



Nutrient Removal with Grain Corn: Not Just a Yield Story

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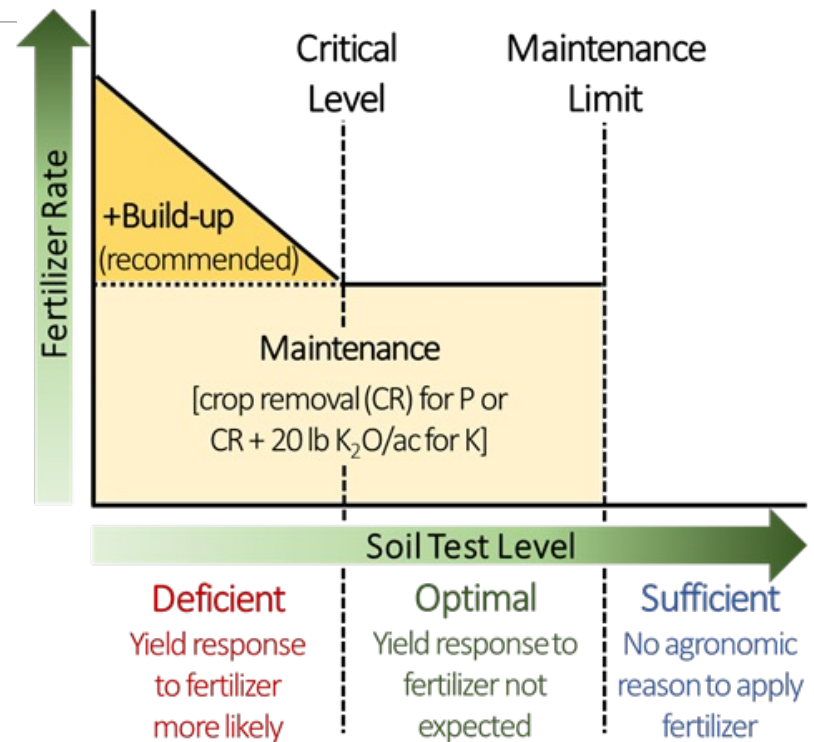
Presented to:

Indiana CCA Conference on Dec. 14, 2022



Critical levels and maintenance limits for corn and soybean

Mehlich-3 extraction	Critical level	Maintenance limit
P, ppm	20	40
K, ppm; CEC<5	100	130
K, ppm; CEC≥5	120	170



Note: If soil test is reported in lb/acre multiply ppm by 2

Three Questions!

Question #1. How much are grain nutrient removals per bushel affected by yield ranges up to 300 bushels/acre? _____

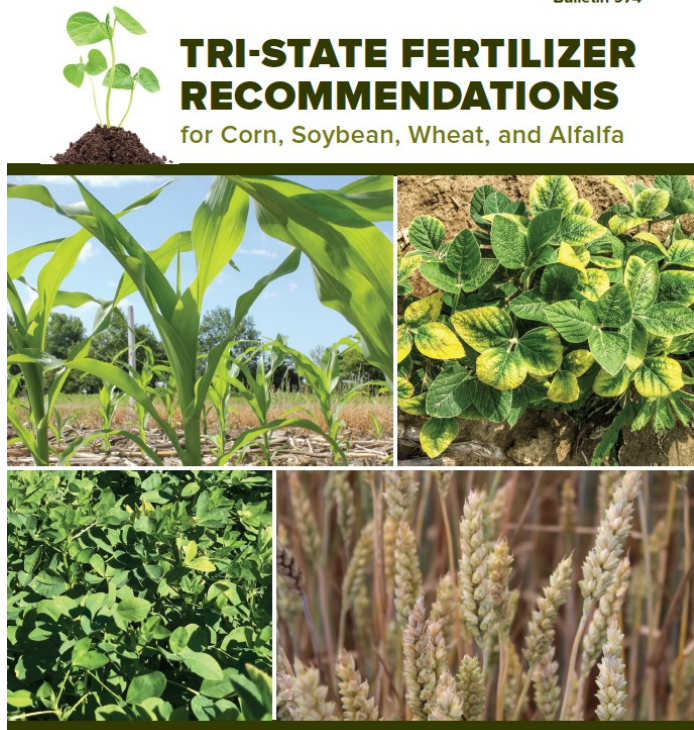
Question #2. How dependent are grain nutrient concentrations on corn yield response to the same (or different) nutrients? Why?



Question #3. How dependent are actual nutrient removals per bushel to hybrid and other management differences (e.g. tillage, population)?

Nutrient Removal Assumptions Based on Yield Alone

Bulletin 974



Nutrients Removed in Harvested Grain		
Crop	Grain Nutrient Removal Rate	
	lb P ₂ O ₅ / bushel	lb K ₂ O/ bushel
Corn	0.35	0.20
Soybean	0.80	1.15
Wheat	0.50	0.25

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Knowledge Connections

Source: Culman et al., 2020

Nutrients Removed with Harvested Corn, Soybean, and Wheat Grain in Ohio

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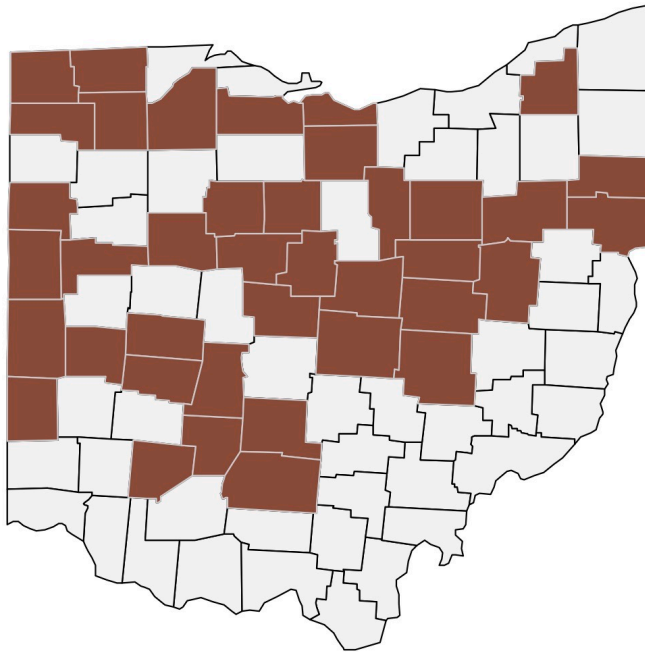
ANR-74

Agriculture and
Natural Resources

Date: Jun 14, 2019

Steve Culman, Phoo P. Zone, Nakian Kim, Anthony Fulford, Laura Lindsey, Peter Thomison, Anne Dorrance, Rich Minyo, Eric Richer, Ed Lentz, Ryan Haden, Harold Watters, Greg LaBarge

The purpose of this fact sheet is to report grain nutrient removal rates in corn, soybean, and wheat in Ohio.



