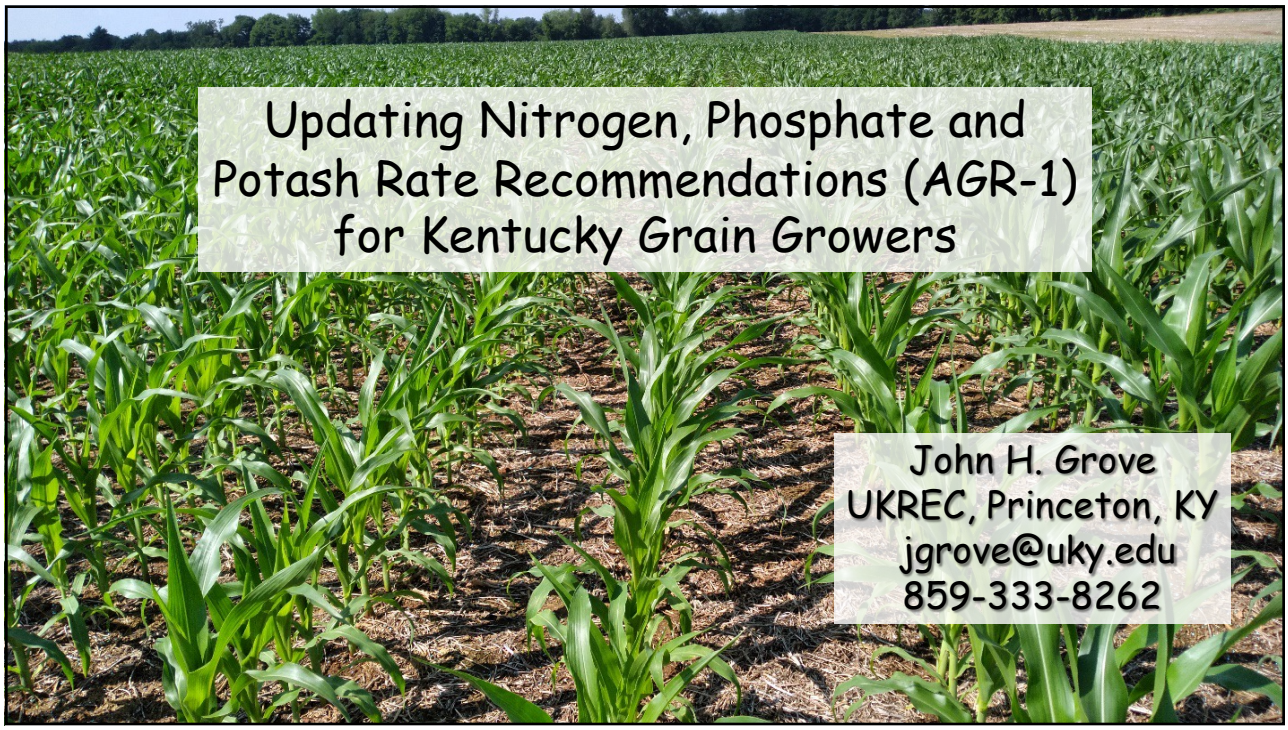


1

What's AGR-1?

AGR-1

Cooperative Extension Service

2025-2026 Lime and Nutrient Recommendations

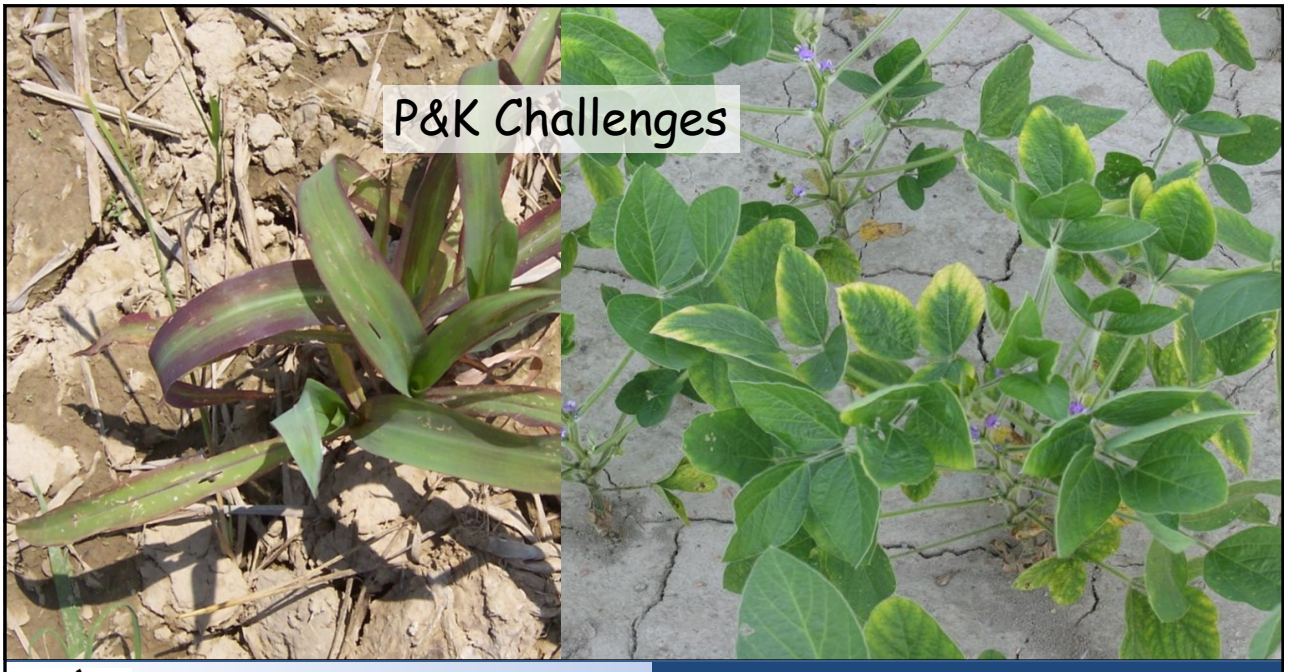
UKAg Department of Plant and Soil Sciences

2

Outline

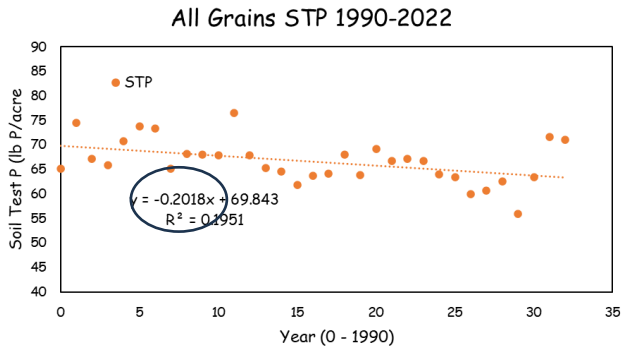
- 1st challenge – Declining UK client soil test P and K values for grain (corn, soybean and small grain) crops
- 2nd challenge – Nitrogen nutritional adequacy for corn

3



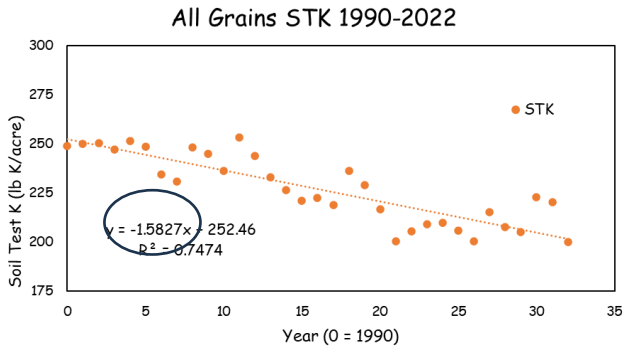
IPNI Deficiency Symptom Library

4



UK Soil Test Client P & K Values Have Been Slowly Declining – Despite Our Recommendations.

