A Fresh Look at Phosphorus and Potassium

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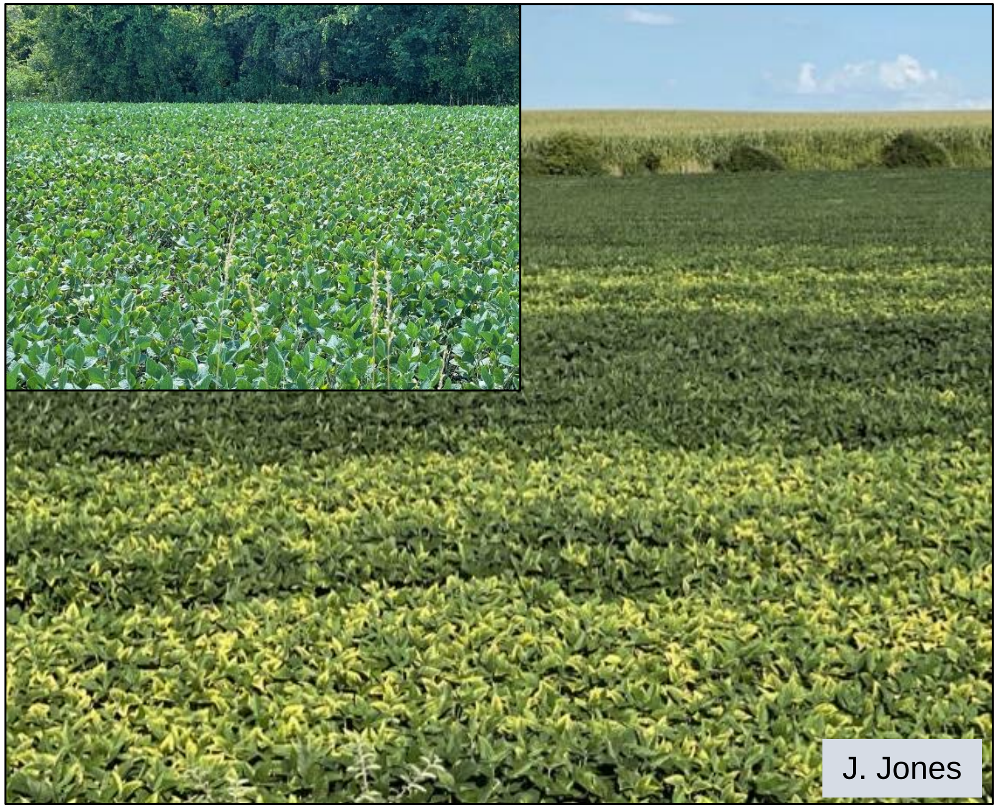
Presentation outline

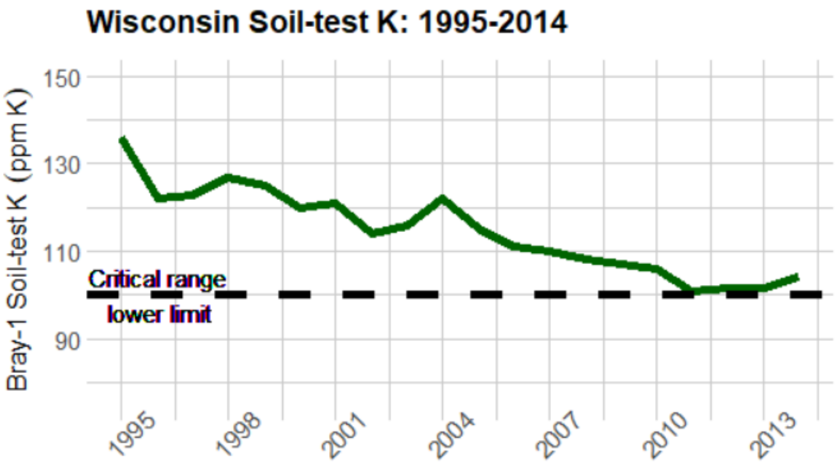
1. Widespread challenges for P and K
2. Questions we’re trying to answer in Wisconsin
3. Long-term focused response studies
4. P, K, interaction effects on yield
5. Plant P & K status and removal
6. New soil tests in state recommendations
7. Lingering challenges and solutions…

Recent concerns about phosphorus and potassium

1. Fertilizer price – hovering around: urea ($757/t), MAP ($909), potash ($790), 10-34-0 ($751/t) as of 12/28 (DTN)
2. Prioritizing nutrients – Is there an opportunity to cut back? How can that be decided?
3. Relevancy of current WI recommendations – 30+ year old support data
4. Agronomics – inconsistency with yield response observations