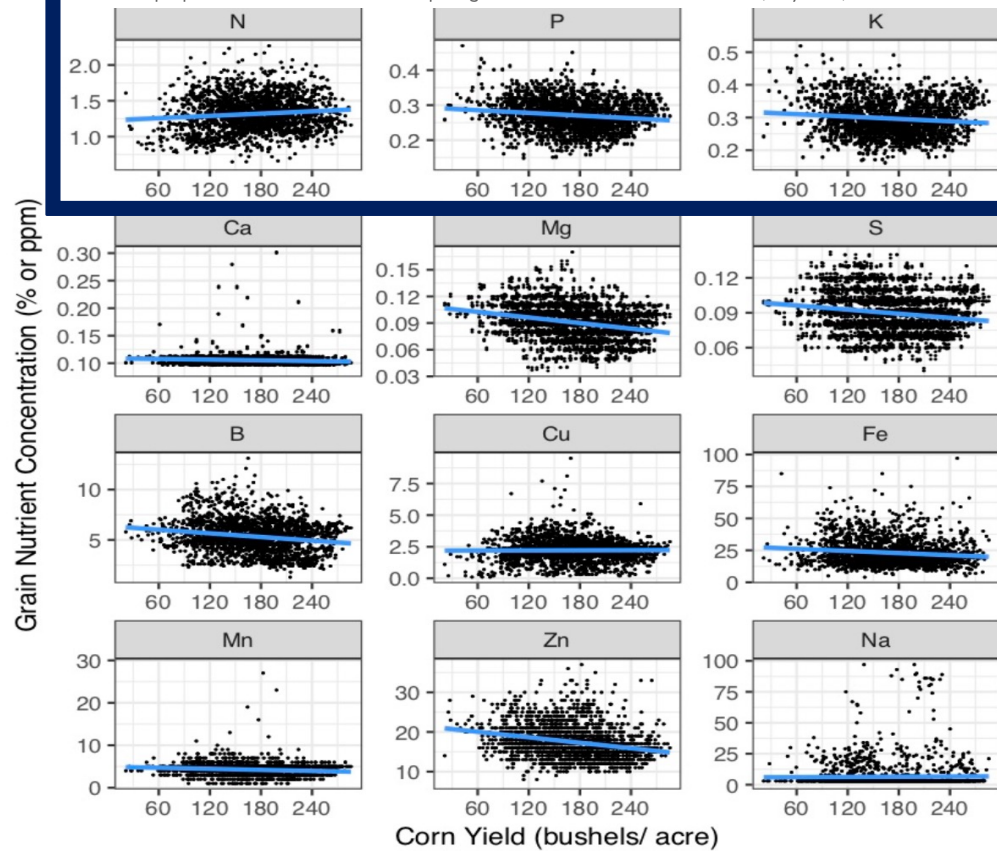
**2338 samples of grain corn from 2014-2018
in a larger state-wide trial with 39 counties
and 300 fertilizer trials**

**Corn yields ranged from 21-286 bu/acre,
and averaged 171 bu/acre**

Nutrients Removed with Harvested Corn, Soybean, and Wheat Grain in Ohio

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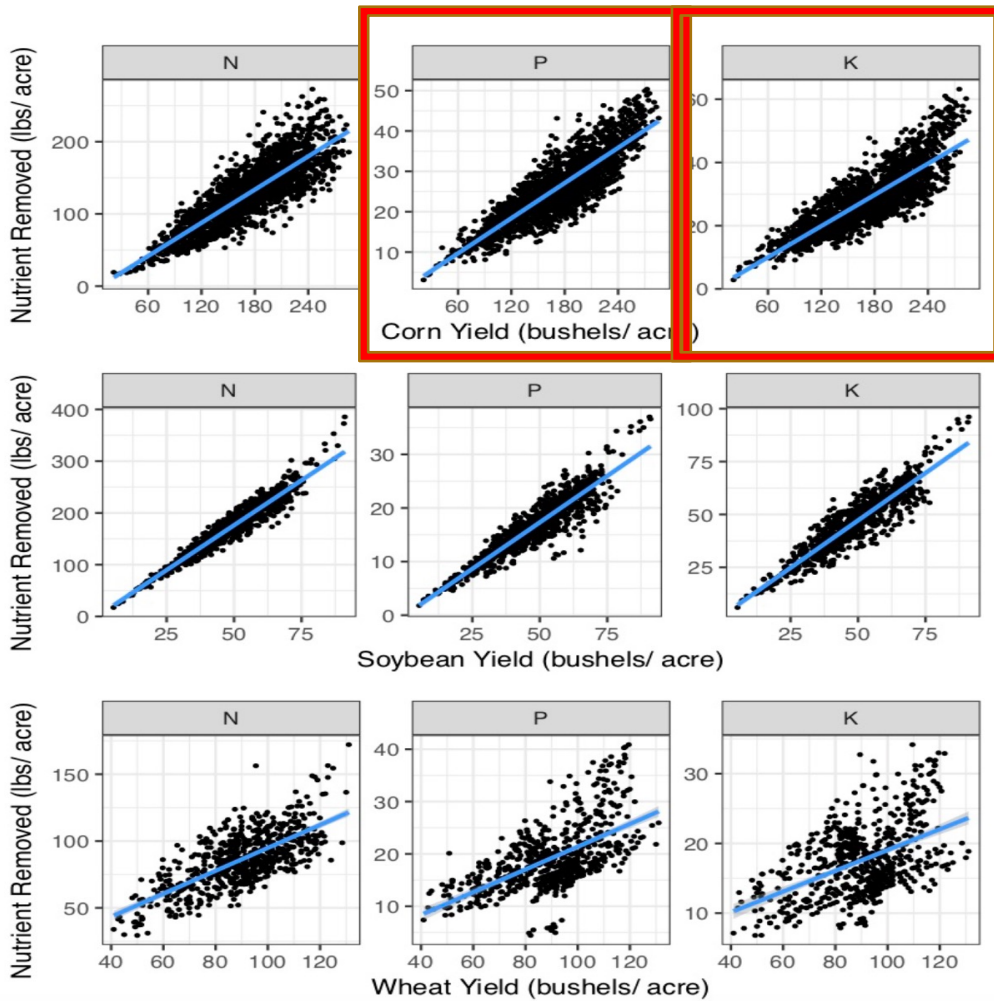
ANR-74

Agriculture and
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Average Grain Nutrient Concentrations in Corn, S

	Corn
	% -----
Nitrogen (N)	1.33
Phosphorus (P)	0.27
Potassium (K)	0.30
Calcium (Ca)	0.11
Magnesium (Mg)	0.09
Sulfur (S)	0.09
	ppm -----
Boron (B)	5.2
Copper (Cu)	2.2
Iron (Fe)	23.4
Manganese (Mn)	4.2
Zinc (Zn)	17.2





Grain nutrient removal rates			
	Corn	Soybean	Wheat
	(lb of nutrient/bushel grain)		
N	0.74	3.55	0.96
P ₂ O ₅	0.35	0.79	0.49
K ₂ O	0.20	1.14	0.24
Ca	0.06	0.22	0.08
Mg	0.05	0.14	0.07
S	0.05	0.18	0.07
B	0.0003	0.0023	0.0003
Cu	0.0001	0.0008	0.0003
Fe	0.0013	0.0054	0.0025
Mn	0.0002	0.0017	0.0022
Zn	0.0010	0.0023	0.0015

Kernel Moisture Variation Complicates Nutrient Concentration and Removal Calculations

Grain Removal of 0.2 pounds of K₂O per bushel:

- 1. Assumes that direct K removal is 0.165 lbs/bu of yield.**
- 2. Assumes that the grain K concentration at 15.5% moisture is 0.295 % K.**
- 3. However, if grain is dried to near 0% moisture and then ground, the equivalent grain K concentration is 0.349 % K.**

Actual grain removal estimates depends on moisture of the kernel samples at the time of analysis.

