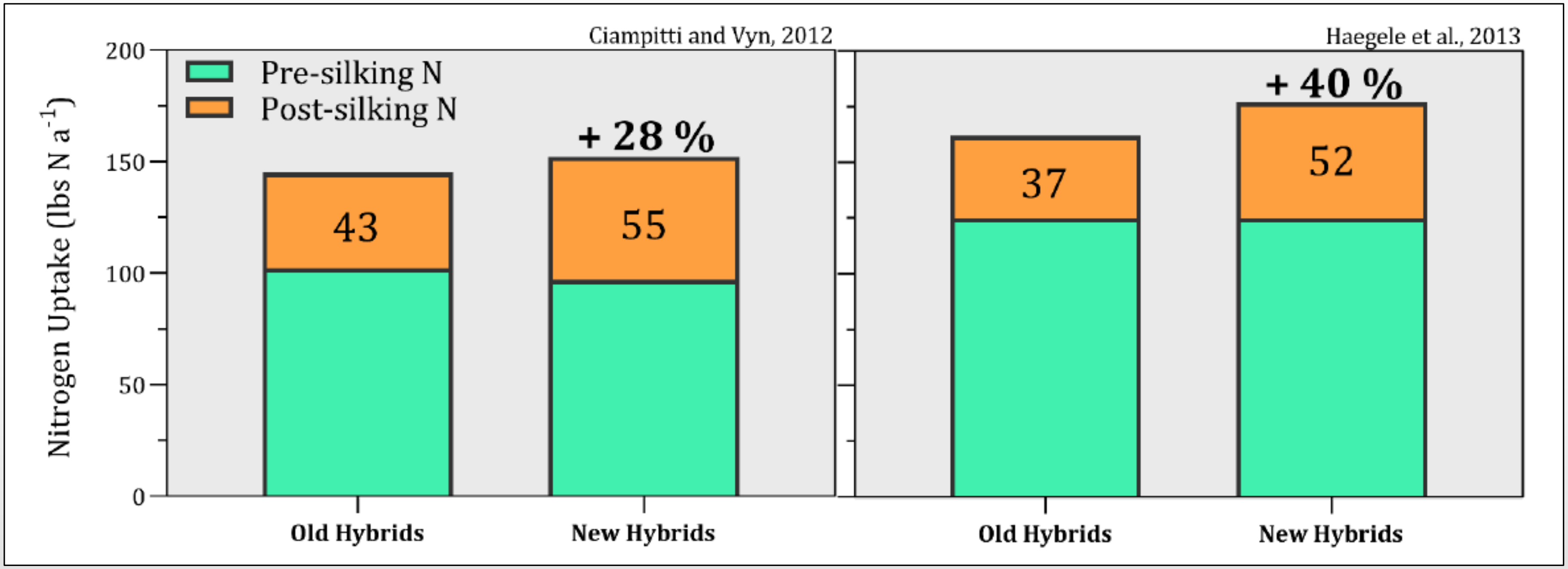
- **No**

- Greater NUE (1960 – 2010)
  - Agronomic Efficiency (AE)
  - Partial Factor Productivity (PFP)
  - Nitrogen Recovery Efficiency (NRE)
  - Total Production Efficiency (TPE)
  - ***Woli et al., 2016***

- Lower grain protein (1980-2020)
  - -0.32%/year (***Archontoulis, 2023***)



Hybrids today uptake more total nitrogen and more nitrogen after silking



~30% overall increase in post-silking nitrogen uptake in newer (1991 – 2011) hybrids than older (1940 – 1990) hybrids (Data and Figure by Ciampitti, 2024)

Nitrogen Availability is SIGNIFICANTLY controlled by the environment

- So….
- We need to try and control what we can control
  - Minimize N losses
  - Maintain available N when crop needs it

Ongoing Purdue Univ. Corn Nitrogen Management Research

- Inhibitors
- Biologicals
- And….Popcorn

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Overview of inhibitors tested

- Urease Inhibitor – **Duromide + NBPT – Anvol**

- Nitrification Inhibitor
  - **Nitrapyrin – Instinct NXTGEN**
  - **Pronitridine – Centuro**
  - Dicyandiamide (DCD) – SuperU, other experimental products

Corn Response to Duromide + NBPT Across Multiple N Rates (West Lafayette, IN 2023)

Anvol (0.17 oz/gal UAN)	N Fertilizer Rate (lbs/ac)	Grain Yield (bu/ac)
No	60	232.8 e
Yes	60	242.0 de

Across all applied N Rates Application of Anvol = +9 bu/ac when compared to control (surface-banded UAN application, very dry conditions)

* Mean grain yield values which do not contain the same letter and are within the same column are statistically different at alpha = 0.1

Corn Response to Pre-plant Surface Applied Urea + Various Inhibitor Products (West Lafayette, IN 2024)

Treatment Description	Nitrogen Fertilizer Rate	Grain Moisture	Grain Yield
	---- lbs/ac ----	---- % ----	---- bu/ac ---
Nontreated Control	0	15.6	114.7 d

- **Surface Application of Urea (120 lbs N/ac) + Anvol increase corn yield +15 bu/ac in comparison to the nontreated control**
- **Urea (120 lbs N/ac) + Anvol yielded the same as Nontreated Urea (180 lbs N/ac)**
- **Dry soil conditions following surface application**

Treatment Description	Nitrogen Fertilizer Rate	Grain Moisture	Grain Yield
Urea + Instinct NXTGEN	120	16.1	217.1 b
Pr>F		0.387	<0.001

Corn Response to Pronitridine Across Multiple N Rates (West Lafayette, 2023)