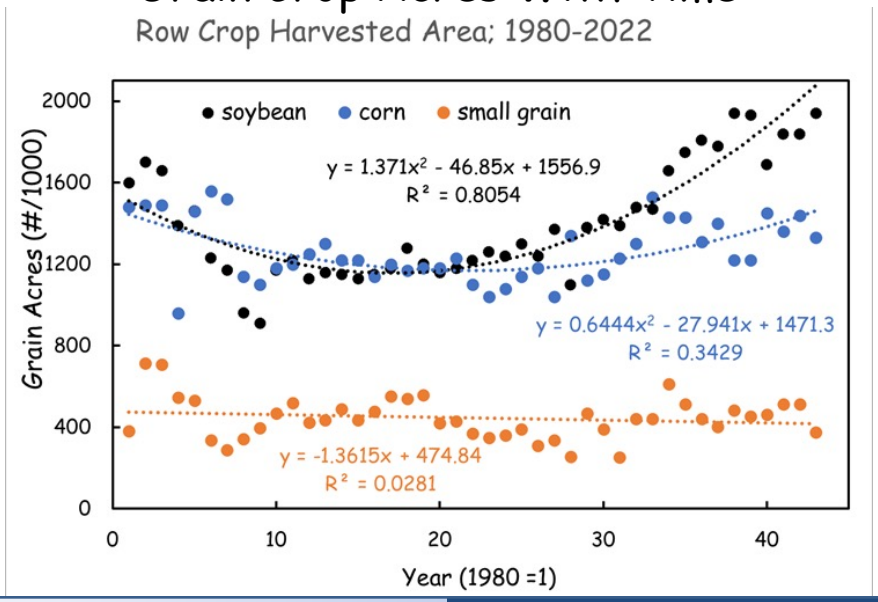
Why?



Why? Couple of Ideas

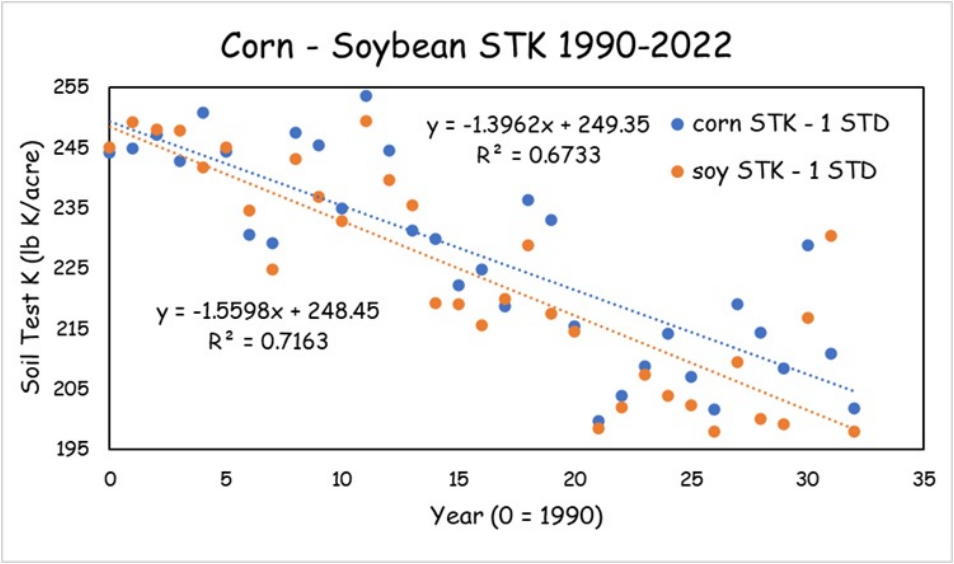
- Changing/expanding crop production area. New acres less fertile than existing cropland. Lower soil test P and K levels.
- Changing/increasing crop productivity. As yields increase more nutrients being removed – lower soil test P and K levels. Maintenance phosphate and potash rates too low?

Grain Crop Acres With Time



7

Corn or Soybean Soil Test K With Time



8

Grain Crop Area Changes and Soil Test P&K

- Soybean area rose; corn and wheat areas essentially unchanged over time.
- Soil test P&K declines about the same across all grain crops.
- The acreage expansion to fields with lower fertility idea was not well supported by the data.
- Grain P & K removal rising? Maintenance fertilizer P&K rates too low?

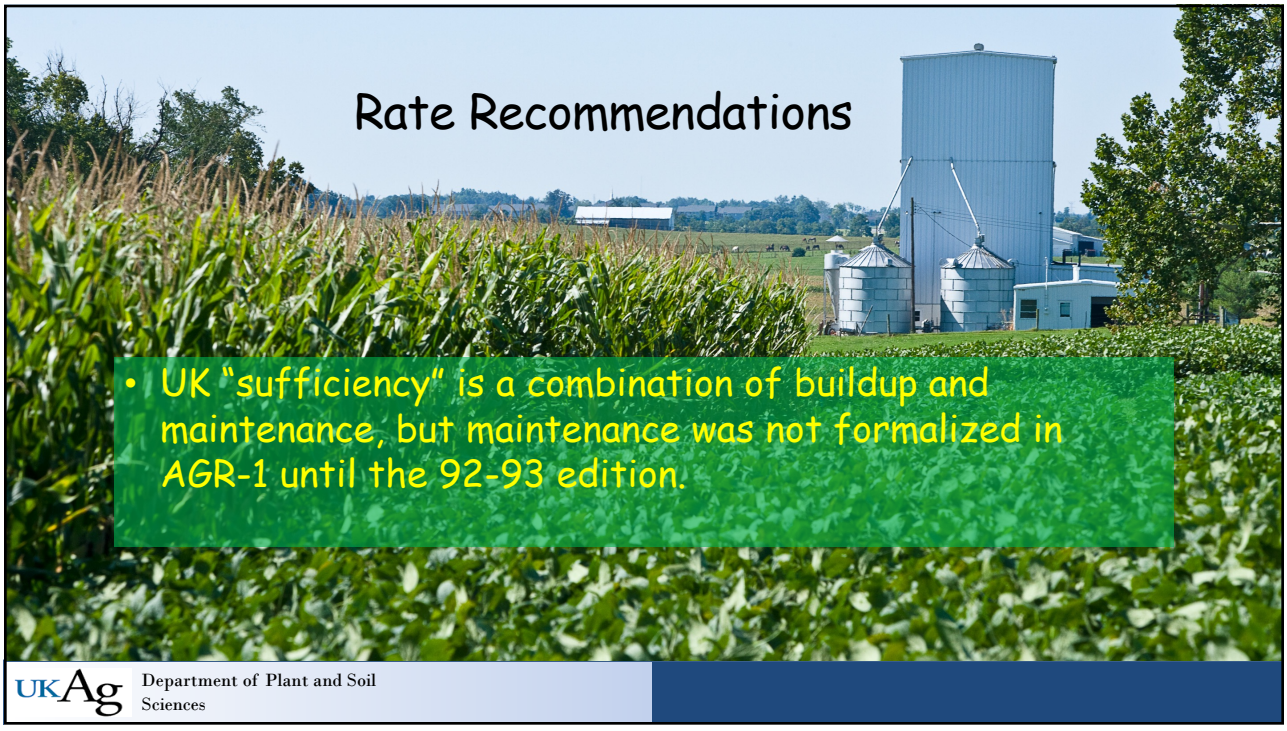


Table 15. Phosphate and potash recommendations (lb/A), soybean.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
High	>60	0	>300	0
Medium	40 - 60	30	242 - 300	30
	34 - 39	40	226 - 241	40
	28 - 33	50	209 - 225	50
			191 - 208	60
Low	22 - 27	60	173 - 190	70
	16 - 21	70	155 - 172	80
	11 - 15	80	136 - 154	90
	9 - 10	90	118 - 135	100
	7 - 8	100	100 - 117	110
	6	110		
Very low	1 - 5	120	82 - 99	120
			64 - 81	130
			46 - 63	140
			<46	150

Maintenance rate rec

Sufficiency + some buildup

Sufficiency + heavier buildup

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AGR-1, 2020-2021

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Yield vs. Soil Test Follows the Law of Diminishing Returns AGR-1 Maintenance Fertilizer Recommendations Began at Mid-Medium, Ended at High, Soil Test Levels