Recent concerns about phosphorus and potassium

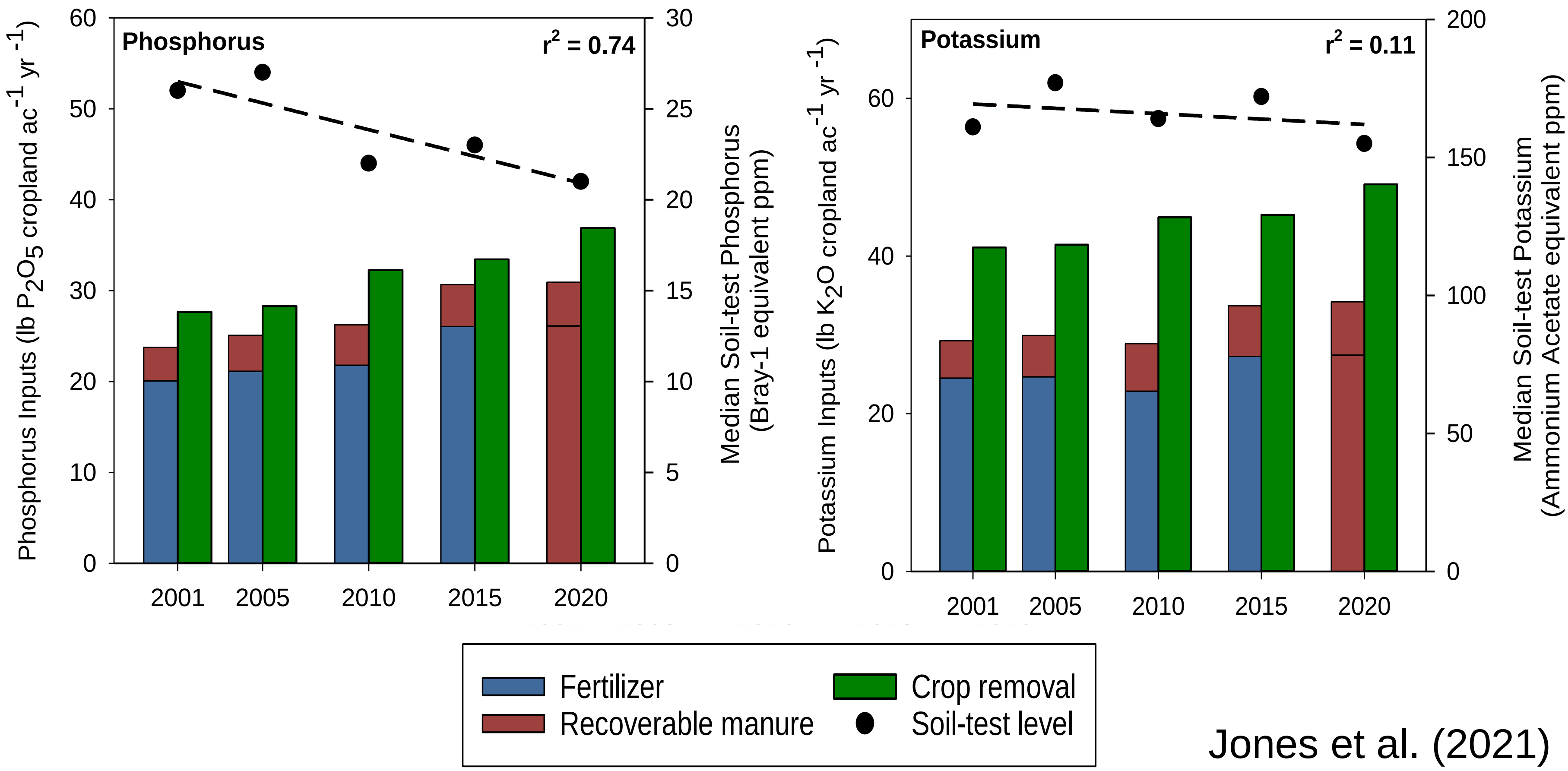




Adapted from J. Peters (2014)

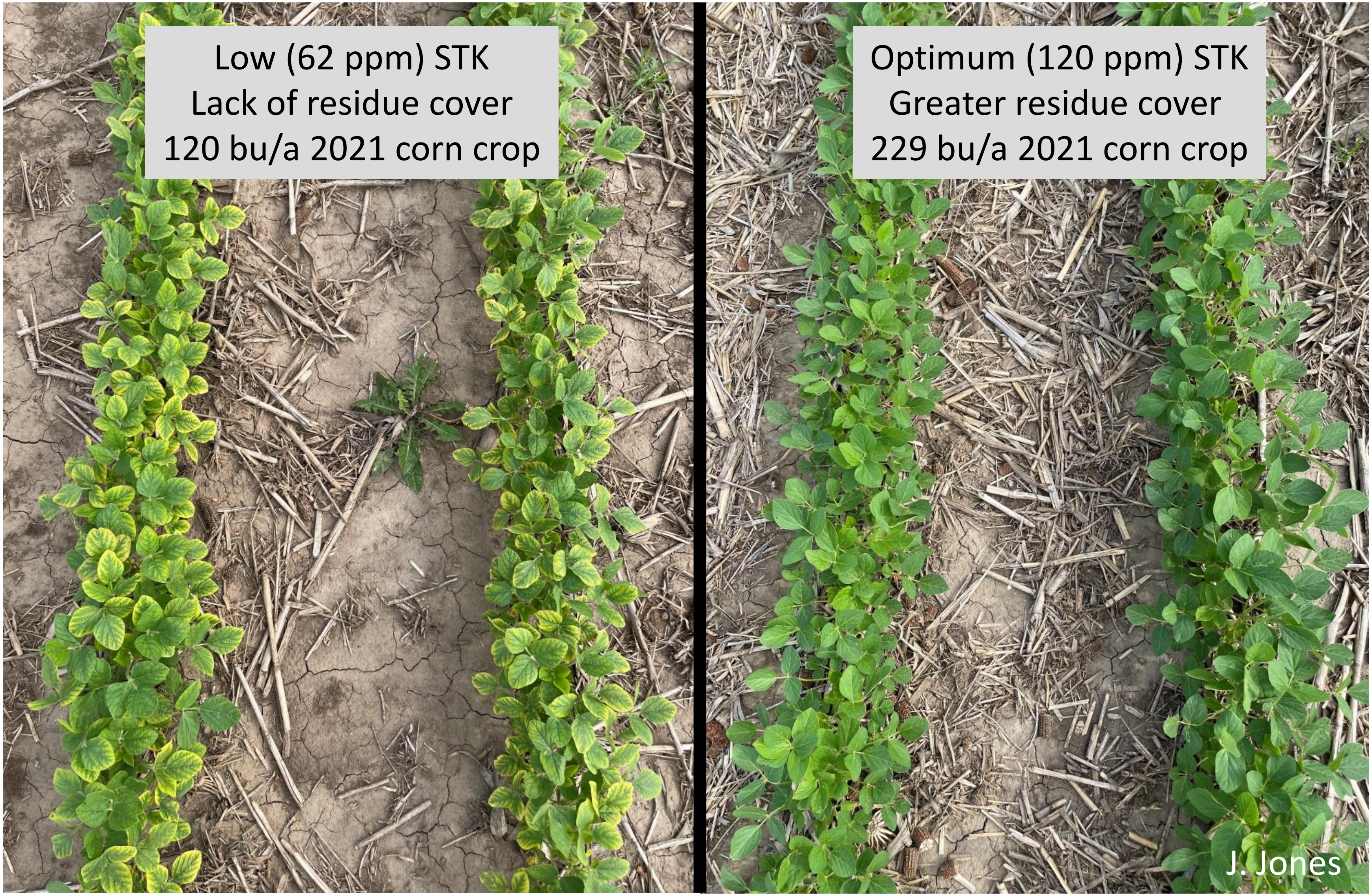
Recent concerns about phosphorus and potassium

North Central Region 2001-2020 Soil test summary



Jones et al. (2021)

Potassium and soil health?