Centuro (1 oz/gal UAN)	N Fertilizer Rate (lbs/ac)	Grain Yield (bu/ac)
No	60	217.5 e
Yes	60	216.9 e

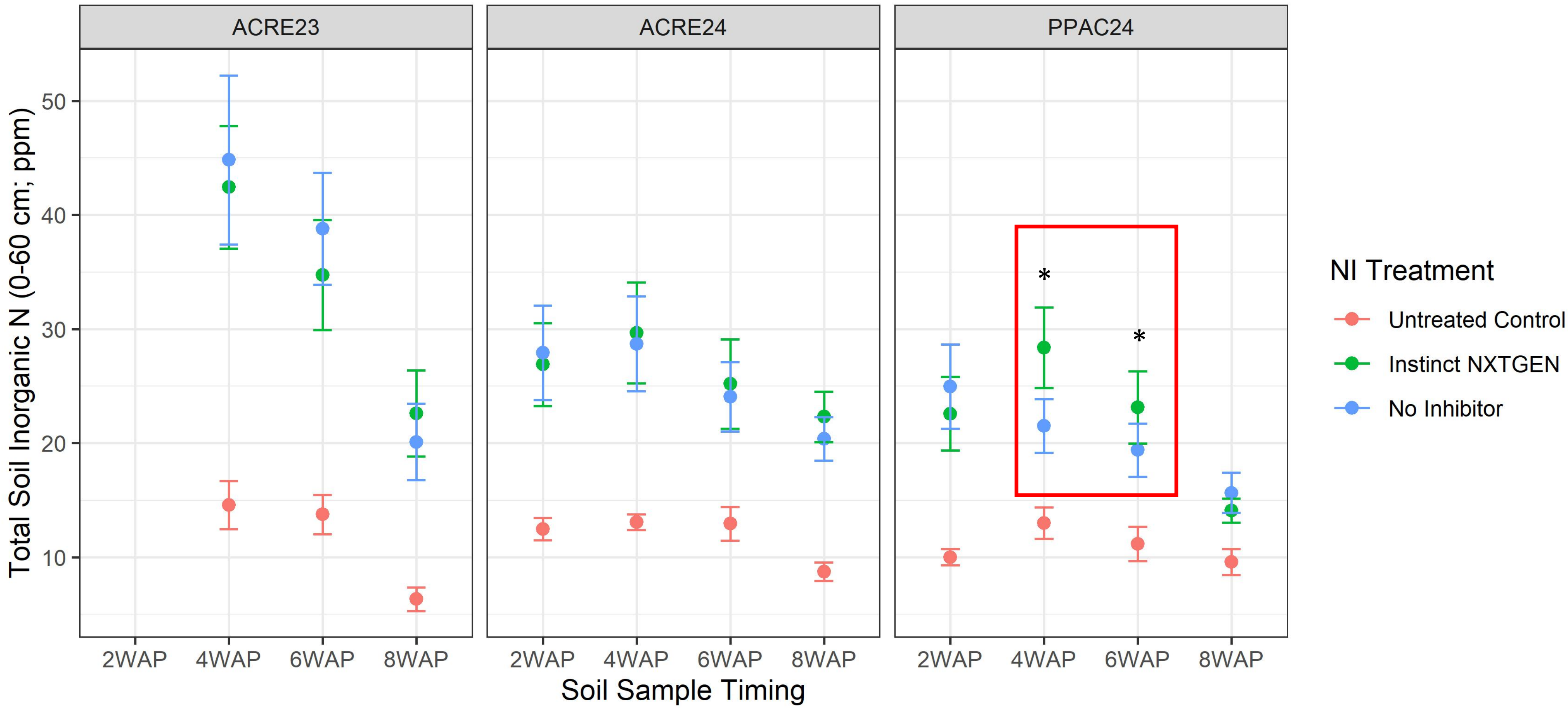
Across all applied N Rates Application of Centuro = +11 bu/ac when compared to control (coulter injected right after planting), greatest response at highest N rates applied

* Mean soil N values which do not contain the same letter and are within the same column (depth and type) are statistically different at alpha = 0.1

Corn Yield Response to N Rate, N Timing, and Nitrapyrin Application – 2023-24

Trial Site Year		**PPAC 2024**	**ACRE 2024**	**ACRE 2023**
N Fertilizer Timing	**Instinct NXTGEN**		**Grain Yield (bu/ac)**	
28% UAN V2-V4	No	**194.1 c***	259.2 a	288.7 a
28% UAN V2-V4	Yes	**211.6 a**	259.9 a	287.7 ab
28% UAN- Split	No	206.2 ab	**251.9 b**	**279.3 b**
28% UAN- Split	Yes	210.1 a	**256.9 ab**	**289.4 a**
Urea- PPL	No	200.1 bc	223.3 c	288.5 a
Urea- PPL	Yes	204.5 ab	230.1 c	287.4 ab

* Mean yield values which do not contain the same letter and are within the same location are considered statistically different at alpha = 0.1



Total soil (0-60 cm) inorganic N (NH4-N + NO3-N) differences in response to the inclusion of nitrification inhibitor Instinct NXTGEN at 2, 4, 6, 8 weeks after planting (WAP). * Indicates a statistical difference between the Instinct NXTGEN and no inhibitor treatments (P<0.1). Untreated control was excluded from the final analysis.