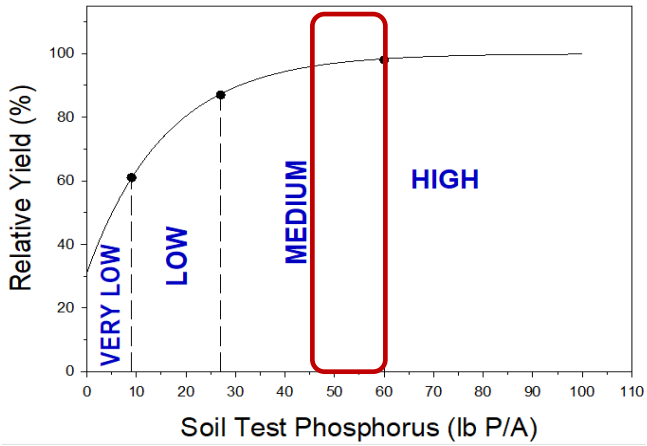

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Figure from Teutsch, 2023

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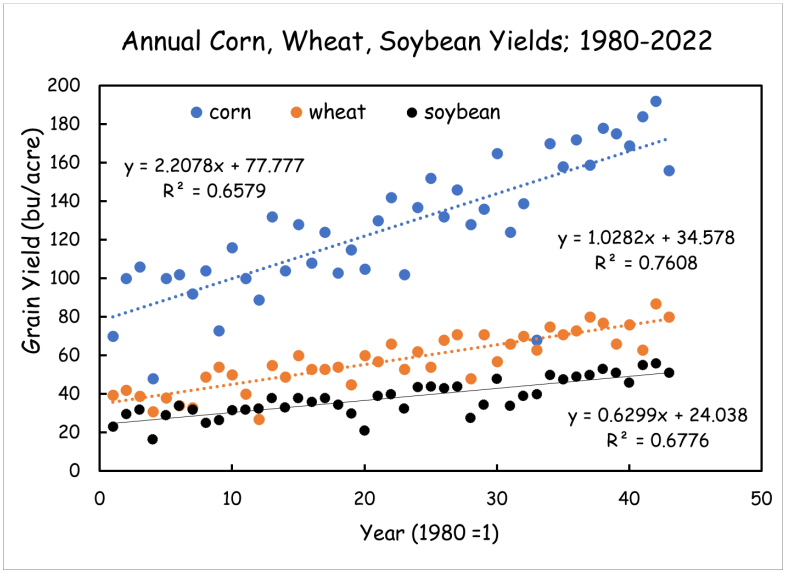
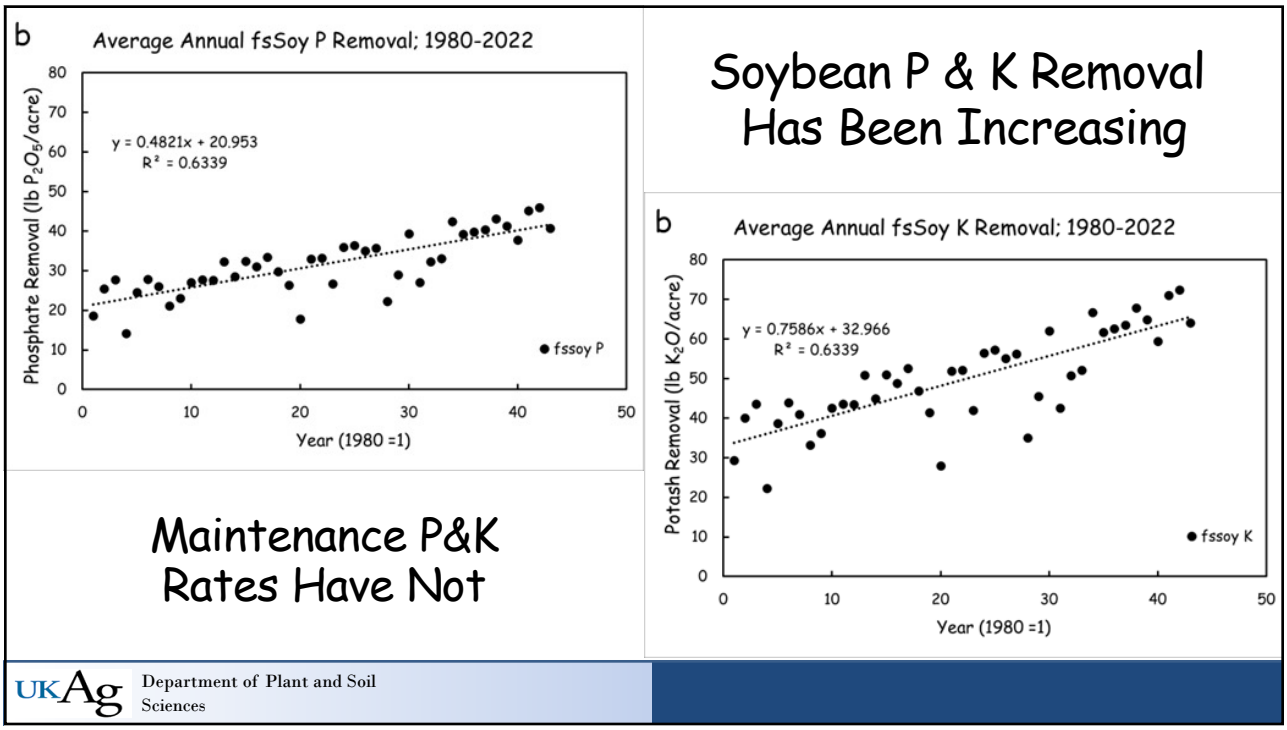
Grain Yields Have Been Rising



Grain P and K Concentrations Have Also Changed

Grain Crop	Grain P		Grain K	
	AGR-1	Villamil et al., 2019	AGR-1	Villamil et al., 2019
	lb P_2O_5/bu		lb K_2O/bu	
corn	0.40	0.37	0.35	0.24
soybean	0.70	0.75	1.10	1.18
wheat	0.50	0.46	0.30	0.28


b
Average Annual fsSoy P Removal; 1980-2022
Phosphate Removal (lb P_2O_5/acre)
y = 0.4821x + 20.953
R² = 0.6339
fssoy P
Year (1980 =1)
Soybean P & K Removal Has Been Increasing
b
Average Annual fsSoy K Removal; 1980-2022
Potash Removal (lb K_2O/acre)
y = 0.7586x + 32.966
R² = 0.6339
fssoy K
Year (1980 =1)
Maintenance P&K Rates Have Not
UKAg
Department of Plant and Soil Sciences

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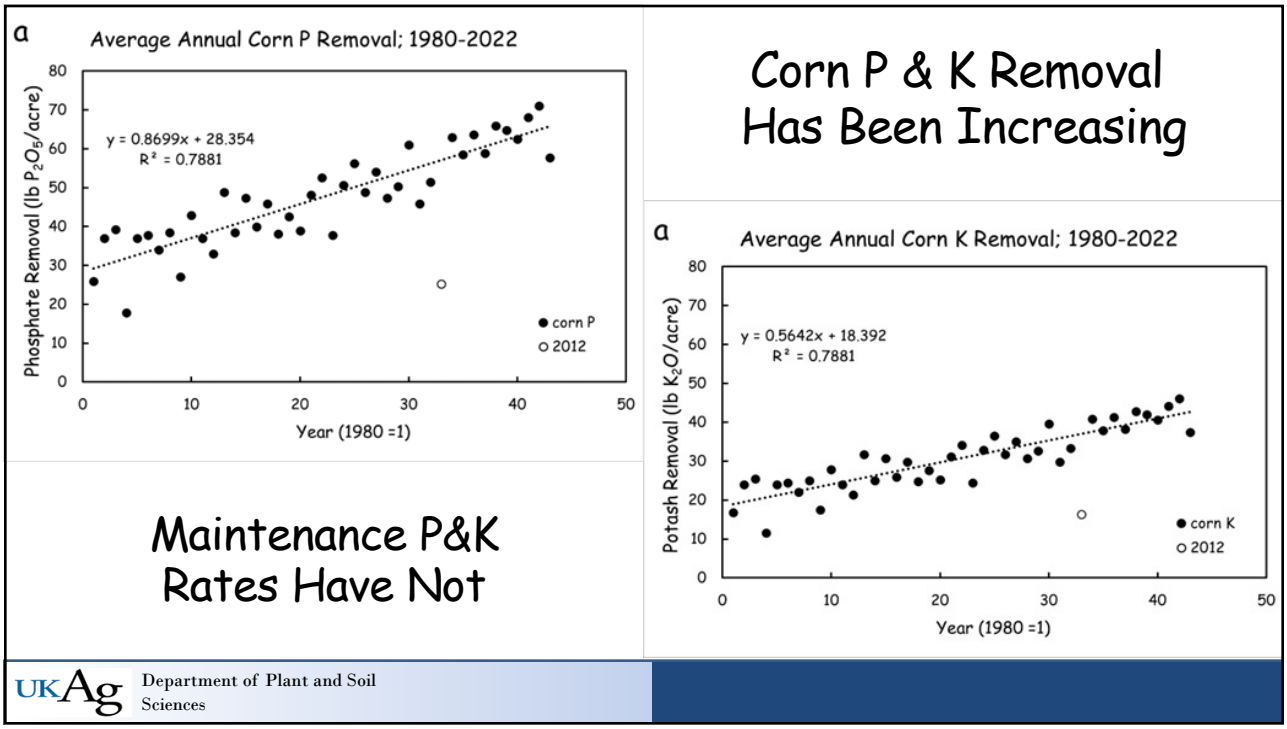
a
Average Annual Corn P Removal; 1980-2022
Phosphate Removal (lb P_2O_5/acre)
y = 0.8699x + 28.354
R² = 0.7881
corn P
2012
Year (1980 =1)
Corn P & K Removal Has Been Increasing
a
Average Annual Corn K Removal; 1980-2022
Potash Removal (lb K_2O/acre)
y = 0.5642x + 18.392
R² = 0.7881
corn K
2012
Year (1980 =1)
Maintenance P&K Rates Have Not
UKAg
Department of Plant and Soil Sciences