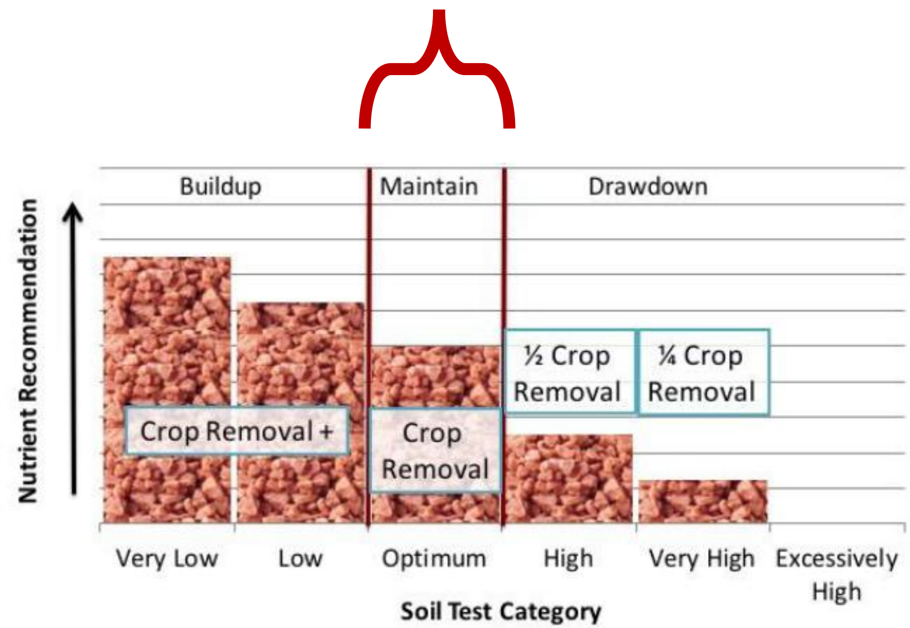
Where we're at…

- University of Wisconsin recommendation philosophy

	Soil test category					
	Very low (VL)	Low (L)	Optimum (O)	High (H)	Very high (VH)	Excessively high (EH)
Soil group[a]	soil test K ppm[b]					
Demand level 1: corn grain, soybean, clover, small grains (but not wheat), grasses, oilseed crops, pasture						
Loamy	< 70	70–100	101–130	131–160	161–190	> 190
Sandy, Organic	< 45	45–65	66–90	91–130	—	> 130
Demand level 2: alfalfa, corn silage, wheat, beans, sweet corn, peas, fruits						
Loamy	< 90	90–110	111–140	141–170	171–240	> 240
Sandy, Organic	< 50	50–80	81–120	121–160	161–200	> 200
Demand level 3: tomato, pepper, brassicas, leafy greens, root, vine, and truck crops						
Loamy	< 80	80–140	141–200	201–220	221–240	> 240
Sandy, Organic	< 50	50–100	101–150	151–165	166–180	> 180
Demand level 4: potato						
Loamy	< 80	80–120	121–170	171–190	191–220	> 220
Sandy, Organic	< 70	70–100	101–130	131–160	161–190	> 190

Laboski and Peters (2012)

Critical concentration range



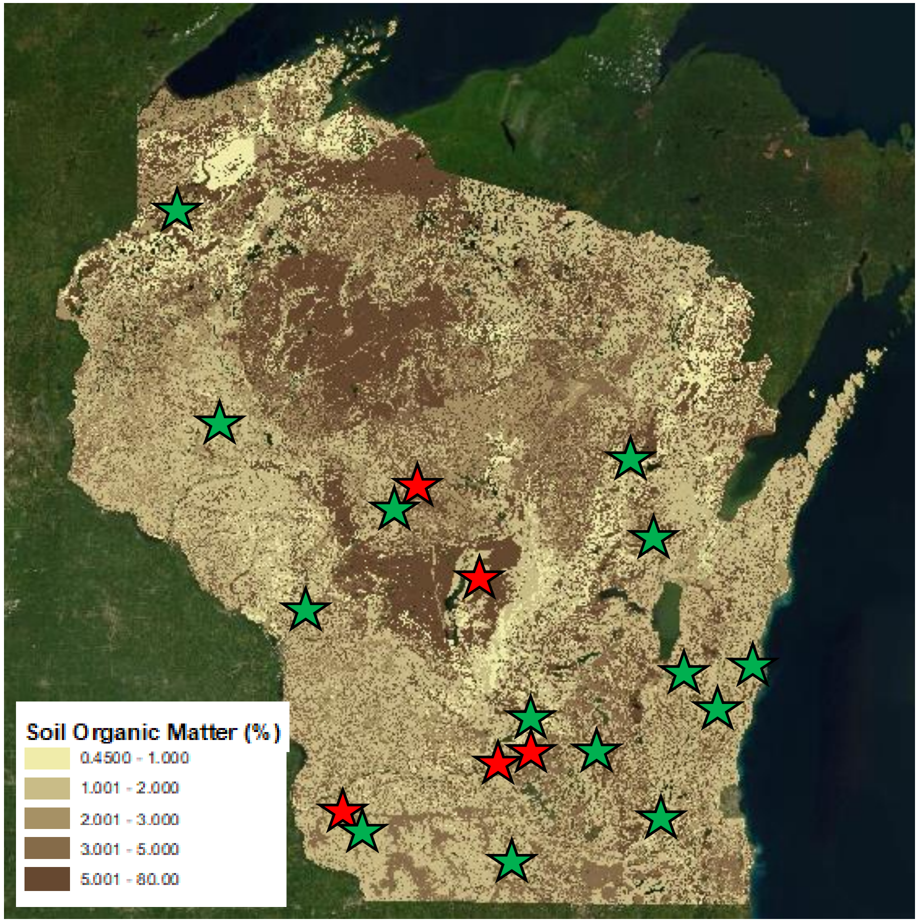
Laboski (2012)