Dataset Information:

Title	Cropland Nutrient Budget
Abstract	The Cropland Nutrient Budget domain contains information on the flows of nitrogen, phosphorus, and potassium from synthetic fertilizer, manure applied to soils, atmospheric deposition, crop removal, and biological fixation over cropland and per unit area of cropland. The flows are aggregated to total inputs and total outputs, from which the overall nutrient budget and nutrient use efficiency on cropland are calculated. Statistics are disseminated in units of tonnes and in kg/ha, as appropriate. Nutrient use efficiency is expressed as a fraction (%). Data are available by country, with global coverage relative to the period 1961-2020, with annual updates.

Corn Grain Nutrient Removal:

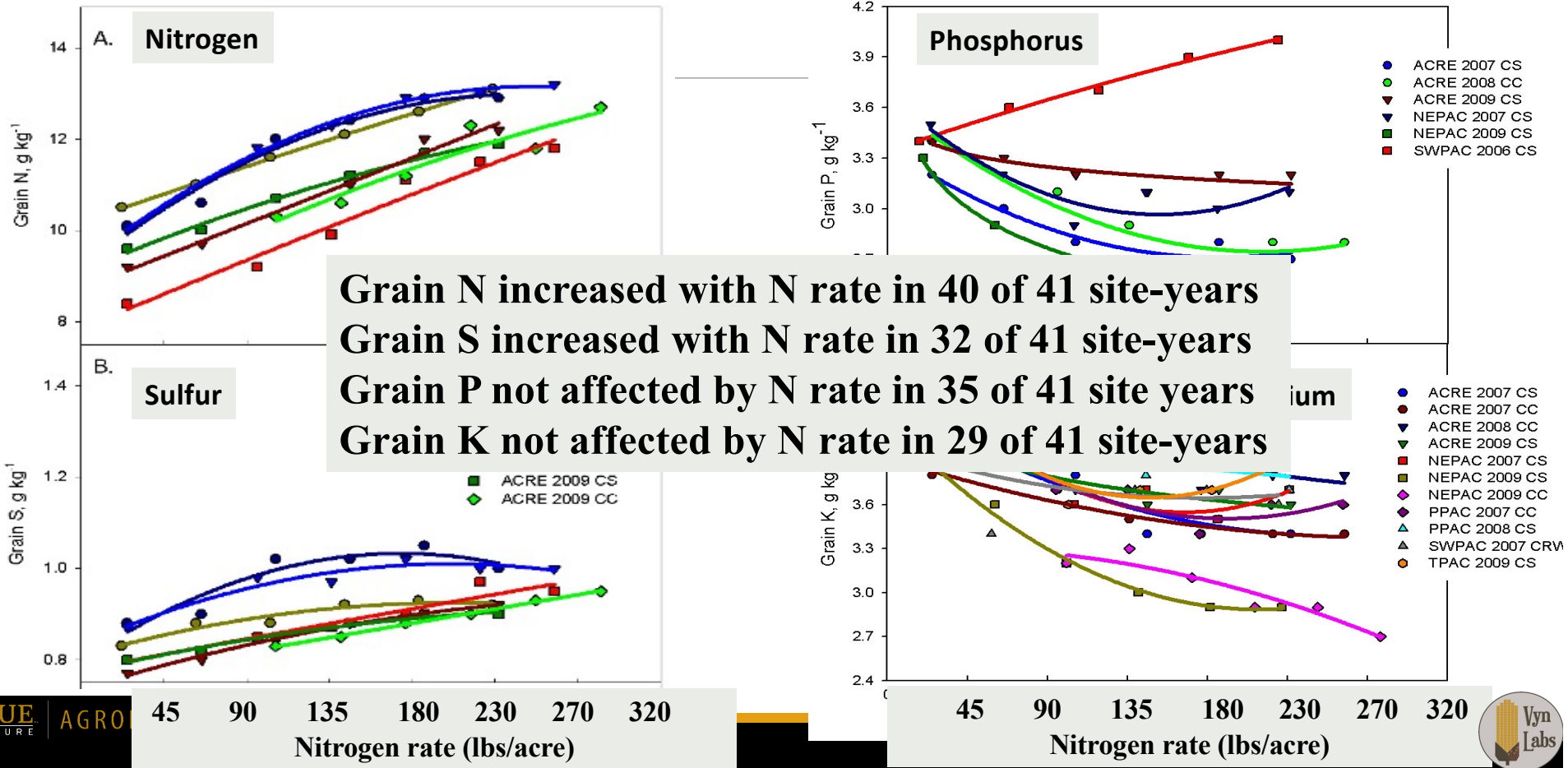
N: 1.24 kg N/tonne = 1.47% N on a dry weight basis (0% moisture).

P: 3.4 kg P/tonne = 0.4 % P on a dry weight basis (0 % moisture) and 0.44 lb/bu P₂O₅.

K: 4.3 kg K/tonne = 0.5% K on a dry weight basis (0% moisture) and 0.29 lb K₂O/bu.

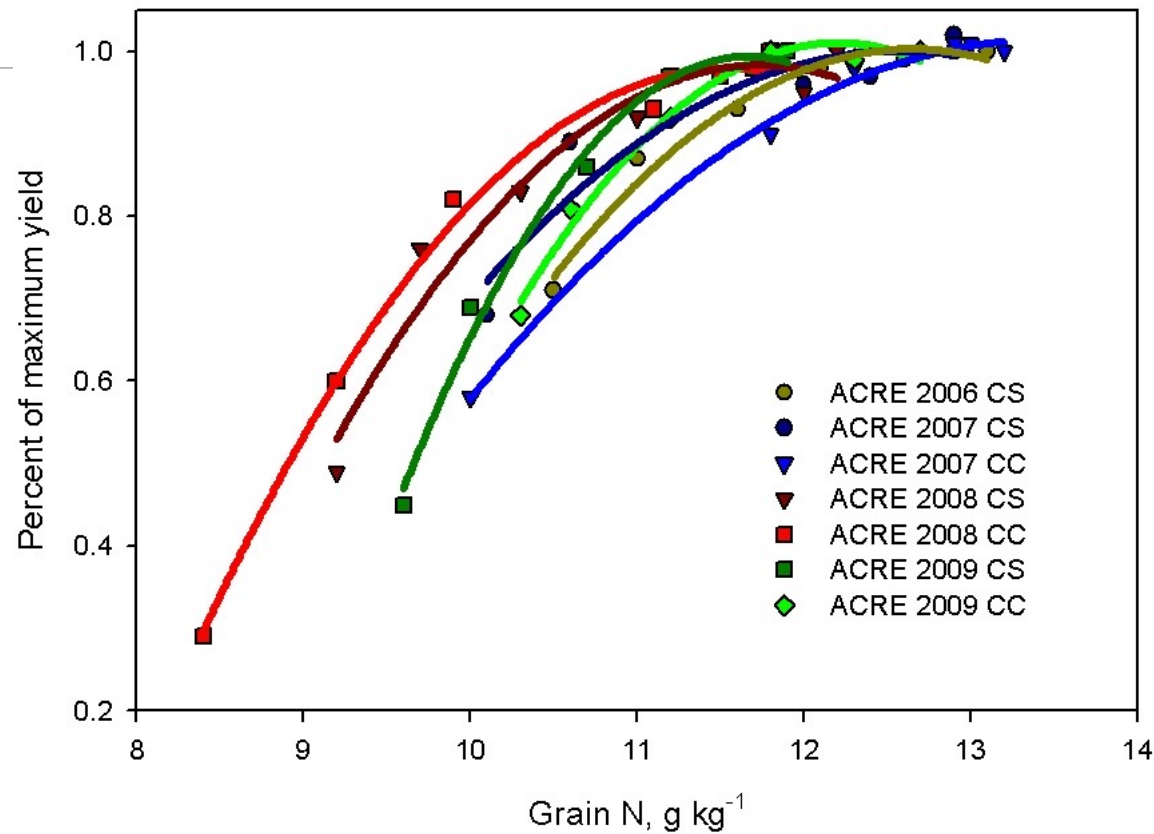
Indiana Grain Nutrient Concentrations in Corn Response to N Fertilizer Rates (41 site-years, 2006-2009)