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Old Maintenance P&K Rate Recs

Table 13. Phosphate and potash recommendations (lb/A), corn.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
Very high			>420	0
High	>60	0	355 - 420	0
			336 - 354	0
			318 - 335	0
			301 - 317	0
Medium	46 - 60	30	282 - 300	30
	41 - 45	40	264 - 281	30
	37 - 40	50	242 - 263	30
	33 - 36	60	226 - 241	40
	28 - 32	70	209 - 225	50
			191 - 208	60
Low	23 - 27	80	173 - 190	70
	19 - 22	90	155 - 172	80
	14 - 18	100	136 - 154	90
	9 - 13	110	118 - 135	100
	6 - 8	120	100 - 117	110
Very low	1 - 5	200	<100	120

Table 18. Phosphate and potash recommendations (lb/A), small grains.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
High	>60	0	>300	0
Medium	48 - 60	30	213 - 300	30
	45 - 47	40	187 - 212	40
	41 - 44	50		
	38 - 40	60		
	34 - 37	70		
	31 - 33	80		
Low	24 - 30	90	159 - 186	50
	17 - 23	100	132 - 158	60
	10 - 16	110	104 - 131	70
Very low	<10	120	<104	80

Table 15. Phosphate and potash recommendations (lb/A), soybean.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
High	>60	0	>300	0
Medium	40 - 60	30	242 - 300	30
	34 - 39	40	226 - 241	40
	28 - 33	50	209 - 225	50
			191 - 208	60
Low	22 - 27	60	173 - 190	70
	16 - 21	70	155 - 172	80
	11 - 15	80	136 - 154	90
	9 - 10	90	118 - 135	100
	7 - 8	100	100 - 117	110
	6	110		
Very low	1 - 5	120	82 - 99	120
			64 - 81	130

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New Maintenance P&K Rate Recs: No Change In STP or STK Where 0 Fert Rec.

Table 13. Phosphate and potash recommendations (lb/A), corn.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
Very high			>420	0
High	>60	0	355 - 420	0
			336 - 354	0
			318 - 335	0
			301 - 317	0
Medium	46 - 60	50	282 - 300	50
	41 - 45	50	264 - 281	50
	37 - 40	50	242 - 263	50
	33 - 36	60	226 - 241	50
	28 - 32	70	209 - 225	50
			191 - 208	60
Low	23 - 27	80	173 - 190	70
	19 - 22	90	155 - 172	80
	14 - 18	100	136 - 154	90
	9 - 13	110	118 - 135	100
	6 - 8	120	100 - 117	110
Very low	1 - 5	200	<100	120

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Medium	48 - 60	40	213 - 300	40
	45 - 47	40	187 - 212	40
	41 - 44	50		
	38 - 40	60		
	34 - 37	70		
	31 - 33	80		
Low	24 - 30	90	159 - 186	50
	17 - 23	100	132 - 158	60
	10 - 16	110	104 - 131	70
Very low	<10	120	<104	80

Table 15. Phosphate and potash recommendations (lb/A), soybean.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
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	34 - 39	40	226 - 241	60
	28 - 33	50	209 - 225	60
			191 - 208	60
Low	22 - 27	60	173 - 190	70
	16 - 21	70	155 - 172	80
	11 - 15	80	136 - 154	90
	9 - 10	90	118 - 135	100
	7 - 8	100	100 - 117	110
	6	110		
Very low	1 - 5	120	82 - 99	120
			64 - 81	130

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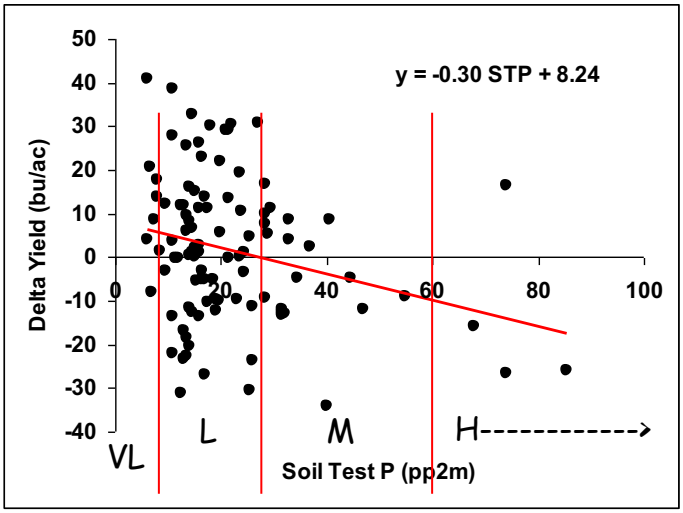
But What's a "Maintenance" Rate Recommendation?

- A maintenance fertilizer rate recommendation is intended to 'maintain' a level of soil-based nutrition that minimizes the possibility of nutrient deficiency. This kind of 'insurance' ***recommendation*** does not imply that there is a good probability of an economic benefit to that fertilizer ***application***.

LDR is Not the Whole Story – There is Also the Probability of a Profitable Response



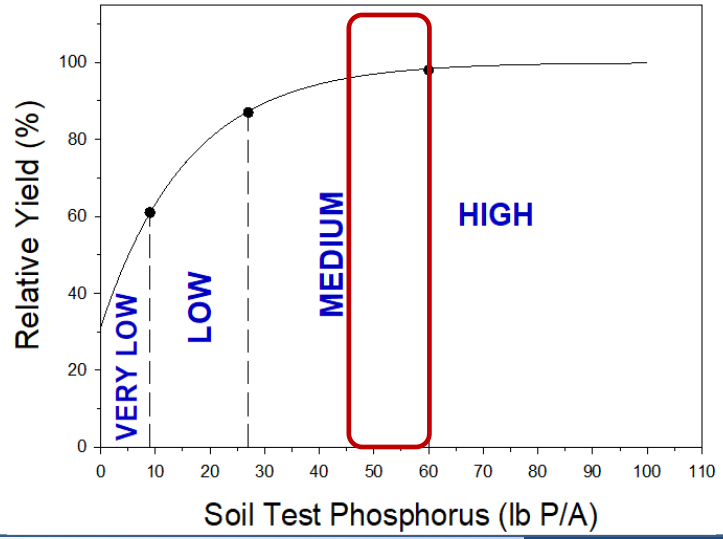
Considering the Probability of a Profitable Response:

Soil Test Level	Probability of a Profitable Response†
High	< 15%
Medium +	15 to 40%
Medium	≈ 40%
Medium -	40 to 60%
Low	60-90%
Very Low	> 90%
†These are estimates and will vary with soil type and seasonal weather.	

Likelihood/probability of a profitable yield response to maintenance fertilizer application is relatively low (15 to 40%), especially in the season of application.