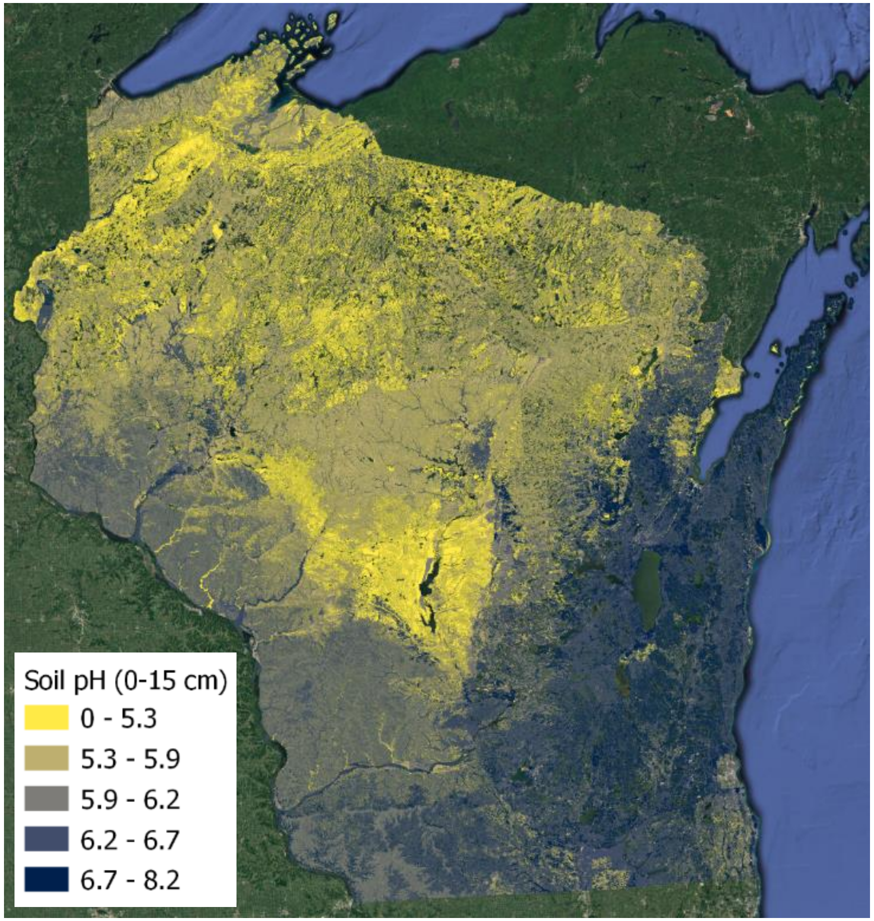
Soil-test P & K Calibration Studies

- Four university research station sites, eleven on-farm collaborators – calibration work
- 100+ sites (~50 soil map units) - method comparison
- Corn and soybean each year
- No-till and disk/chisel-plow
- 0.7 to 5.8% SOM, silty clay loam to sand surface textures, pH 5.5 to 7.4 (6")
- Full factorial of P & K treatments
- Annual soil, grain, tissue analyses
- Revisiting current recommendations & calibrating "new" soil P & K tests

Soil-test P & K Calibration Studies

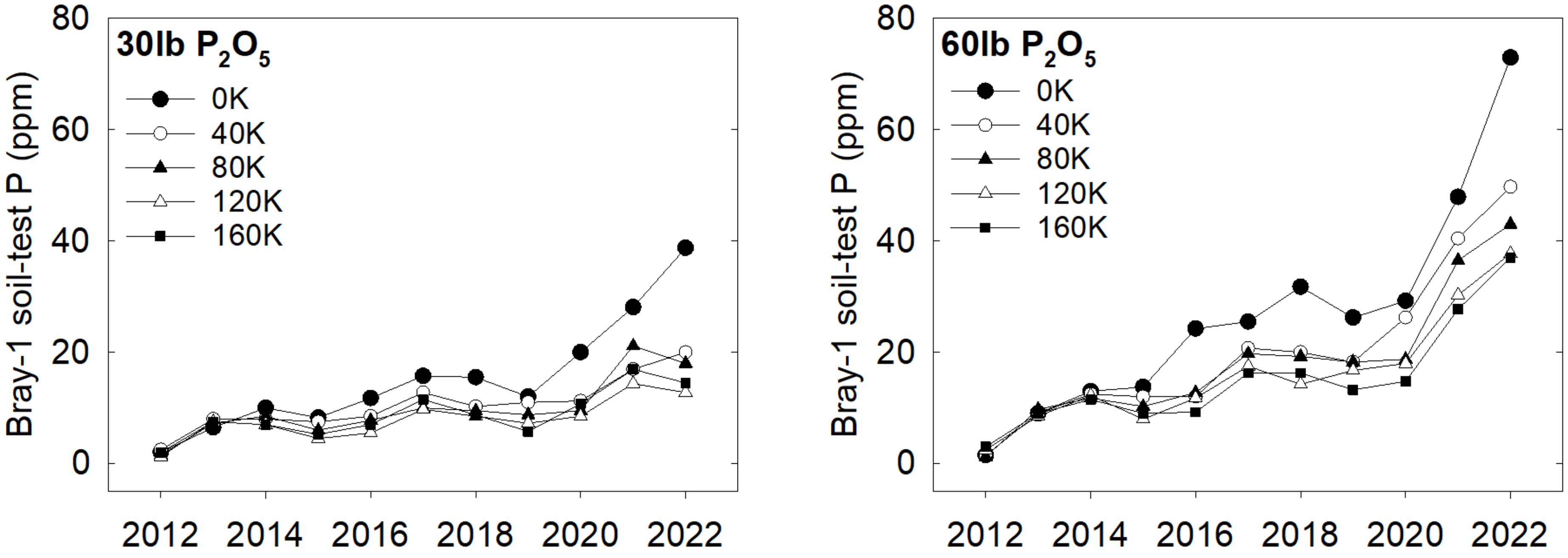
Response study sites (2011-present)
Soil P&K test method sites





Soil sampling director

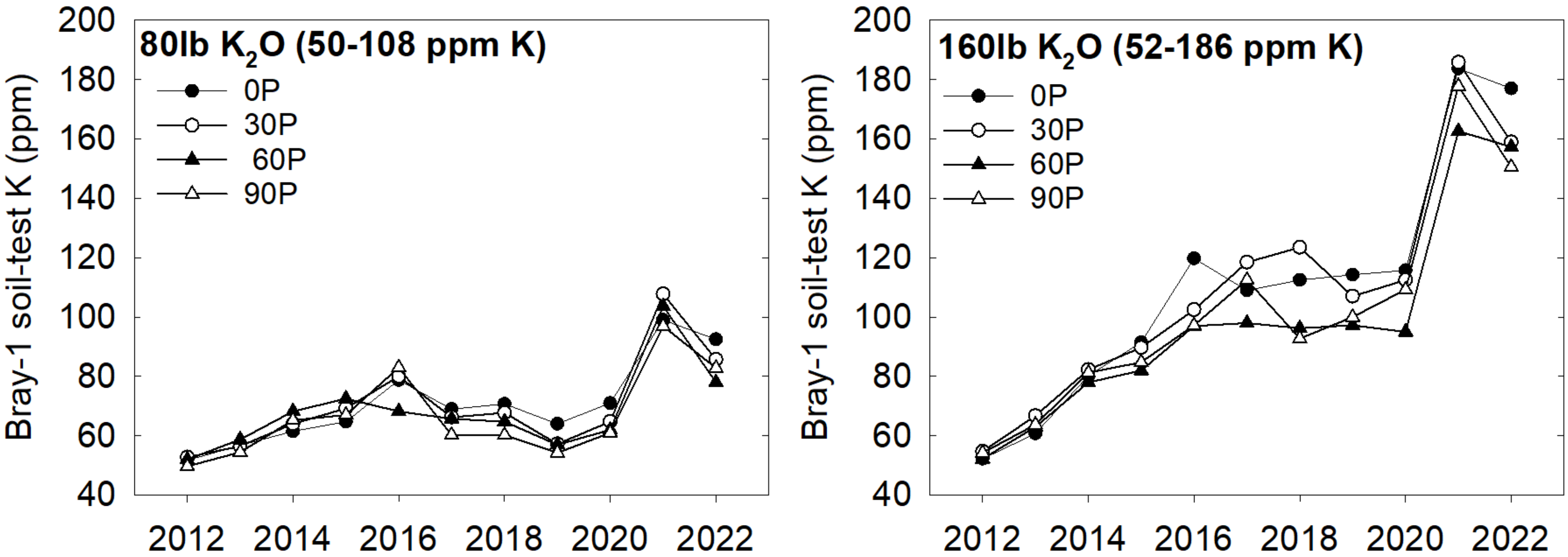
Maintaining optimum soil-test levels



Maintaining optimum STP (16-20 ppm P) was affected by K nutrition

Jones (2022)