(Miller, Nielsen & Camberato, 2012, unpublished)



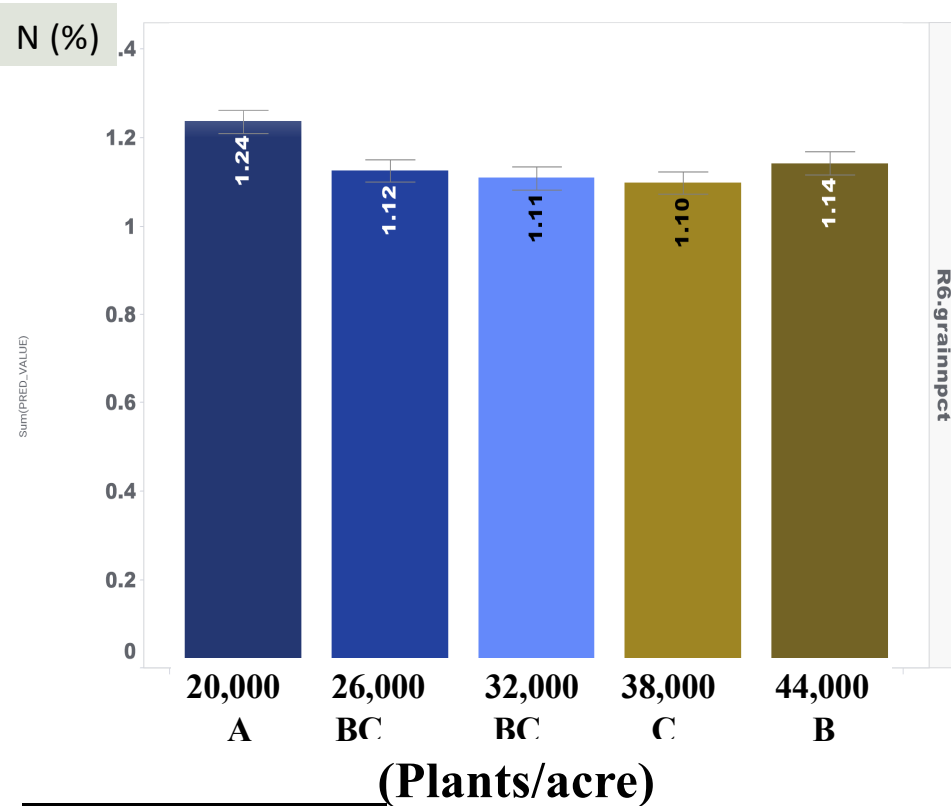
In well-fertilized situations, grain N can continue to increase even when grain yield doesn't.

(Miller, Nielsen & Camberato, 2012, unpublished)

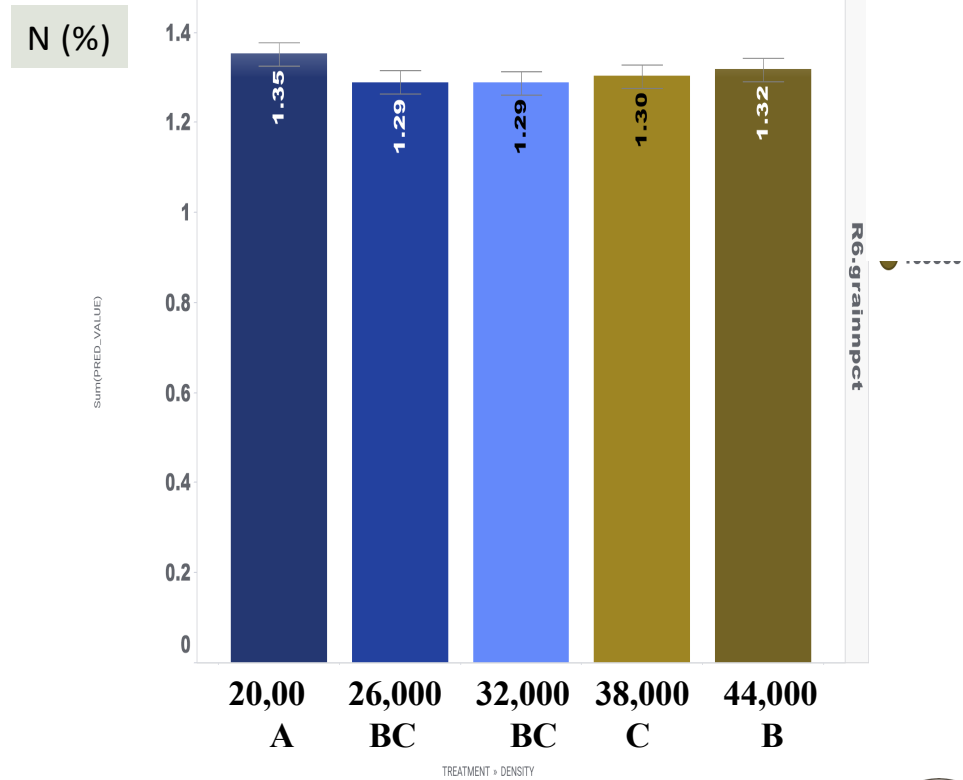


Grain N Concentrations: Big impact of N rates, but only a minor impact of Plant Densities.