Rainfall following N applications – 2024

- Preplant N (Urea)
  - ACRE 2023 – 0.5” over 3 weeks following application
  - ACRE 2024 – 1.30” over 3 weeks following application
  - PPAC 2024 - 0.27” over 3 weeks following application

- Early V3 Sidedress (UAN)
  - ACRE 2023 – 0.3” over 3 weeks following application
  - ACRE 2024 – 1.43” over 3 weeks following application
  - **PPAC 2024 – 4.68” over 3 weeks following application**

- Split N Application (UAN)
  - ACRE 2023 – 0.5” following planting and 2.13” over 3 weeks following final application (V5).
  - ACRE 2024 – 1.30” following planting and 1.62” over 3 weeks following final application (V5).
  - PPAC 2024 – 0.27” following planting and **4.33” over 3 weeks following final application (V5).**

Recently Marketed Products

- Pivot Bio – ProveN 40
  - *Kosakonia sacchari* and *Klebsiella variicola*
  - In-furrow or seed treatment
- Corteva – Utrisha N
  - *Methylobacterium symbioticum*
  - Foliar applied
- Azotic – Envita
  - *Gluconacetobacter diazotrophicus*
  - In-furrow or foliar applied
- Others

Marketed to either infect the seed to enable N fixation, or inhabit area around the seed (rhizosphere) for N fixation

Recently Marketed Products

- Pivot Bio – ProveN 40
  - *Kosakonia sacchari* and *Klebsiella variicola*

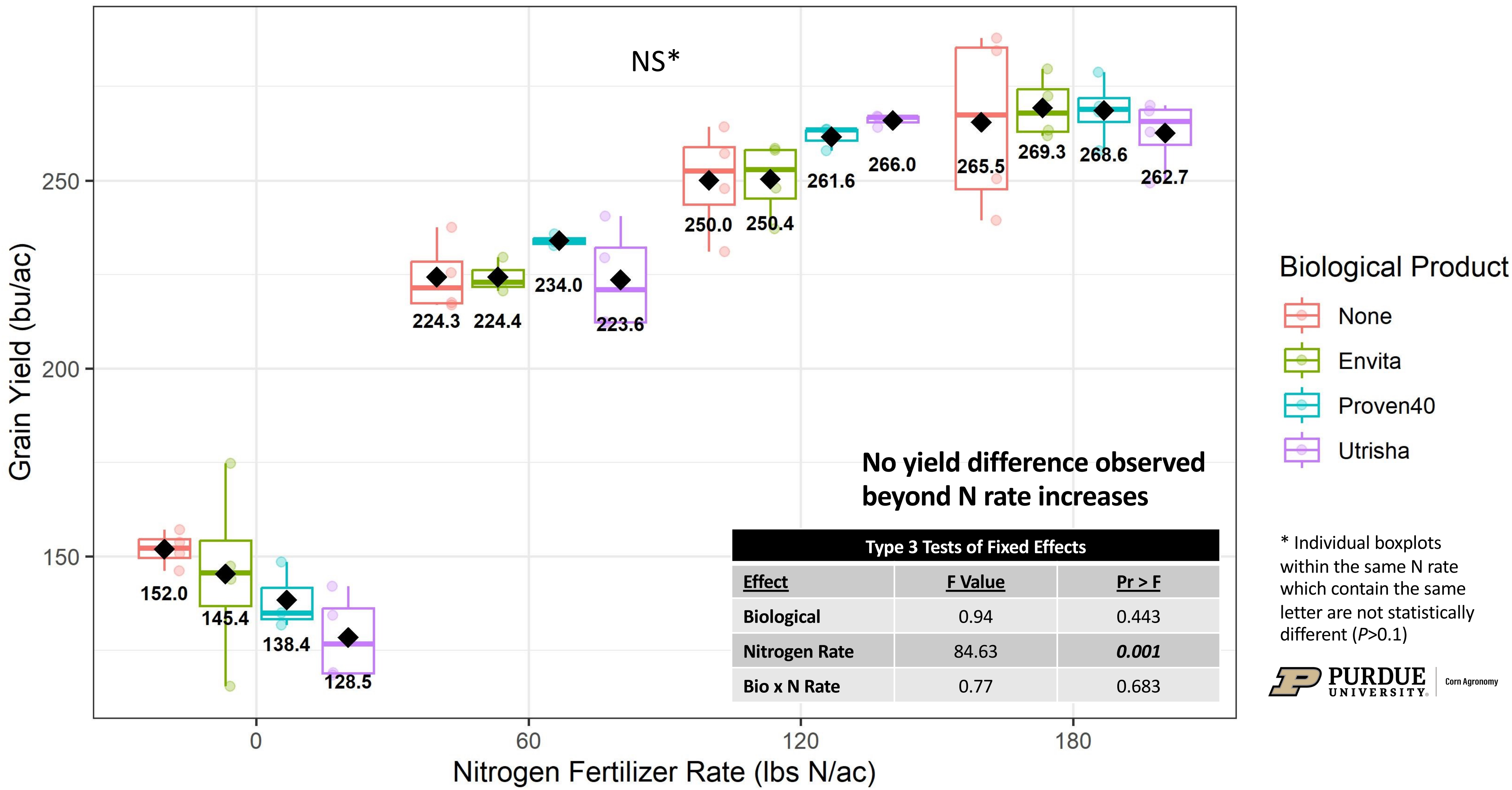
Do these products work?