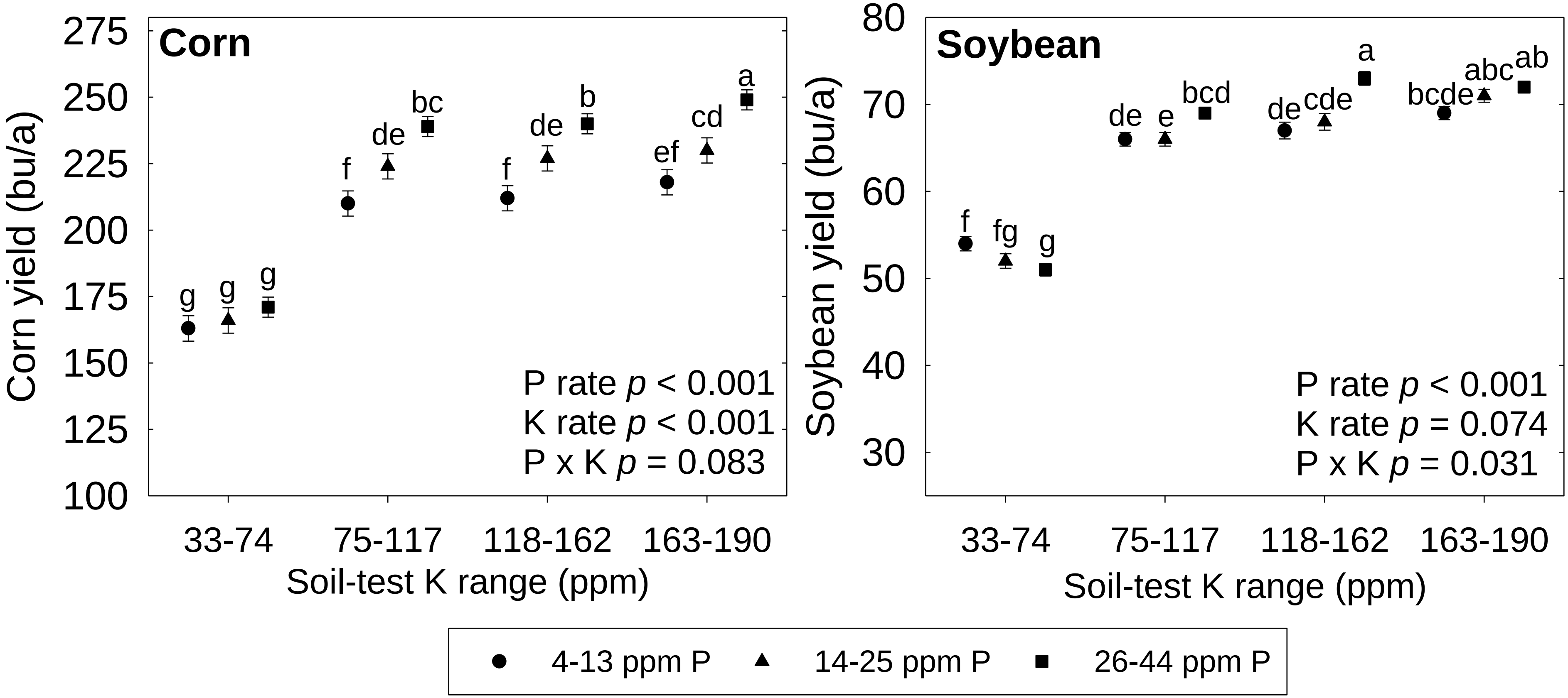
Maintaining optimum soil-test levels



Maintaining optimum STK (100-130 ppm K) was not affected by P

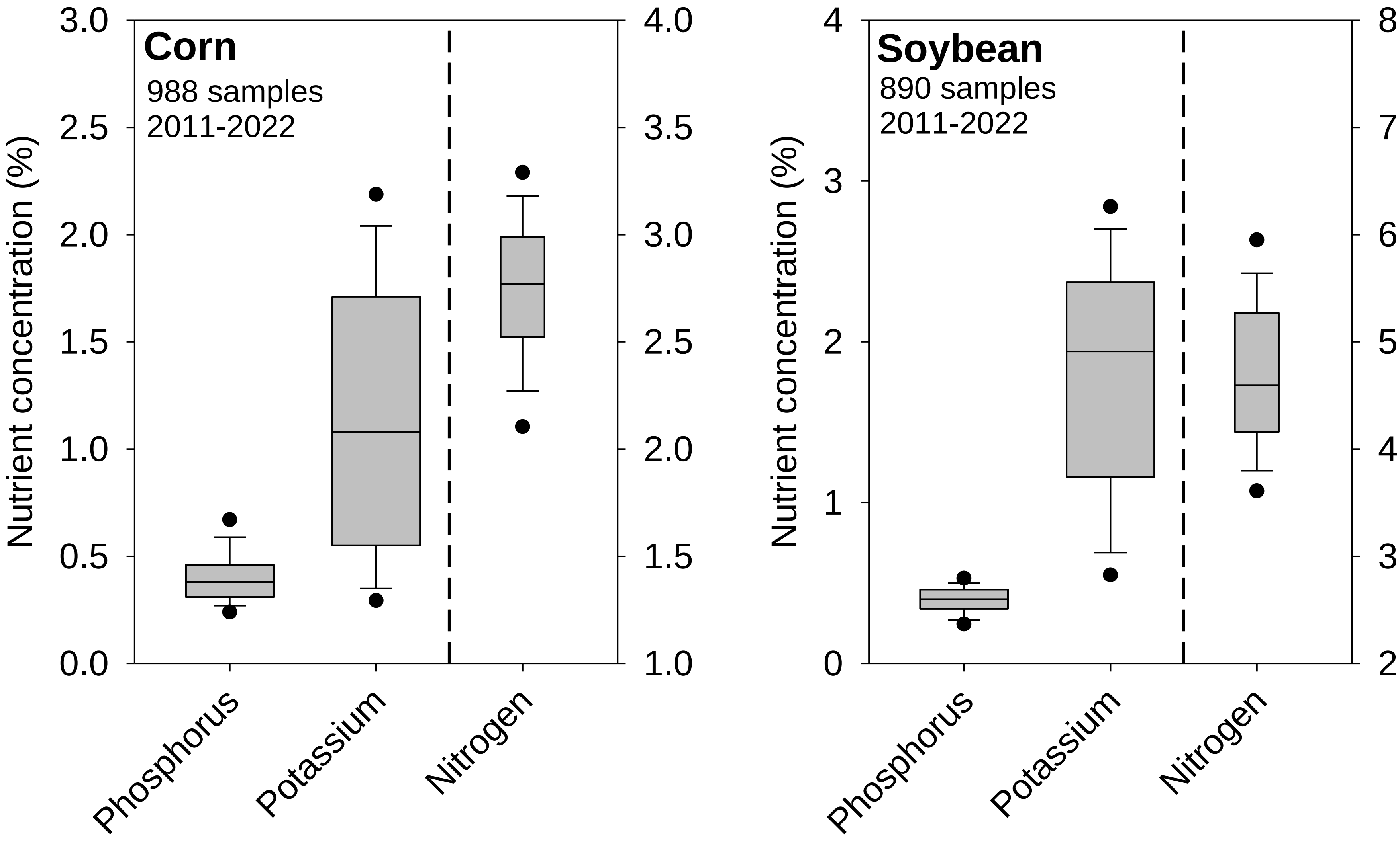
Jones (2022)