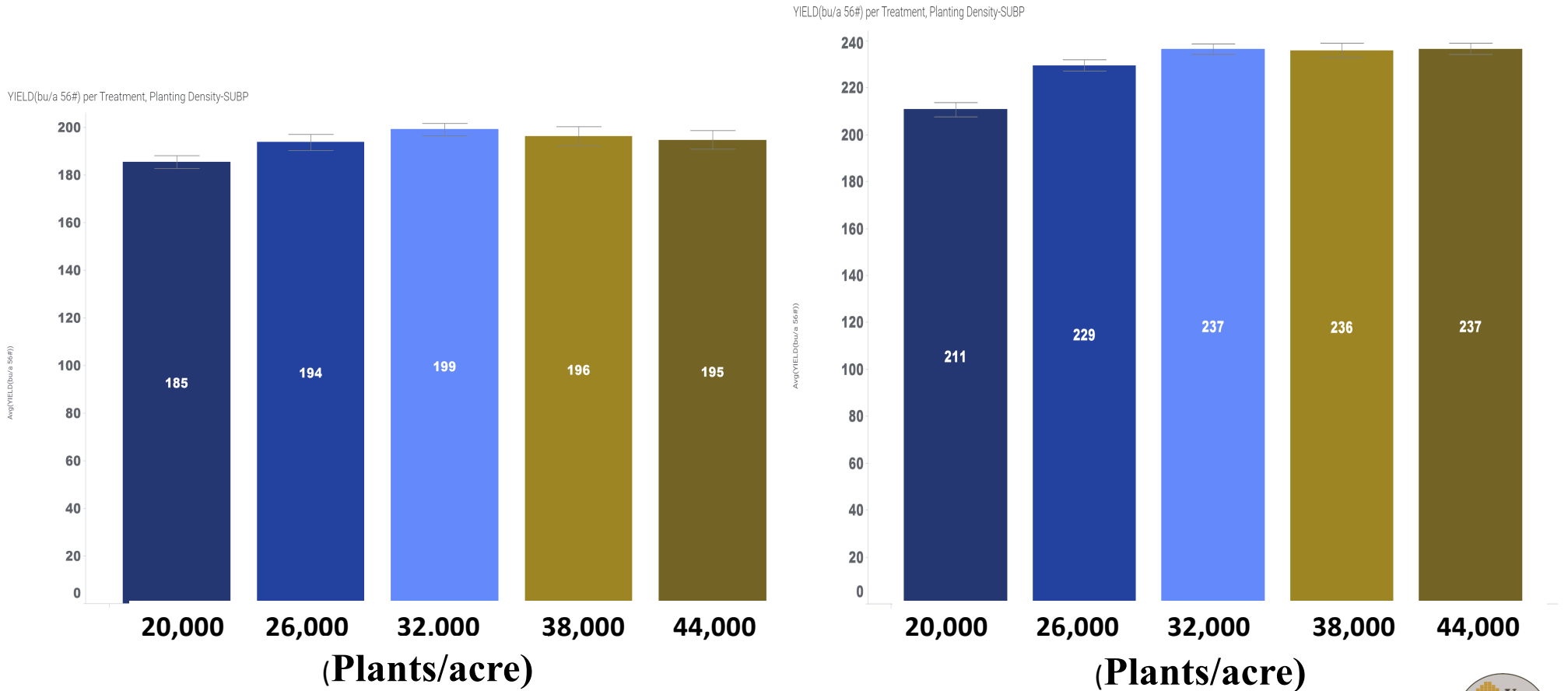
N = 40 lbs/ac



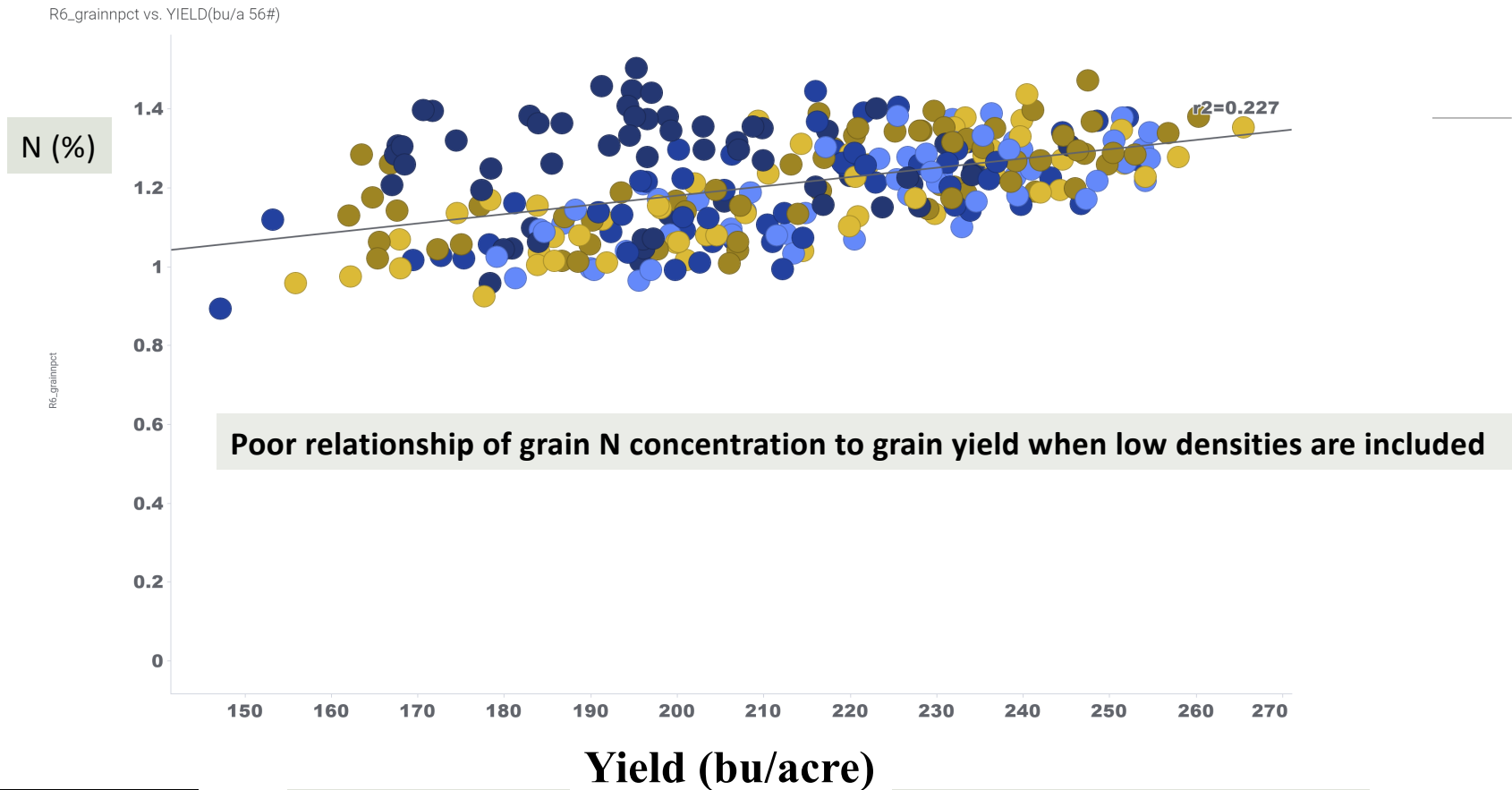
N = 240 lbs/ac



Context to the Previous Slide on Grain N Concentrations: Yield (bu/ac) Response to Planting Density at 40 vs. 240 lbs N/acre