1. **I Don't Know**

2. **It's Complicated**

- Others

ACRE (West Lafayette, IN) - 2023



Type 3 Tests of Fixed Effects		
Effect	F Value	Pr > F
Biological	0.94	0.443
Nitrogen Rate	84.63	***0.001***
Bio x N Rate	0.77	0.683

* Individual boxplots within the same N rate which contain the same letter are not statistically different (*P*>0.1)

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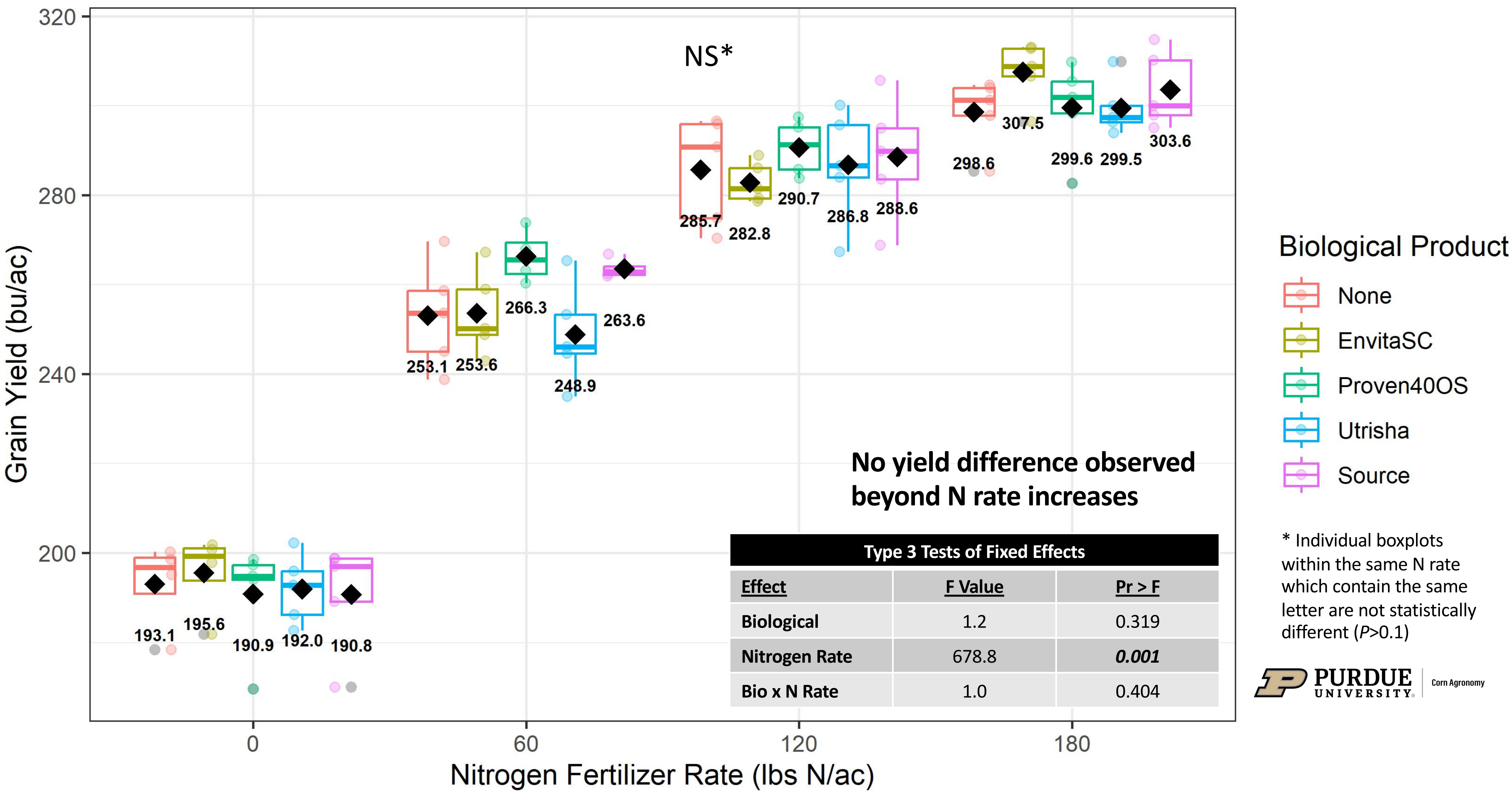
ACRE (West Lafayette, IN) - 2024



No yield difference observed beyond N rate increases

Type 3 Tests of Fixed Effects		
Effect	F Value	Pr > F
Biological	1.2	0.319
Nitrogen Rate	678.8	***0.001***
Bio x N Rate	1.0	0.404

* Individual boxplots within the same N rate which contain the same letter are not statistically different (*P*>0.1)