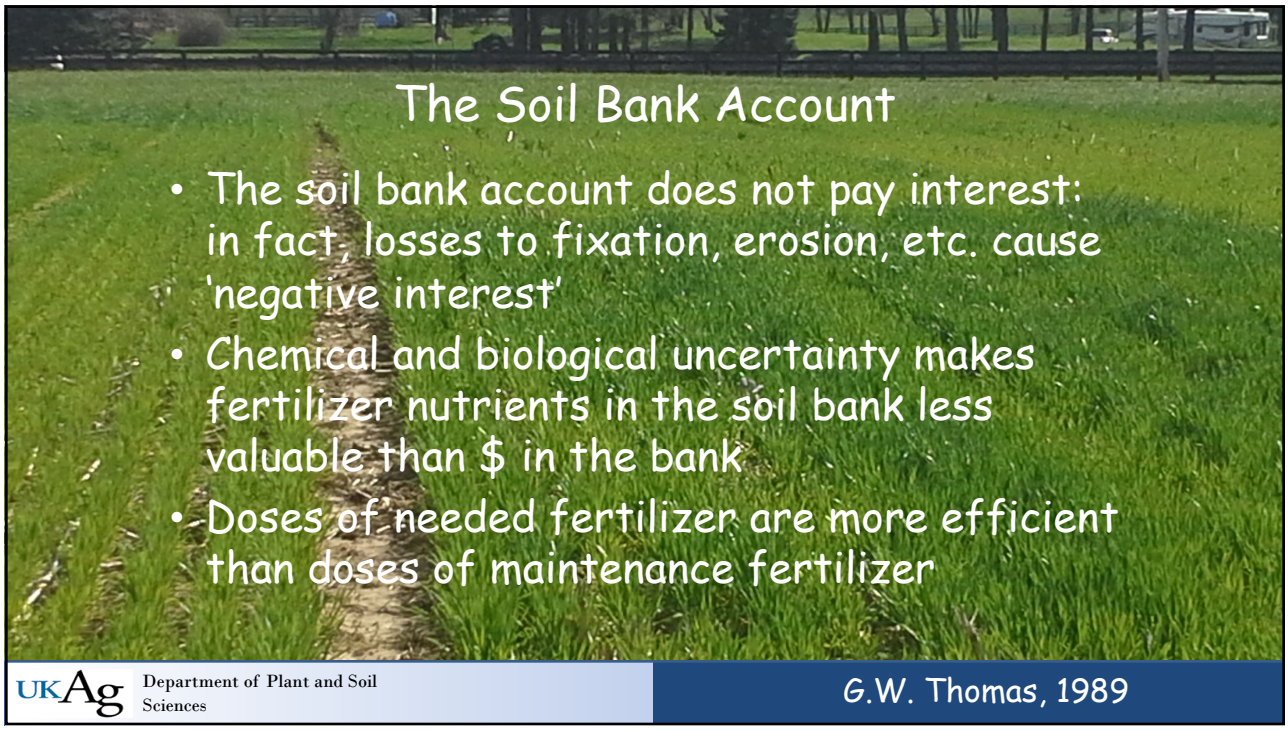
Table derived from Havlin (2005).

Law of Diminishing Returns & Maintenance



Lower probability of a yield benefit in this region. Fertilizer P and K thought needed to 'maintain' nutrient availability. But lower probability of a yield benefit in this region of soil test values causes economic ambiguity.

Figure from Teutsch, 2023


The Soil Bank Account
• The soil bank account does not pay interest: in fact, losses to fixation, erosion, etc. cause 'negative interest'
• Chemical and biological uncertainty makes fertilizer nutrients in the soil bank less valuable than $ in the bank
• Doses of needed fertilizer are more efficient than doses of maintenance fertilizer
UKAg Department of Plant and Soil Sciences
G.W. Thomas, 1989

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Corn N Nutrition
UKAg Department of Plant and Soil Sciences
Photo by Watkins, 2024

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Corn Nitrogen Fertilization: Time to Check Our Recommendations

- "Next level" yields require more N: Possibly, but N use efficiency (NUE) has also improved.

Economically Optimum Nitrogen Rates and NUE in Kentucky: 2001-2003

Soil Series	Economically Opt. N Rate	Corn Yield at EONR	N Required per Bushel
	lbs N/a	bu/a	lb N/bu
Falaya	152	217	0.70
Maury Irrigated	158	188	0.84
Maury Rainfed	157	189	0.83
Pope	132	173	0.76
Huntington	120	195	0.62
Pembroke 2002	109	134	0.81
Pembroke 2001	106	150	0.71
Pembroke 2002	90	122	0.74
Pembroke 2003	90	141	0.64
Crider	No Response to Nitrogen		

Average = 0.74

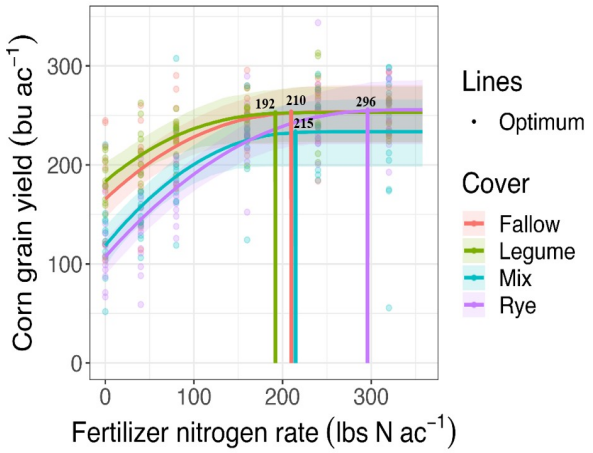
Corn Nitrogen Fertilization: Time to Check Our Recommendations

- "Next level" yields require more N: Possibly, but N use efficiency (NUE) has also improved.
- Lots of field research trials in the past decade.
- Examine these to see where we're at.
- Called for research info. Received 174 N rate by management by site-year entries of N response data.

Initial Work/Assumptions

- Entry data set consisted of two or more N replicated rates.
  - Minimum of 3 N rates needed for economic analysis, but 2 rates are sometimes enough for determination of a "sufficient N rate" (SNR). Got 152 entries with 3 or more N rates.
- Each entry mathematically processed to give the agronomic optimum N rate (AONR), and the associated maximum yield (YAONR), as well as the economic optimum N rate (EONR), and the associated maximum economic yield (YEONR). For EONR/YEONR, a long-term typical price ratio ($P_{lb\ N}/P_{bu\ Corn}$) of 0.1 was used. EONR, not AONR, values used to develop new AGR-1 corn N rate recs.

Corn Response to N Model: Generally Used a Quadratic Plateau



- In this example, corn after cereal rye needed 296 lb N/A for maximum yield. This is the "agronomic" optimum N rate (AONR) and ***does not*** consider the point at which the increment of grain yield just pays for the increment of N applied - the "maximum economic yield".
- In this case, the "economic" optimum N rate (EONR) was 280 lb N/A, when the price ratio ($P_{lb\ N}/P_{bu\ Corn}$) = 0.1.
- AONR values for other cover treatments (fallow-210; legume-192; mix rye&legume-215) are shown.

Rawal, et al. 2023

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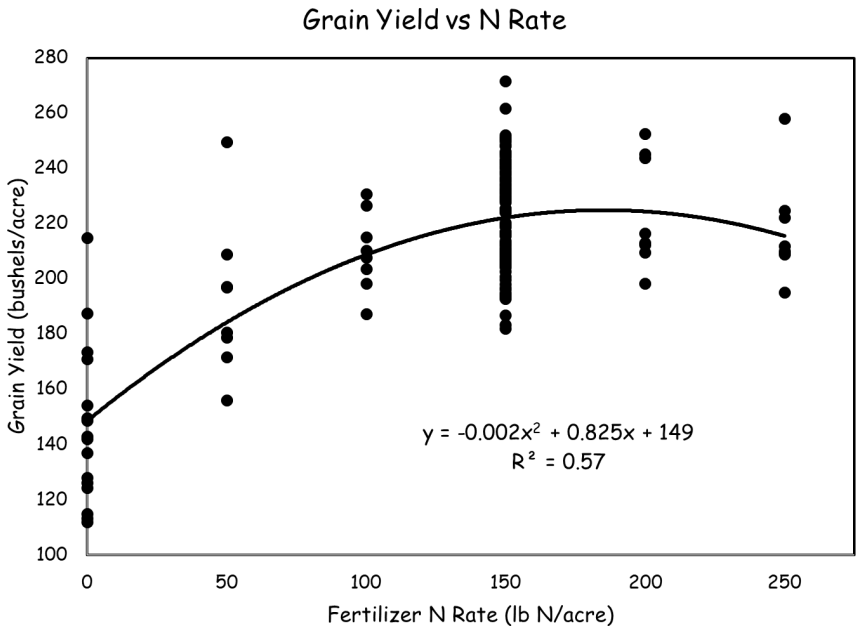