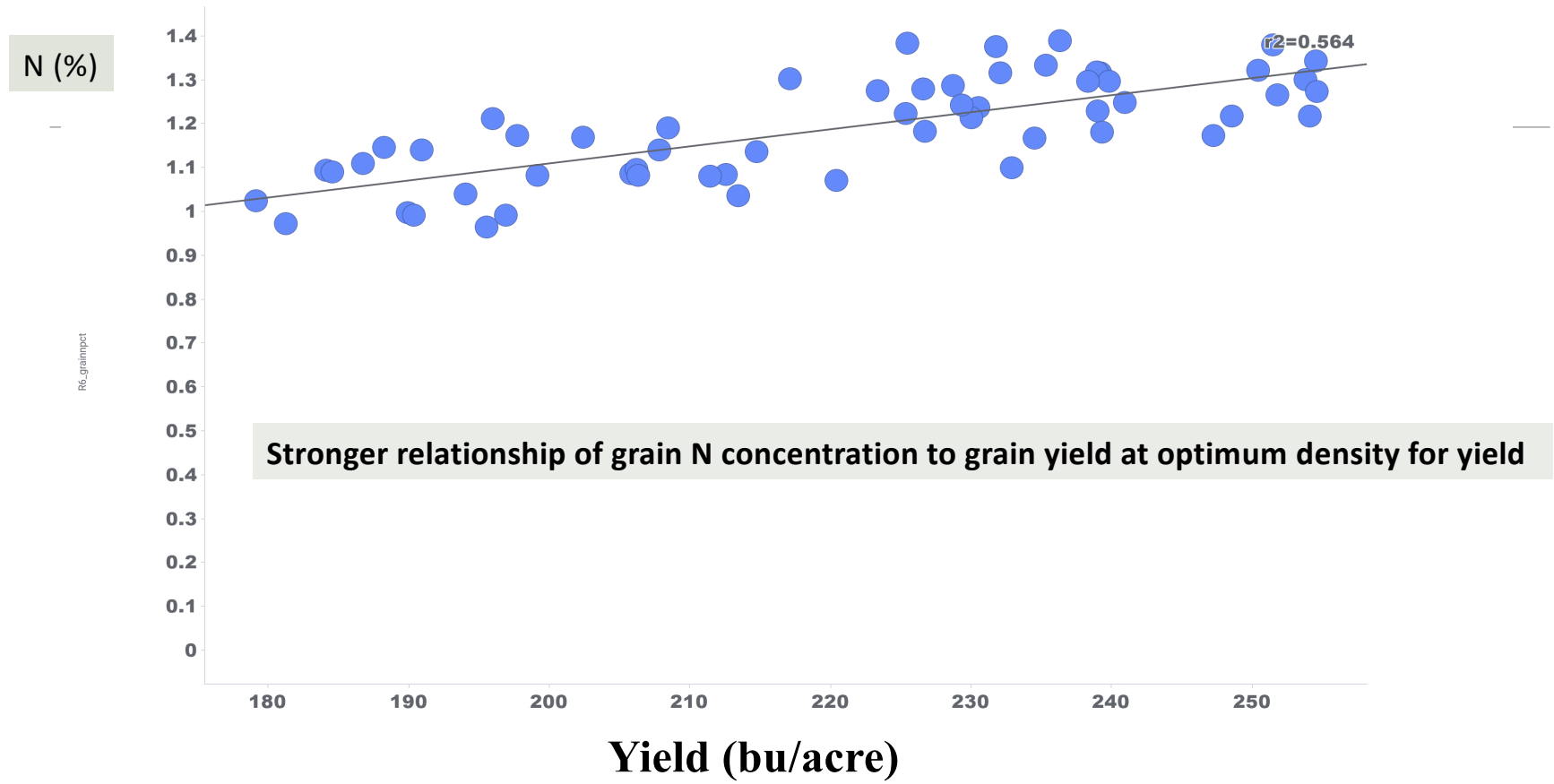


Grain N Concentration Relation to Yield across Densities and N rates



Grain N Concentration Relation to Yield at 32,000 plants/ac

R6_grainnpt vs. YIELD(bu/a 56#)



Nitrogen Balance = Fertilizer N Applied – Grain N Removal

Assumption is that corn grain N is a constant percent of 1.2%
on a dry matter basis across all yield levels.

1.2% N in 47.3 pounds/bu when corn is at 0% H₂O = 0.57 pounds N/bu of yield

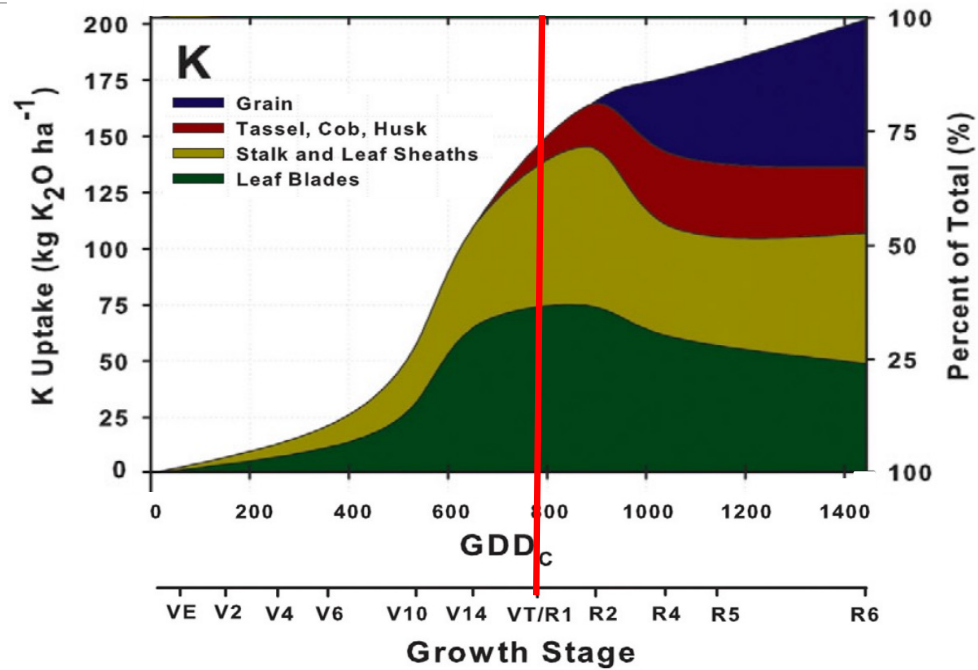
What if grain N% goes up with N rate even when yields change very little?