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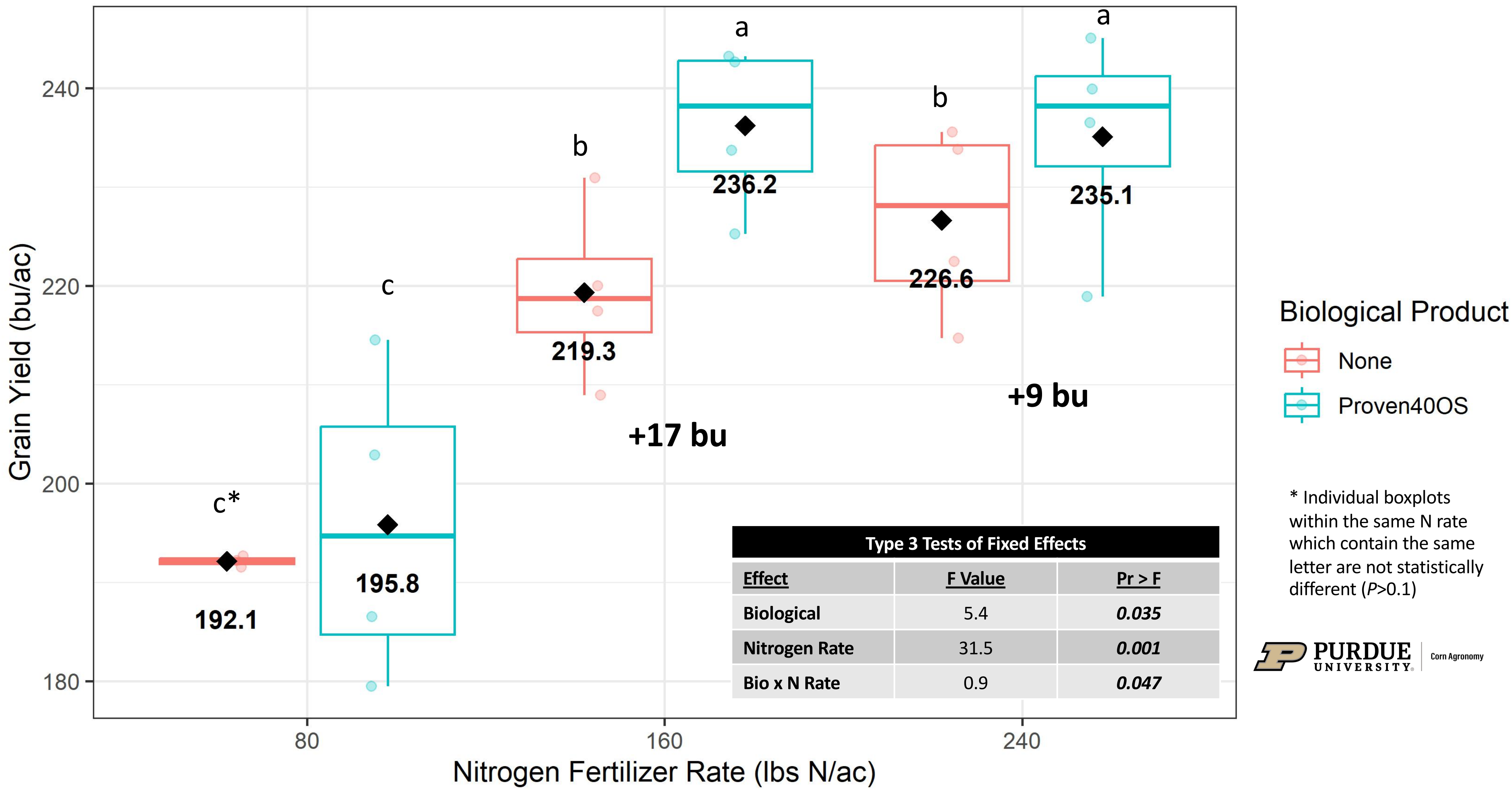
DPAC (Farmland, IN) - 2023



Type 3 Tests of Fixed Effects		
Effect	**F Value**	**Pr > F**
Biological	5.4	***0.035***
Nitrogen Rate	31.5	***0.001***
Bio x N Rate	0.9	***0.047***

* Individual boxplots within the same N rate which contain the same letter are not statistically different (*P*>0.1)

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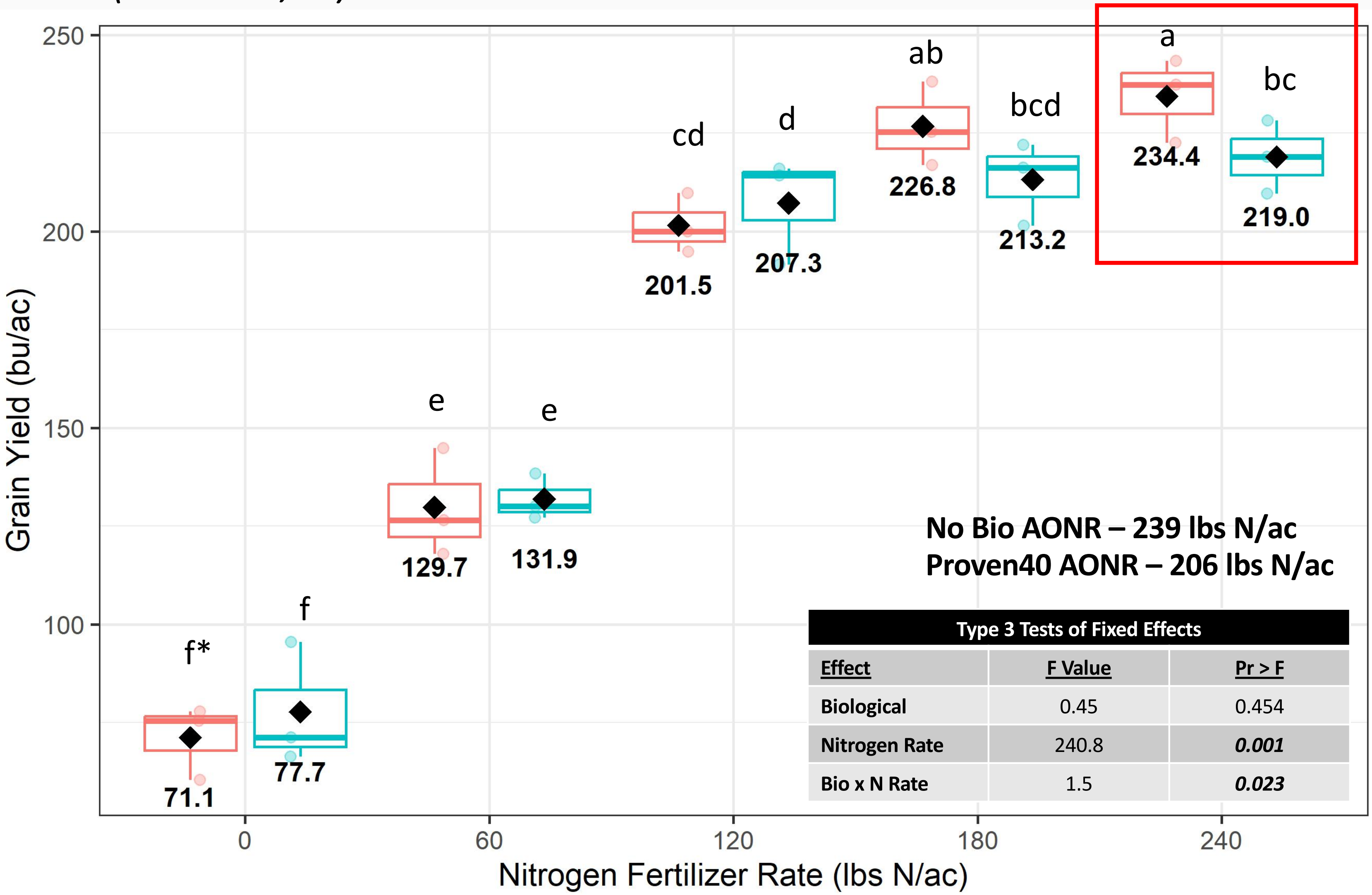
DPAC (Farmland, IN) - 2024