2025 Corn Yield vs N Rate For 4 N Responsive Locations

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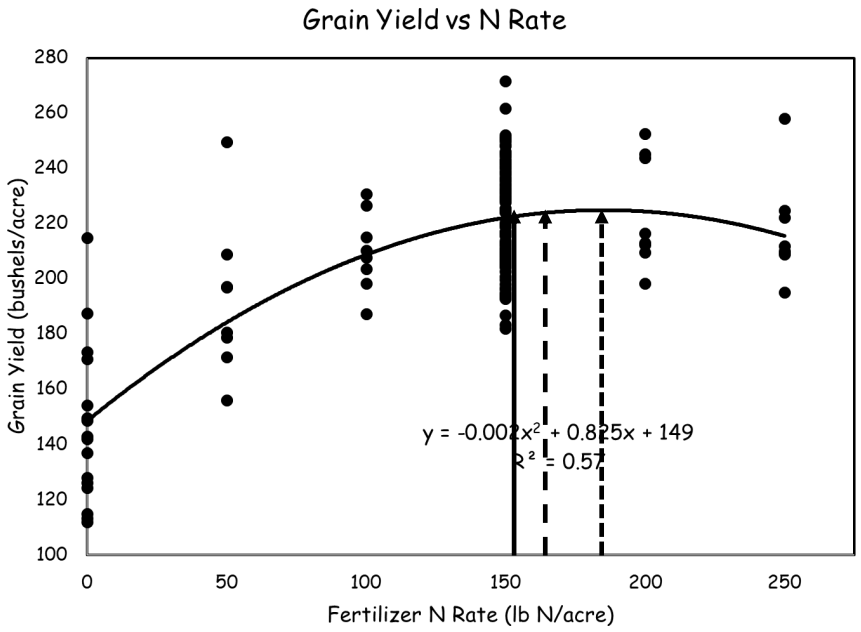
What's The Optimal N Rate?

Item - Estimated From Model	Agronomic Optimum (P_N/P_{corn}) = 0	Economic* Optimum (P_N/P_{corn}) = 0.1	Economic** Optimum (P_N/P_{corn}) = 0.15
N Rate	185 lb N/A	162 lb N/A	151 lb N/A
Yield	225 bu/A	224 bu/A	222 bu/A
NUE	0.82 lb N/bu	0.72 lb N/bu	0.68 lb N/bu

*AGR-1 uses this price ratio for corn N rate recommendations.
**Current economic situation: $0.60/lb N, $4.00/bu corn.



----P_N/P_{corn} = 0

– – P_N/P_{corn} = 0.1

——P_N/P_{corn} = 0.15

Initial Work/Assumptions (cont.)

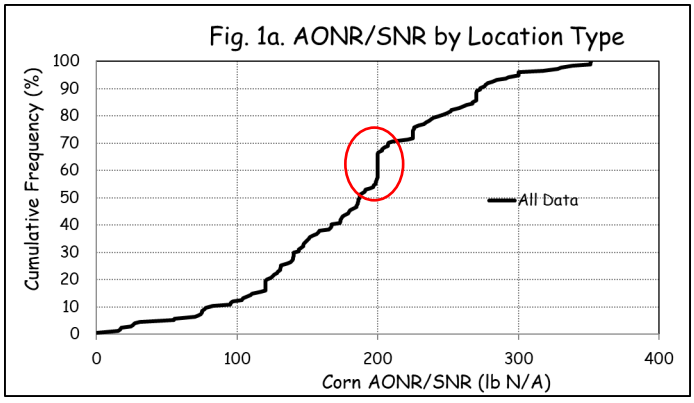
- Meta-data (previous crop, tillage, soil drainage class, irrigation use, rye cover crop presence, N timing, N loss inhibitor presence, etc.) 'binned' to create entry populations as a basis for comparison across the compiled entries.
- The entry populations for a parameter (ex., EONR values for winter fallow versus a rye cover crop) were evaluated for normality and compared statistically.
- Mean/median values used to develop AGR-1 corn N rate recommendations.

Cumulative Frequency Distribution for the Agronomic Optimum or Sufficient N Fertilizer Rate (AONR/SNR): all 174 entries

Assign 1/174th of 100% to each individual entry.

Compile cumulative frequency as AONR/SNR (or another x-axis parameter) increases.

Steep rise indicates a lot of entries with similar parameter values.

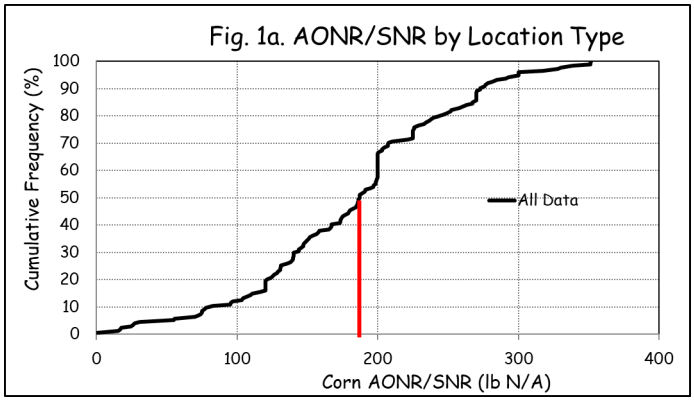


Cumulative Frequency Distribution for the Agronomic Optimum or Sufficient N Fertilizer Rate (AONR/SNR): 174 entries

The distribution of the AONR research results is quite broad (0 to 350 lb N/acre).

The median AONR/SNR is ~ 187 lb N/acre.

The mean AONR/SNR is ~ 182 lb N/acre.

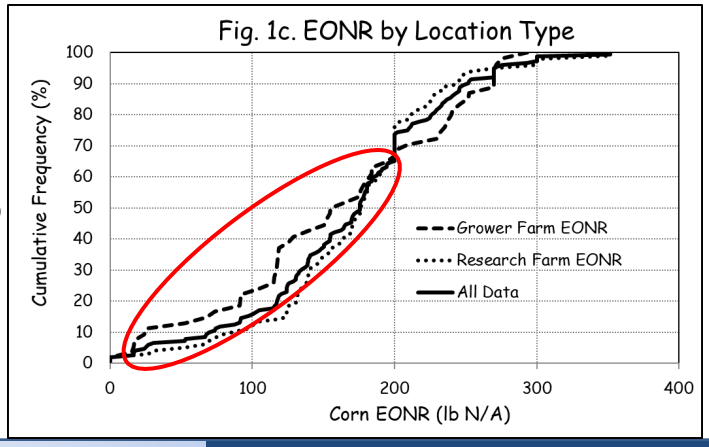


Cumulative Frequency Distribution for the Economic Optimum N Fertilizer Rate (EONR): 152 entries divided by site location type (54 on grower farms; 98 on research farms)

EONR values ranged widely, (0 to 350 lb N/acre).

The median EONR was ~ 168 lb N/acre.

Grower farm sites tended to need less N over the first 70% of the distribution.



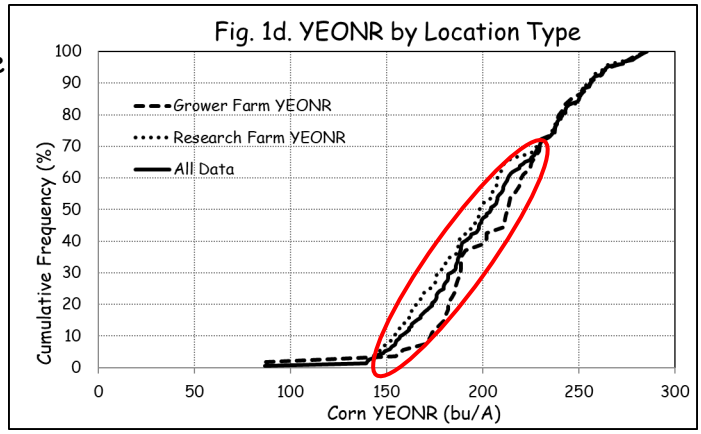
Cumulative Frequency Distribution for Maximum Economic Yield (YEONR): 152 entries divided by location type (54 on grower farms; 98 on research farms)

YEONR values ranged less widely, (87 to 287 bu/acre).