Example: Constant Yield when Total N applied is 190 pounds/acre

Yield (bu/ac)	Grain N (%)	Grain N (lb/acre)	"Surplus N" (lb/ac)
240	1.1	125	65
240	1.2	137	53
240	1.3	148	42
240	1.4	160	30
240	1.47	167	23

*"Surplus N" can change
by 50% or more depending
on grain N concentration
assumption.*

Timing and Plant Allocation of Potassium Uptake



Graphic: (Bender et al., 2013)

Grain K Concentration Responses of Corn to Pre-plant K₂O Applications

(Average of 4 tillage systems and 5 site-years, West Lafayette & Wanatah, IN)



K ₂ O Fertilizer Rate (Aspire) (lb/acre)	Grain Yield in Cycle 1 (bu/acre)	Grain K Concen. (%)	K ₂ O Removal (lb/bu)	Grain Yield in Cycle 2 (bu/acre)	Grain K Concen. (%)	K ₂ O Removal (lb/bu)
Zero	204 b	0.44 b	0.25 b	207 b	0.48 b	0.28 b
116	217 a	0.46 a	0.26 a	234 a	0.54 a	0.31 a

Nutrients Removed in Harvested Grain		
Crop	Grain Nutrient Removal Rate	
	lb P ₂ O ₅ / bushel	lb K ₂ O / bushel
Corn	0.35	0.20

Source: L. Schwarck MS thesis, 2020)

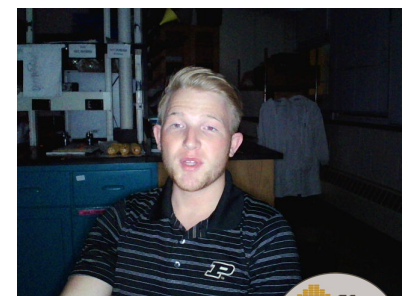
Grain Kernel P and K Concentrations Increase Following S or S + K Fertilizer Applications at West Lafayette, IN (2020-2021)

* Average of 4 hybrids and 4 reps and 2 years in continuous corn



In-season Fertilizer Application	Grain Yield (bu/acre)	Grain P (%)	Actual Grain P ₂ O ₅ Removal (lb/ bu)	Grain K (%)	Actual Grain K ₂ O Removal (lb/ bu)
Zero	188 b	0.28 c	0.34	0.34 c	0.19
Sulfur (ATS at 20 lb/ac)	237 a	0.32 b	0.35	0.39 b	0.22
Sulfur (ATS) + Aspire at 150 lb/ac	237 a	0.36 a	0.40	0.44 a	0.25

Nutrients Removed in Harvested Grain		
Crop	Grain Nutrient Removal Rate	
	lb P ₂ O ₅ / bushel	lb K ₂ O/ bushel
Corn	0.35	0.20



Hybrid Variation in Grain Nutrient Concentrations in Response to In-Season S and K Fertilizer Treatments (West Lafayette, IN, 2020-2021)



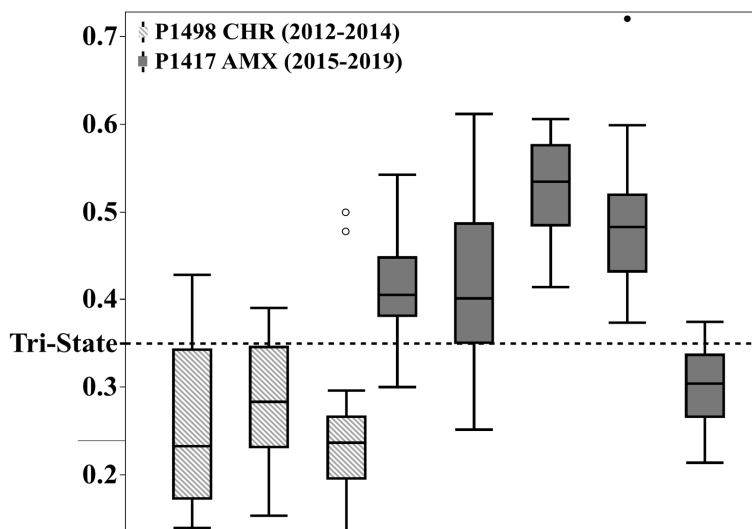
HYBRID	GRAIN YIELD (bu/acre)	GRAIN P (%)	GRAIN P ₂ O ₅ REMOVAL (lb/bu)	GRAIN K (%)	GRAIN K ₂ O REMOVAL (lb/bu)
P0574 AMXT	205 c	0.34 a	0.38 a	0.38 ab	0.22 ab
P1055 Q	228 ab	0.35 a	0.39 a	0.41 a	0.23 a
P1197 AM	232 a	0.29 b	0.32 b	0.36 b	0.21 b
P1464 AML	216 bc	0.30 b	0.33 b	0.40 a	0.23 a

Nutrients Removed in Harvested Grain		
Crop	Grain Nutrient Removal Rate	
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Corn	0.35	0.20

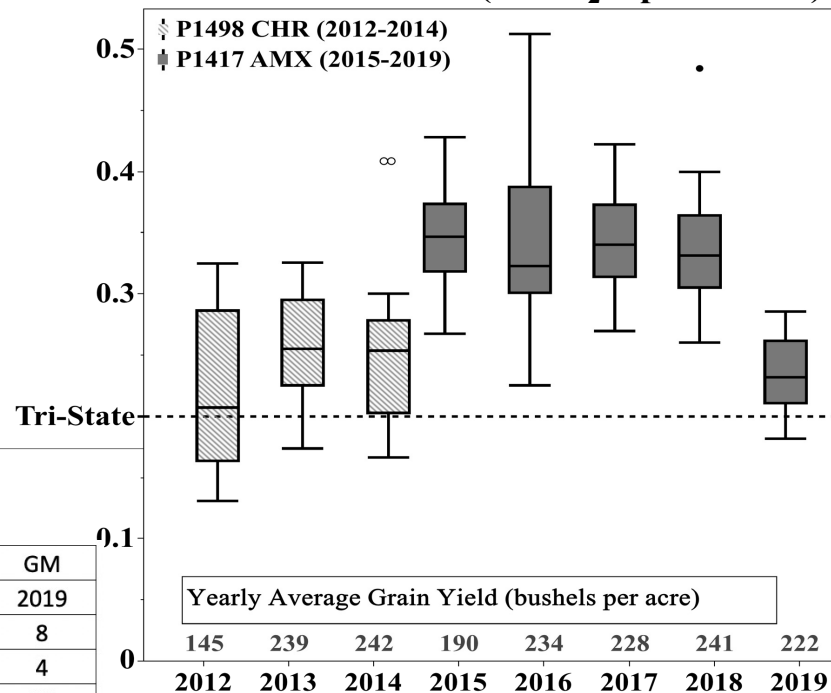
All values are an average of 3 in-season fertilizer treatments with a common N rate: Zero, Sulfur (ATS), and Sulfur + Aspire.