No Bio AONR – 239 lbs N/ac
Proven40 AONR – 206 lbs N/ac

Type 3 Tests of Fixed Effects		
Effect	**F Value**	**Pr > F**
Biological	0.45	0.454
Nitrogen Rate	240.8	***0.001***
Bio x N Rate	1.5	***0.023***

Biological Product
- None
- Proven40OS

* Individual boxplots which contain the same letter are considered not statistically different (*P*>0.1)

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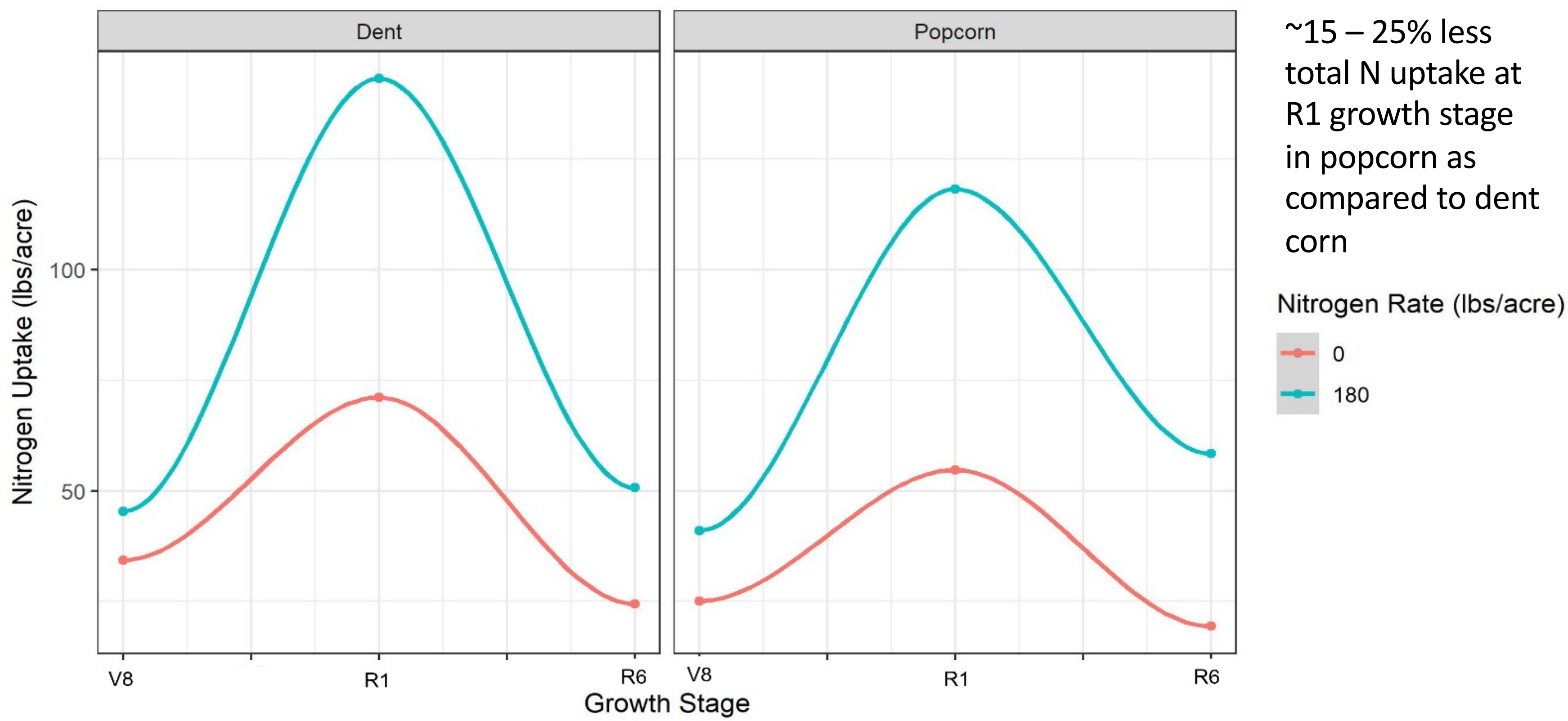
Last but not least….Popcorn

Popcorn Response to N Rate (7 locations, 2023-24)



~15 – 25% less total N uptake at R1 growth stage in popcorn as compared to dent corn