Median YEONR: 206 bu/acre

At the median, 'apparent' fertilizer N use efficiency = 168/206 = 0.82 lb N/bu

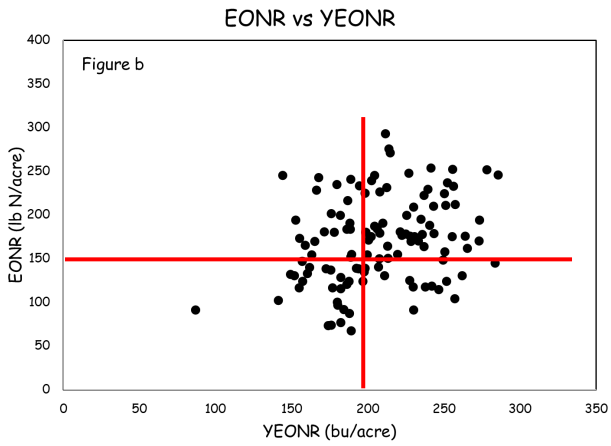
Grower farm sites tended to yield better over the first 70% of the distribution. Yielded better/needed less N = better apparent NUE.



Why 'apparent' NUE (ANUE)?

N rate needed for maximum economic yield was not related to that maximum economic yield.

The cumulative distributions can give an impression that EONR and YEONR, from each site, are found at the same point on each distribution. They are not.



Other Observations

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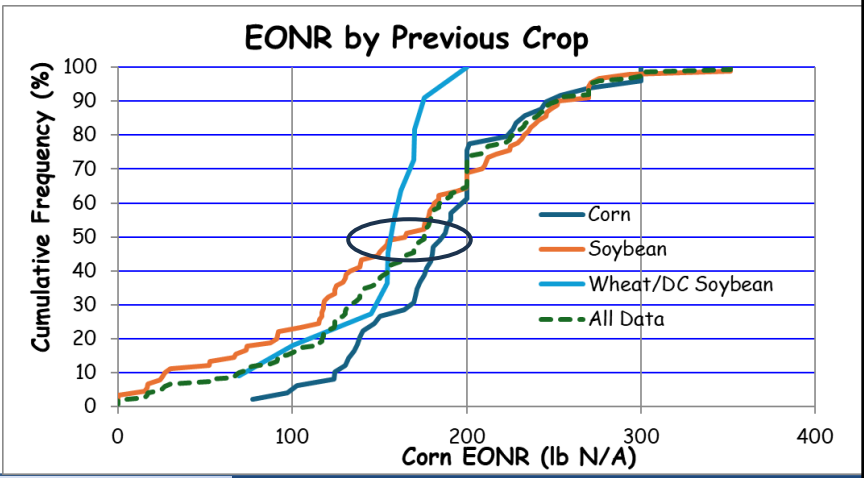
Previous Crop Made a Difference In N Need (49, 90, 11 entries after corn, soybean, wheat/soybean)

Prior corn crop causes greater N need.

The median EONR is ~ 187 lb N/acre for corn after corn, ~ 160 lb N/acre for corn after soybean and ~ 151 lb N/acre for corn after wheat/double-crop soybean.



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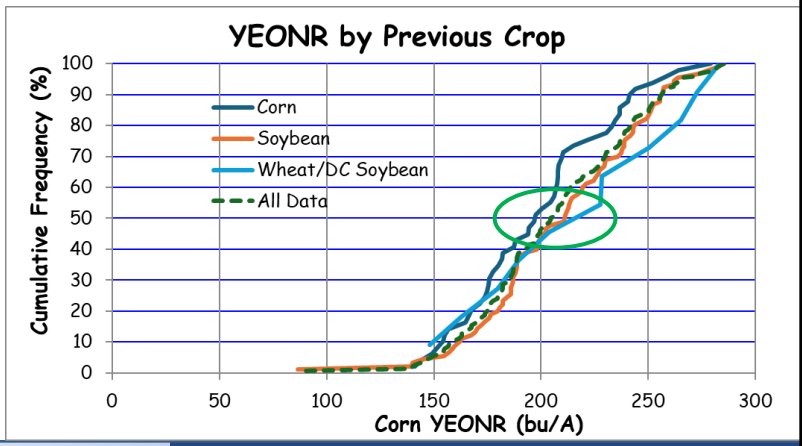
Previous Crop Also Has A Yield Impact (49, 90, 11 entries after corn, soybean, wheat/soybean)

The median YEONR is lower for corn after corn (199 bu/acre) than for corn after soybean (210 bu/acre) or corn after wheat-double crop soybean (219 bu/acre).

ANUE falls from 0.94 (after corn) to 0.76 (after soybean) to 0.69 (after wheat-double crop soybean).

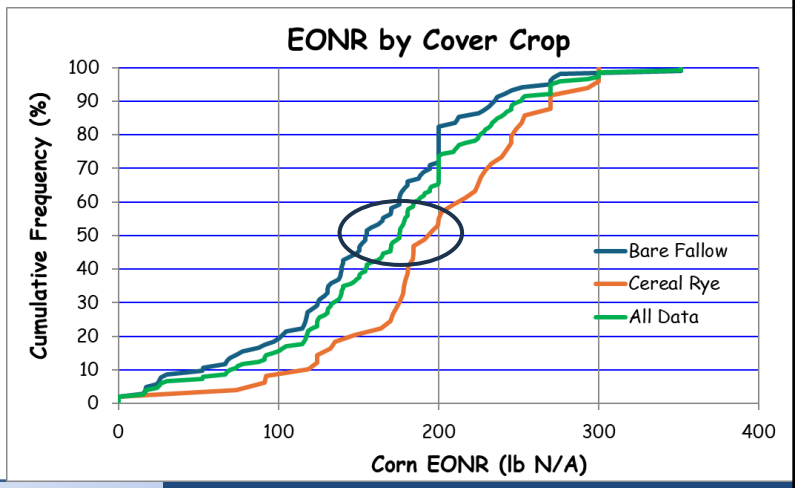


A Rye Cover Crop Increased N Need

49 trial entries with a rye cover; 102 without.

The distributions of the research results were broad (0 to 350 lb N/acre).

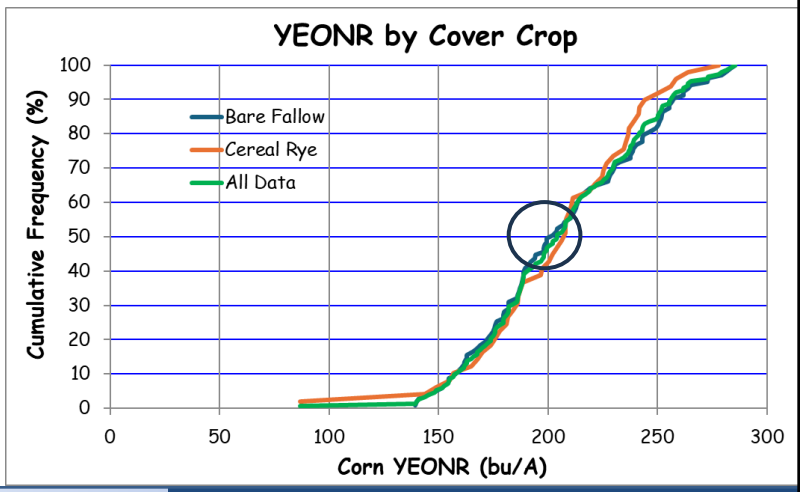
The median EONR was ~ 155 lb N/acre for corn after winter fallow and ~ 193 lb N/acre for corn after winter cereal rye.



But Rye Cover Crop Use Had Little Yield Impact

The distributions of the research results were again less broad (85 to 285 bu/acre).

The median YEONR was similar for corn after winter fallow and cereal rye, about 204 bu/acre.

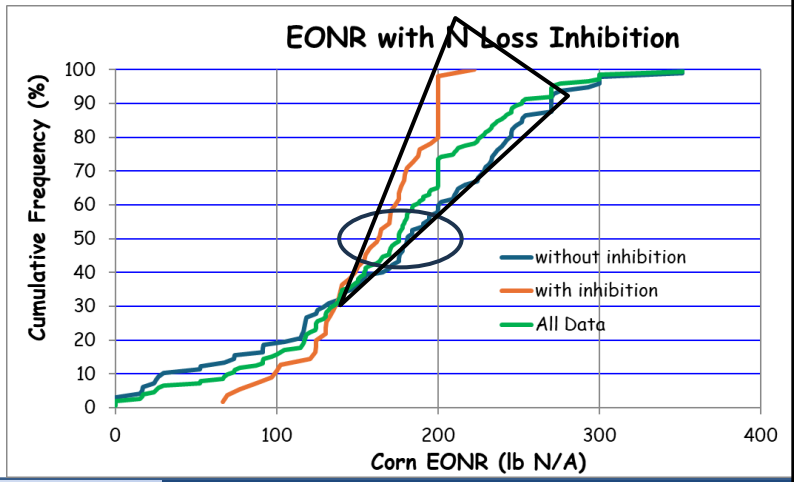


N Loss Inhibitor Use Reduced N Need (55 entries with inhibitor; 97 entries without inhibitor)

Use of N loss inhibitor caused lower N need.