Grain Removal of both P and K can be 50% higher than Tri-State values when N is not limiting. Hybrid and non-N fertilizer additions influence real removal!
 2012-2019 Global Maize Study - West Lafayette, IN

Phosphorus Removal (lbs. P₂O₅ per bushel)



Potassium Removal (lbs. K₂O per bushel)



Exp	GM	GM	GM	GM	GM	GM	GM	GM
Year	2012	2013	2014	2015	2016	2017	2018	2019
Depth (in)	8	8	8	8	8	8	8	8
OM	4.4	4.4	4.3	4.1	4.5	3.9	4.5	4
P	31	25	42	30	26	41	43	30
K	160	110	158	124	165	152	194	130

Tillage System had Minor Influence on Grain Nutrient Concentrations, Unrelated to Yield Differences

Long-term Tillage (1975-present), West Lafayette (2015-2021)



Tillage System	Grain Yield (bu/acre)	Grain P (%)	Grain K (%)	Grain Fe (ppm)
Moldboard Plow	227 a	0.32	0.48	17.8 a
Chisel Plow	217 b	0.32	0.48	16.6 b
Strip-Till	225 a	0.32	0.48	16.1 b
No-Till	219 b	0.32	0.47	15.9 b

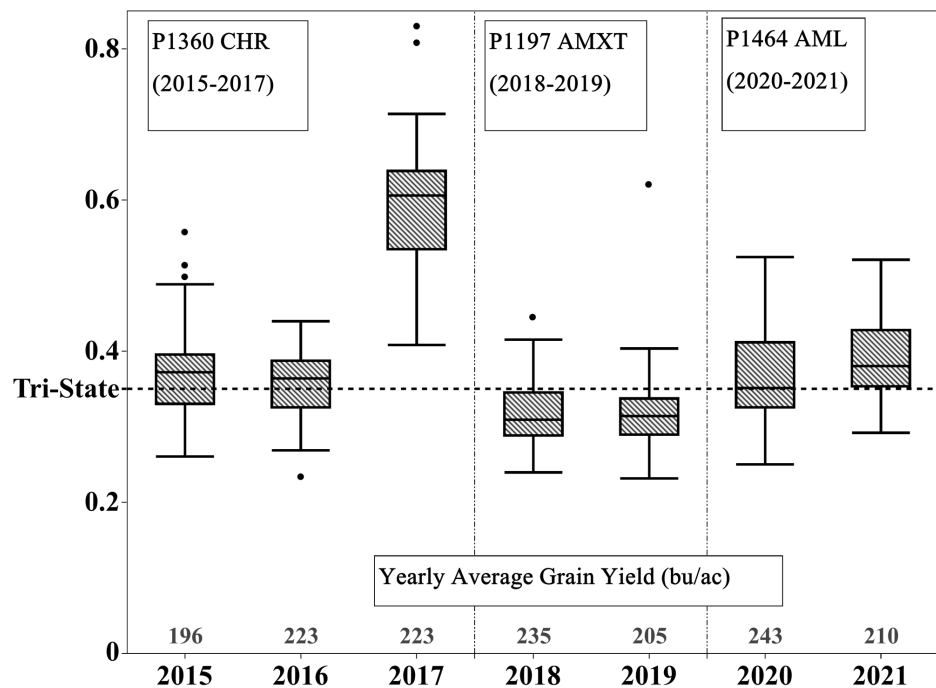


Soil OM%	Avail. P (ppm)	Exch. K (ppm)	Fe (ppm)
4.3	43	210	143

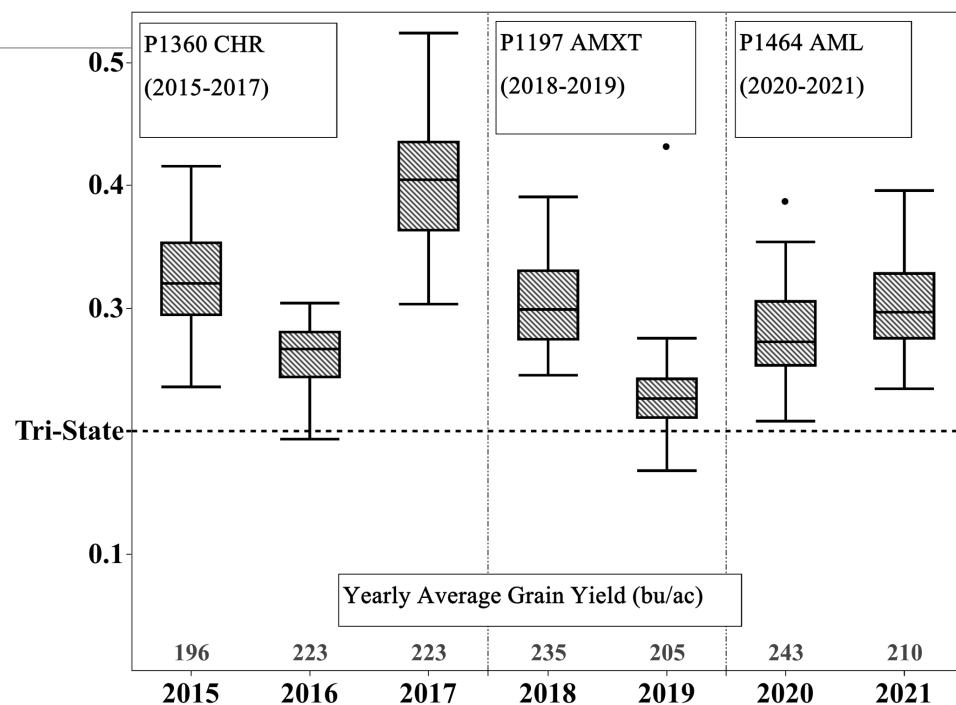
However, average grain K removals were 10-100% above Tri-State levels!

2015-2021 Long Term Tillage study - West Lafayette, IN

Phosphorus Removal (lbs. P₂O₅ per bushel)



Potassium Removal (lbs. K₂O per bushel)



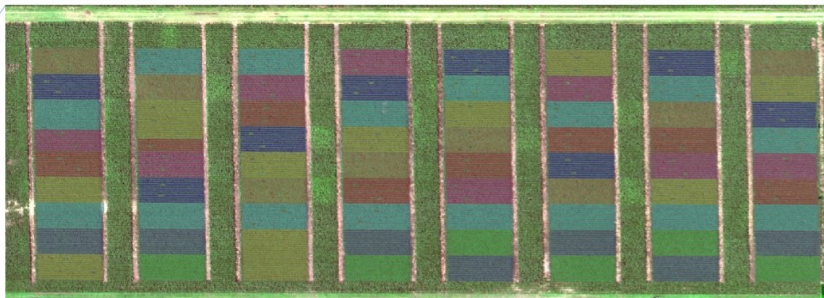
Suggestions in Attempting to Tailor Nutrient Rates to an Estimated Grain Nutrient Removal

- **Nutrient removals per bushel don't necessarily go down at higher yield levels. In fact, they often go up and especially when integrated nutrient applications occur (multiple nutrients, split timing, etc.).**
- **Hybrids can have substantial differences in grain nutrient concentrations under the same soil and management. There is considerable flex in grain nutrient concentrations depending on grain filling dynamics.**
- **Tillage systems and plant densities only have a small impact on grain nutrient concentrations.**
- **Crop management specialists will never escape the hybrid/soil/management uncertainty to reaching farmer-relevant conclusions in deciding on nutrient replacement rates in a maintenance soil fertility program.**



Two More Suggestions in Attempting to Tailor Maintenance Nutrient Management to Known Corn Yield Levels

- **Good soil sampling is a more reliable guide than an assumed replacement per bushel. Or submit grain samples for analysis?**
- **Tissue sampling is another way to detect nutrients that may have been under-applied with use of too-conservative nutrient removal assumptions in yield-based rate determinations.**



Acknowledgments

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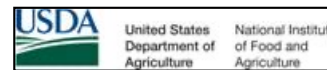
Pioneer Hybrid/Corteva Agriscience

John Deere

The Mosaic Company

Equipment:

John Deere Cropping Systems Unit



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Thank you!