Popcorn Yield and Popping Parameter Response to N Fertilizer Rate – 2023-24

Trial Year	Trial Location	Popcorn Agronomic Optimum Nitrogen Rate (AONR)	Popcorn Yield at the AONR
		--- lbs/acre ---	--- lbs/acre ---
2023	West Lafayette, IN	132.6	7384.3
	Delphi, IN	162.3	6675.6
	Oaktown, IN	134.4	4125.1
2024	Wanatah, IN	179.7	6137.7
	West Lafayette, IN	146.1	6289.6
	Butlerville, IN	168.2	5800.1

N Fertilizer Rate	Mushroom	Butterfly	Kernel Density	Expansion
-- lbs N ac^{-1} --	%	%	--- k/10g ---	--- cc/g ---
0	37.5 b*	62.5 a	52.0 a	40.8 c
60	38.5 b	61.5 a	45.0 b	43.5 ab
120	38.8 b	61.2 a	44.2 b	44.0 a
180	45.7 a	54.3 b	42.7 b	43.3 ab
240	44.6 a	55.5 b	44.9 b	41.8 bc

Snapshot of Preliminary Results

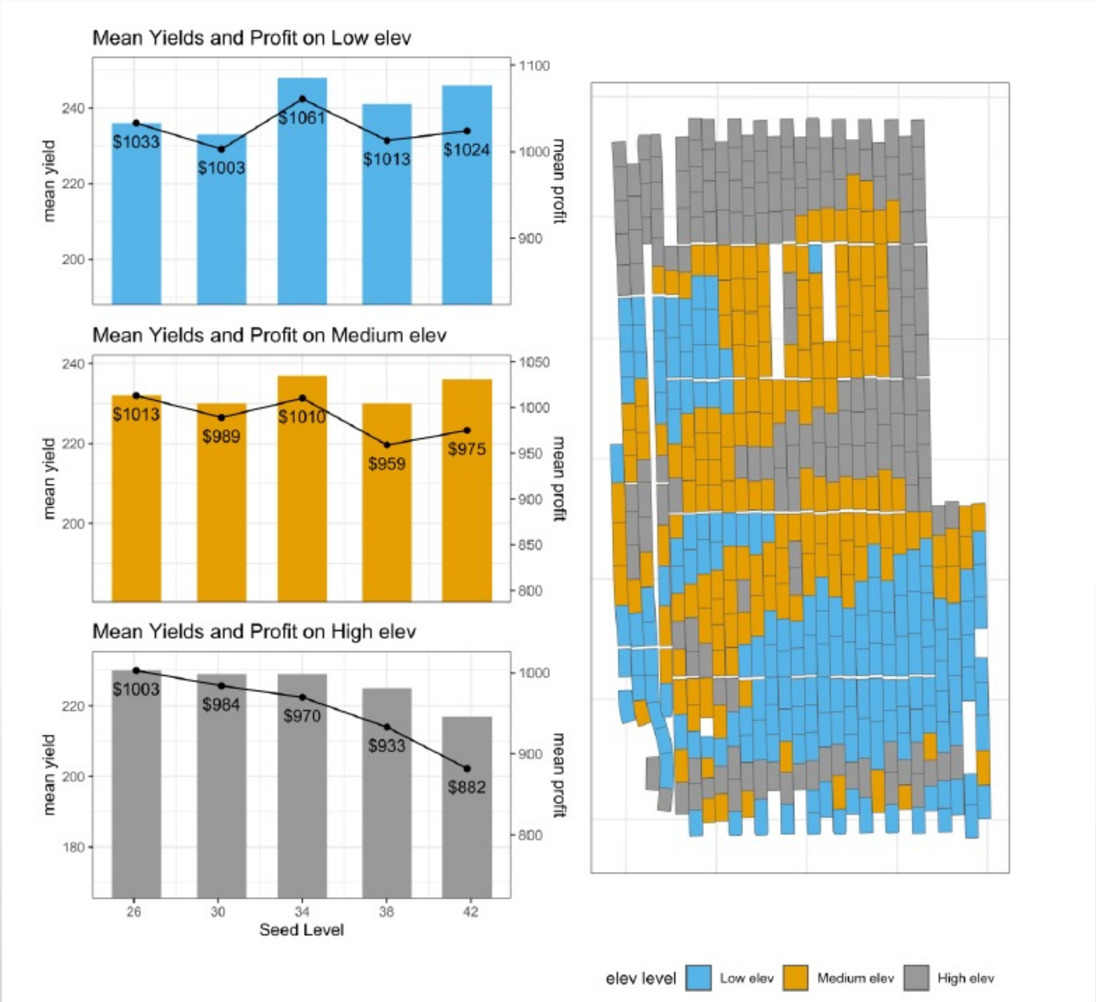
- Inhibitors do what they are supposed to (urease, nitrification)
  - But environmental conditions and application methods often dictate magnitude of response

- Asymbiotic N-fixing biologicals offer minimal and inconsistent responses
  - Challenging N environments?