Yield response to P & K



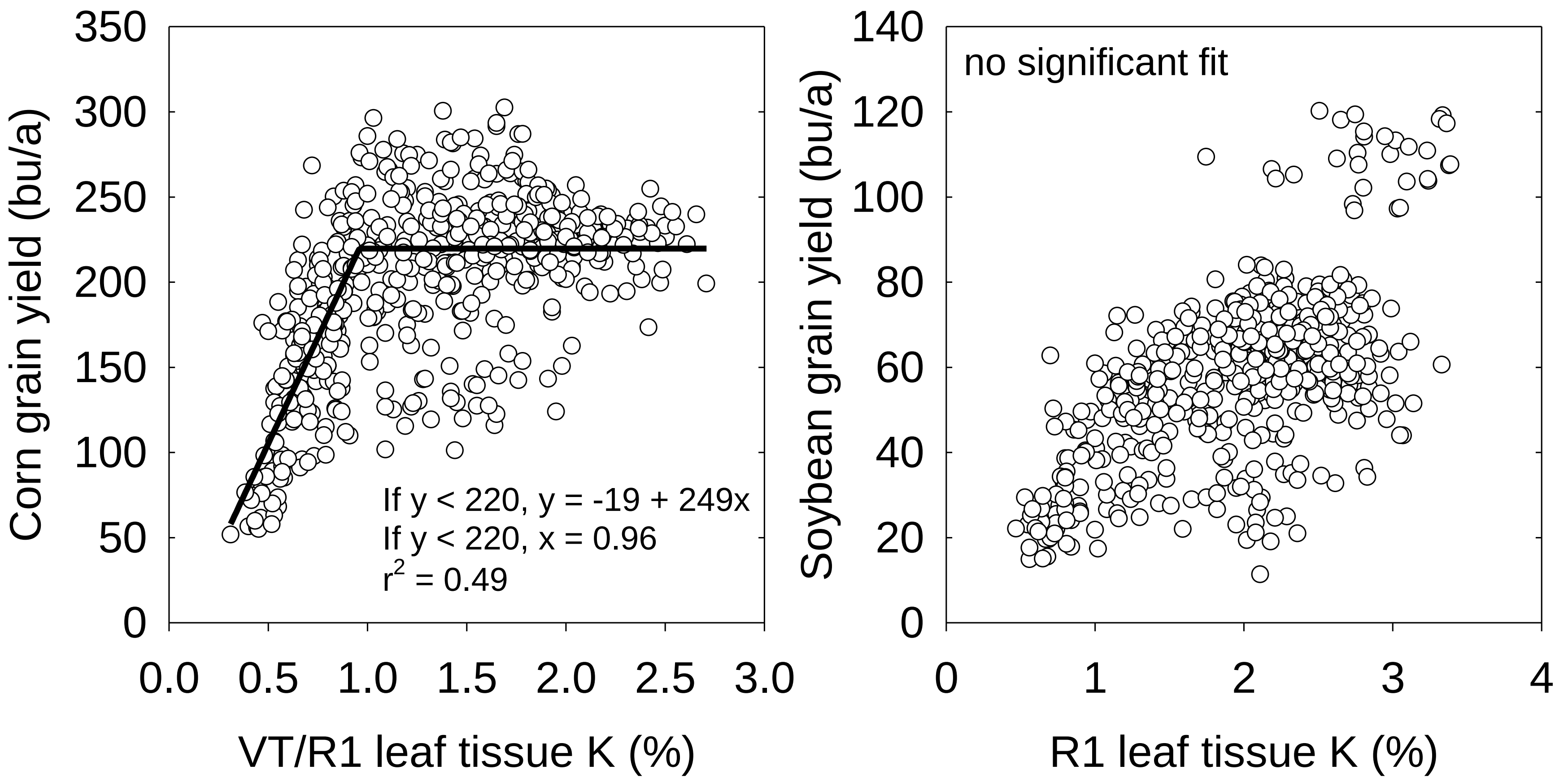
- P, K, and P x K interaction affected corn and soybean yield
- Corn P response only when soil-test is above 75 ppm K
- Soybean less consistent, K threshold of greater importance