The median EONR was ~ 174 lb N/acre without inhibitor use, and ~ 157 lb N/acre for corn with inhibitor use.

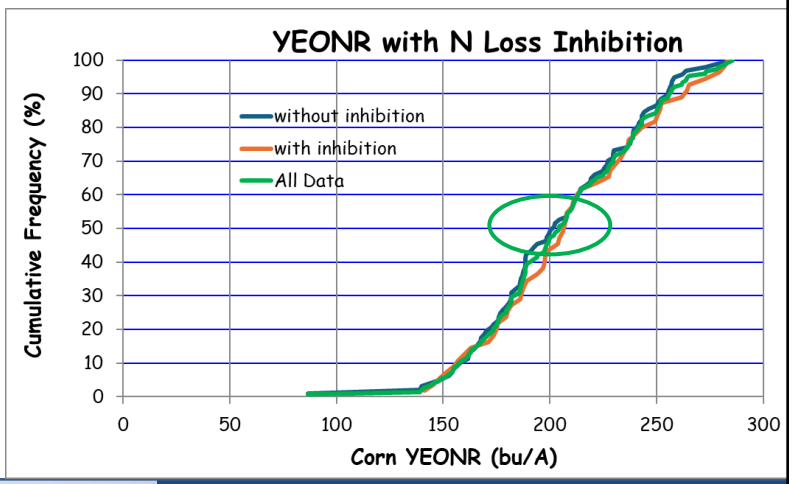
Much more important at high EONR values.



Inhibitor Use Only Slightly Increased Yield (55 entries with inhibitor; 97 entries without inhibitor)

The median YEONR is a bit lower without inhibitor use (205 bu/acre) than with inhibitor use (210 bu/acre).

At the median, ANUE falls from 0.85 (without inhibitor) to 0.75 (with inhibitor). Due mostly to reduced N need.



Old Corn N Rate Recommendations

Table 12. Recommended application of nitrogen (lb N/A), corn.[1]

Cover Crop	Tillage[3]	Soil Drainage Class[2]		
		Well-Drained	Moderately Well-Drained[4]	Poorly Drained
Corn, sorghum, soybean, small grain, fallow	Intensive	100 - 140	140 - 175	175 - 200
	Conservation	125 - 165	165 - 200	
Grass, grass-legume sod (4 years or less), winter annual legume cover	Intensive	75 - 115	115 - 150	150 - 175
	Conservation	100 - 140	140 - 175	
Grass, grass-legume sod (5 years or more)	Intensive	50 - 90	90 - 125	125 - 150
	Conservation	75 - 115	115 - 150	

[1] Nitrogen rate for irrigated corn should be increased to 175 to 200 lb N/A.
[2] Soil drainage class examples are given on Page 2.
[3] Intensive tillage has less than 30% residue cover, and conservation tillage has more than 30% residue cover on the soil at planting.
[4] Poorly drained soils that have been tile drained should be considered moderately well- drained.

Previous crop of corn lumped into all other grain crops.

Tillage difference based on residue cover.

Three drainage classes.

New Corn N Rate Recommendations – Part 1

Table 12a. Recommended nitrogen application rate (lb N/A) for dryland corn.[1]

Previous Crop	Tillage[3]	Soil Drainage Class[2]	
		Well and Moderately Well Drained[4]	Somewhat Poorly and Poorly Drained
Corn, Sorghum	No-Till	160-190	175-205
	Tilled	150-180	165-195
Soybean, Small Grain, Fallow	No-Till	140-170	155-185
	Tilled	130-160	145-175
Grass, Grass-Legume (≤ 4 years), Winter Annual Legume Cover Crop	No-Till	110-140	125-155
	Tilled	85-115	100-130
Grass, Grass-Legume (≥ 5 years)	No-Till	85-115	100-130
	Tilled	60-90	75-105

[1] Assumes no cereal rye cover crop ahead of corn planting. Assumes no N loss inhibitor used.
[2] Soil drainage class examples are given on Page 2.
[3] No Till = no primary or secondary tillage, fall or spring, prior to planting the crop. Tilled = any primary or secondary tillage, fall or spring, prior to planting the crop.
[4] Somewhat poorly or poorly drained soils that have been tile drained should be considered moderately well drained soils.

Rec N rates increased, especially at lower edge of recommendation ranges.

High C:N ratio prior crop, corn or sorghum, separated from other grain crops.

Tillage difference based on whether any tillage was done.

Two drainage classes.

Assumes no rye cover crop or N loss inhibitor use.

New Corn N Rate Recommendations – Part 2

Table 12b. ***Cereal rye cover crop and/or urease inhibitor use:***[1] Recommended total nitrogen application rate (lb N/acre) for no-till dryland corn grown on well and moderately well drained soils and where two-thirds or more of the total N rate top/side-dressed with surface applied urea-containing fertilizer in the absence/presence of a cereal rye cover crop without/with use of a urease inhibitor.

Previous Crop	Cereal Rye Cover Crop[3]	Recommended Total N Rate (lb N/acre)	
		No Inhibitor	With Inhibitor[2]
Corn, Sorghum	No	160-190	150-180
	Yes	185-215	165-195
Soybean, Small Grain, Fallow	No	140-170	135-165
	Yes	165-195	150-180

Previous grain crop, with or without cover crop use, and with or without urease inhibitor use all factored into this table.

Assumes better drained soil, two-thirds of N top or side-dressed as surface applied urea containing material.

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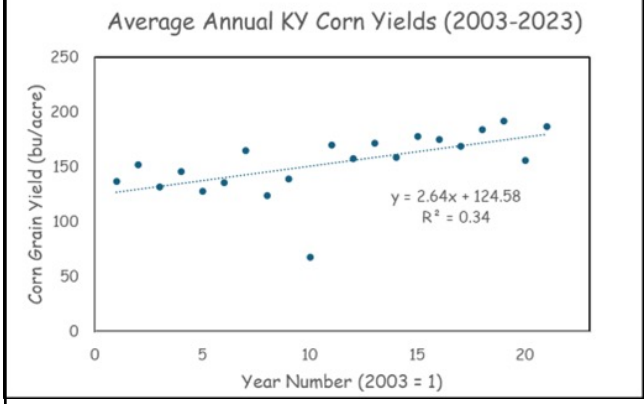
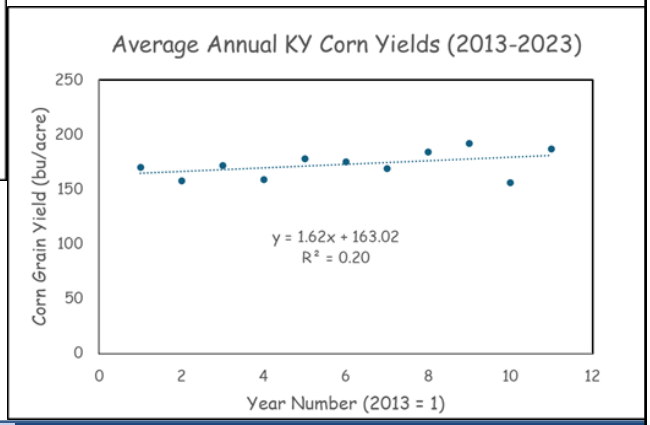


Entry data set YEONR averaged 206 bu/A. Will take another 7 to 15 years for state-wide average yield to reach that level. Resulting N rate recs well suited to above-average producer.

Average Annual Yields Are Rising Though Not As Fast In The Last Decade. 2024 Fell Below Model Projection.



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What Else Do We Need?

- Tillage? Less difference in the newest data, but not many comparisons.
- Irrigation? Yields higher with irrigation, but in these data, little additional N was needed. Still, not enough comparisons.
- N Timing? Delayed N 'tended' to reduce EONR (12 lb N/acre); most data on well-drained soils, but delayed N better for wetter soils.
- Too few/no trials: Corn after forage sod crop; corn on poorly drained soils; corn with different planting dates?

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