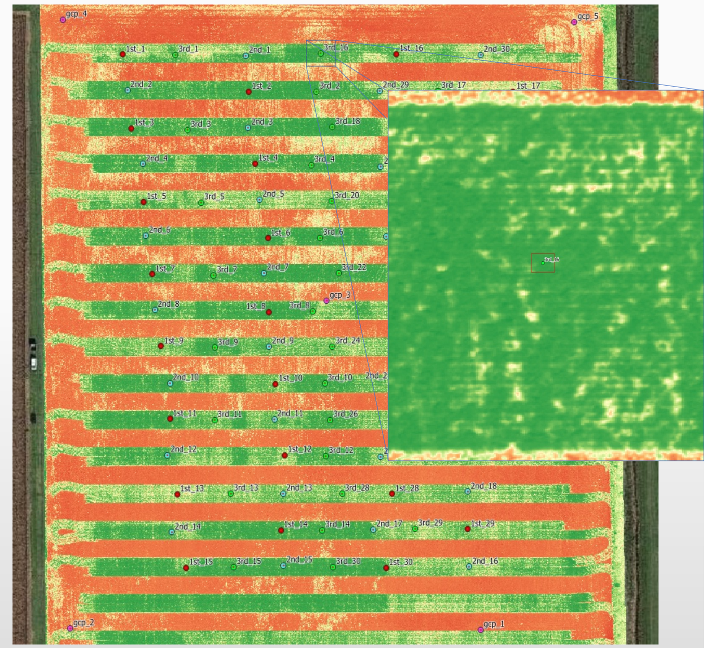
- Popcorn require less total N than dent corn (~50 lbs N/acre)
  - Total N applied may impact popping parameters

Where are we going?

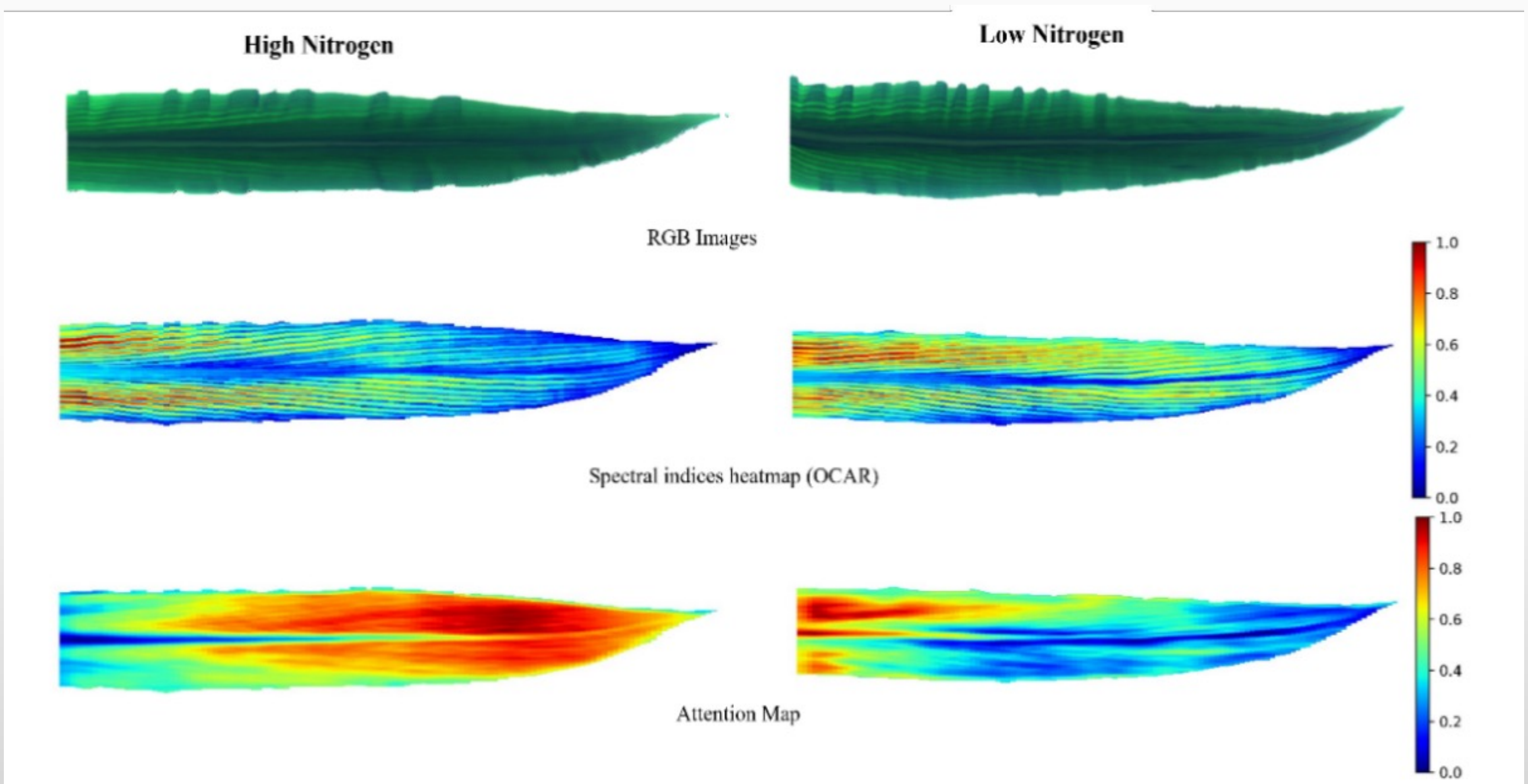
- Continued Evaluation of On-Farm Spatial Responses
  - DIFM Framework (difm.farm; University of Illinois)
- Economics



Can cover crops help inform spatial soil N availability?



Advanced Proximal Sensing – LeafSpec and Early Vegetative Corn



Future Directions

- Obtaining Better, More Accurate Data
  - Advanced Imagery and Sensors (UAV, Satellite, Proximal Sensors)
  - Improved soil nitrogen sensors (real-time available soil N data)

- Crop Modeling, Machine Learning, and AI
  - A lot of data out there, need to feed these

- Need to keep improving (and updating) data to “back-up” N rate recommendations, prescriptions

Questions?

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