Tissue P & K

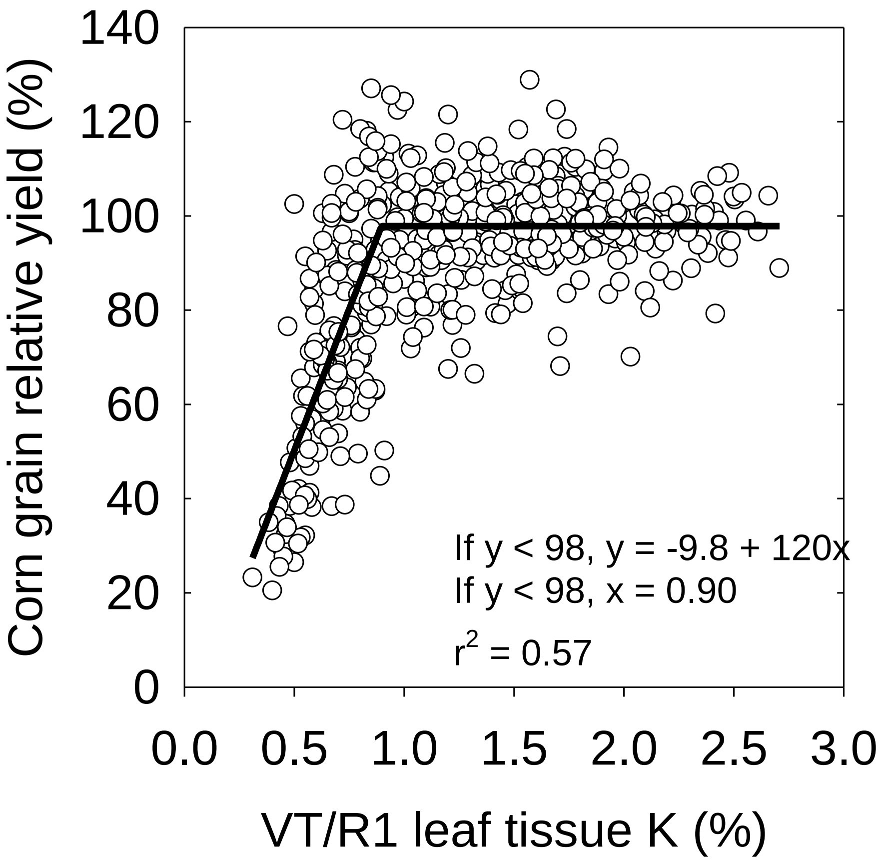


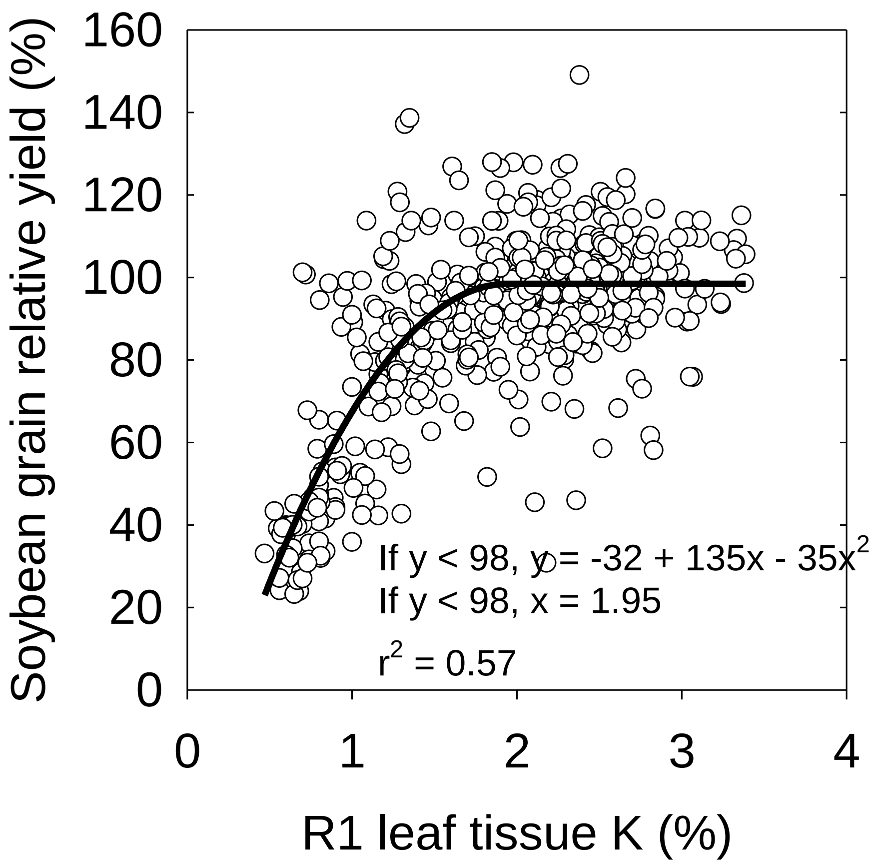
Corn
988 samples
2011-2022
Soybean
890 samples
2011-2022
Nutrient concentration (%)
Phosphorus
Potassium
Nitrogen
0.0
0.5
1.0
1.5
2.0
2.5
3.0
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0
1
2
3
4
2
3
4
5
6
7
8

Yield and tissue K

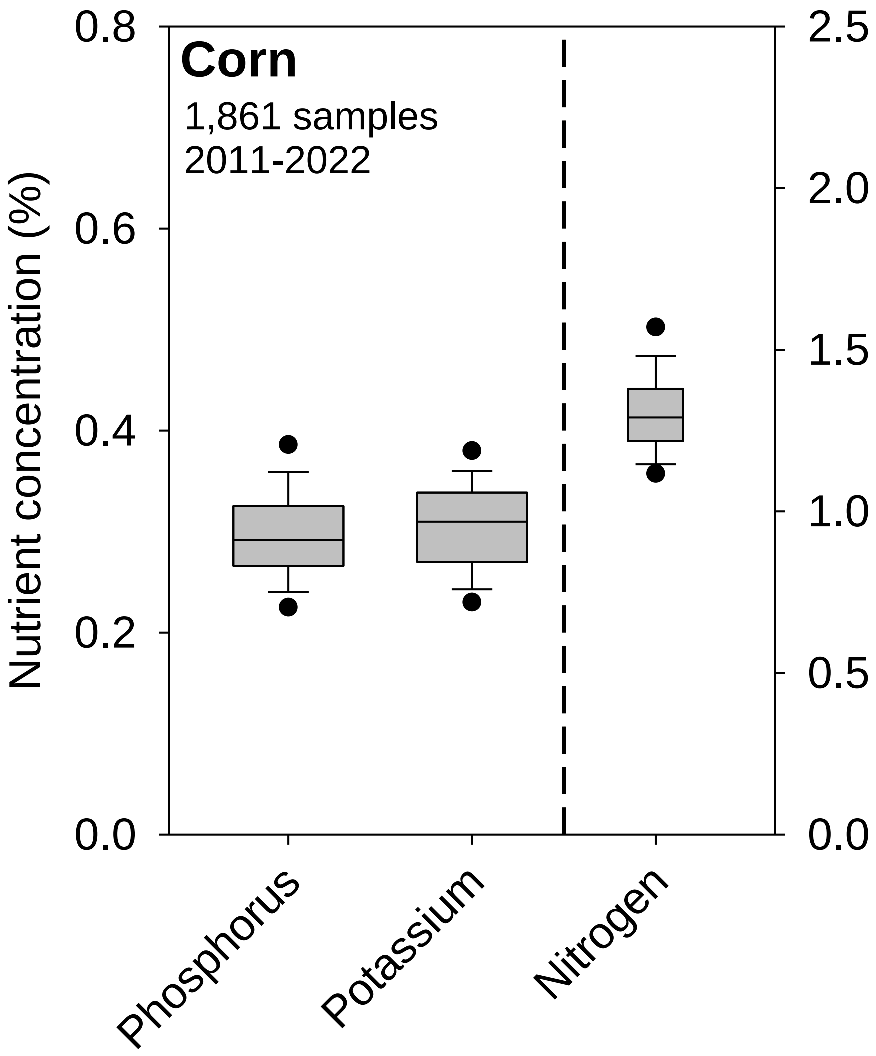


Relative yield and tissue K

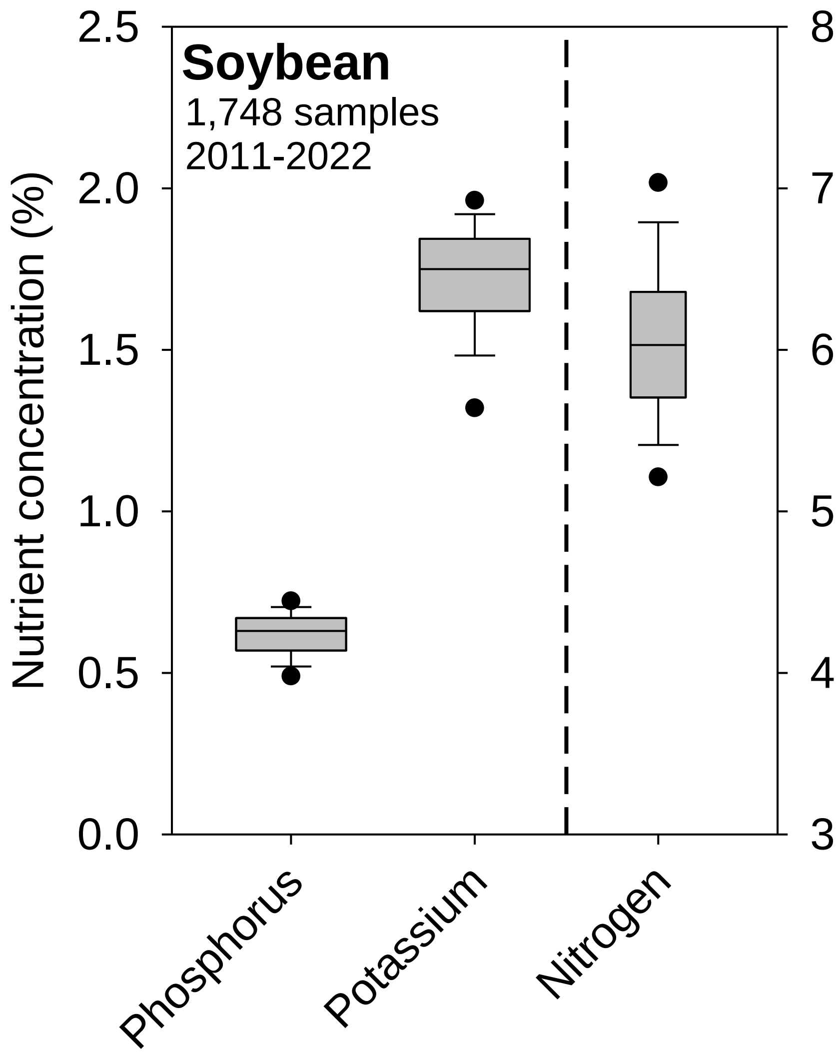




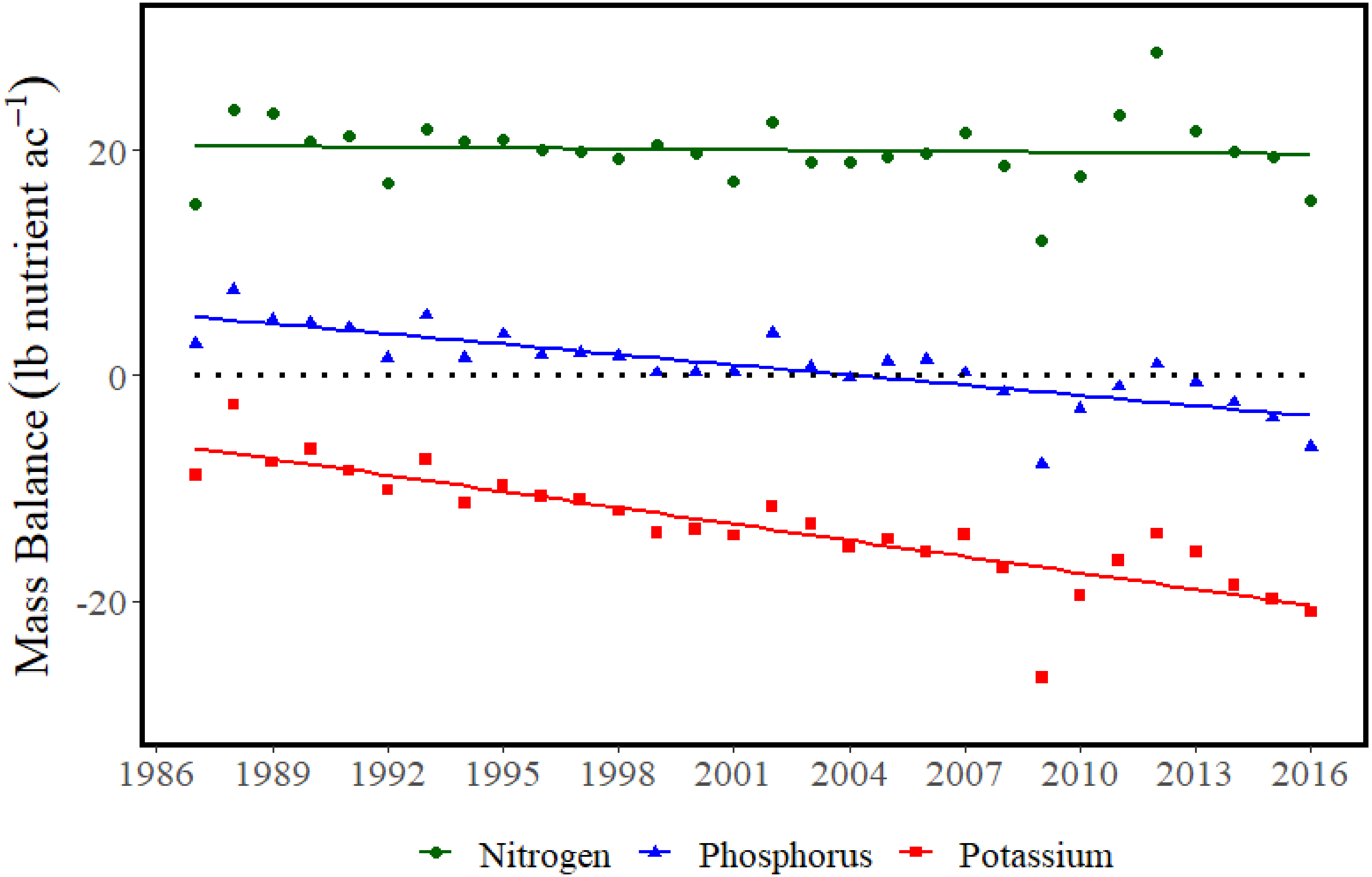
Grain P & K



Corn
1,861 samples
2011-2022
Nutrient concentration (%)
0.8
0.6
0.4
0.2
0.0
2.5
2.0
1.5
1.0
0.5
0.0
Phosphorus
Potassium
Nitrogen



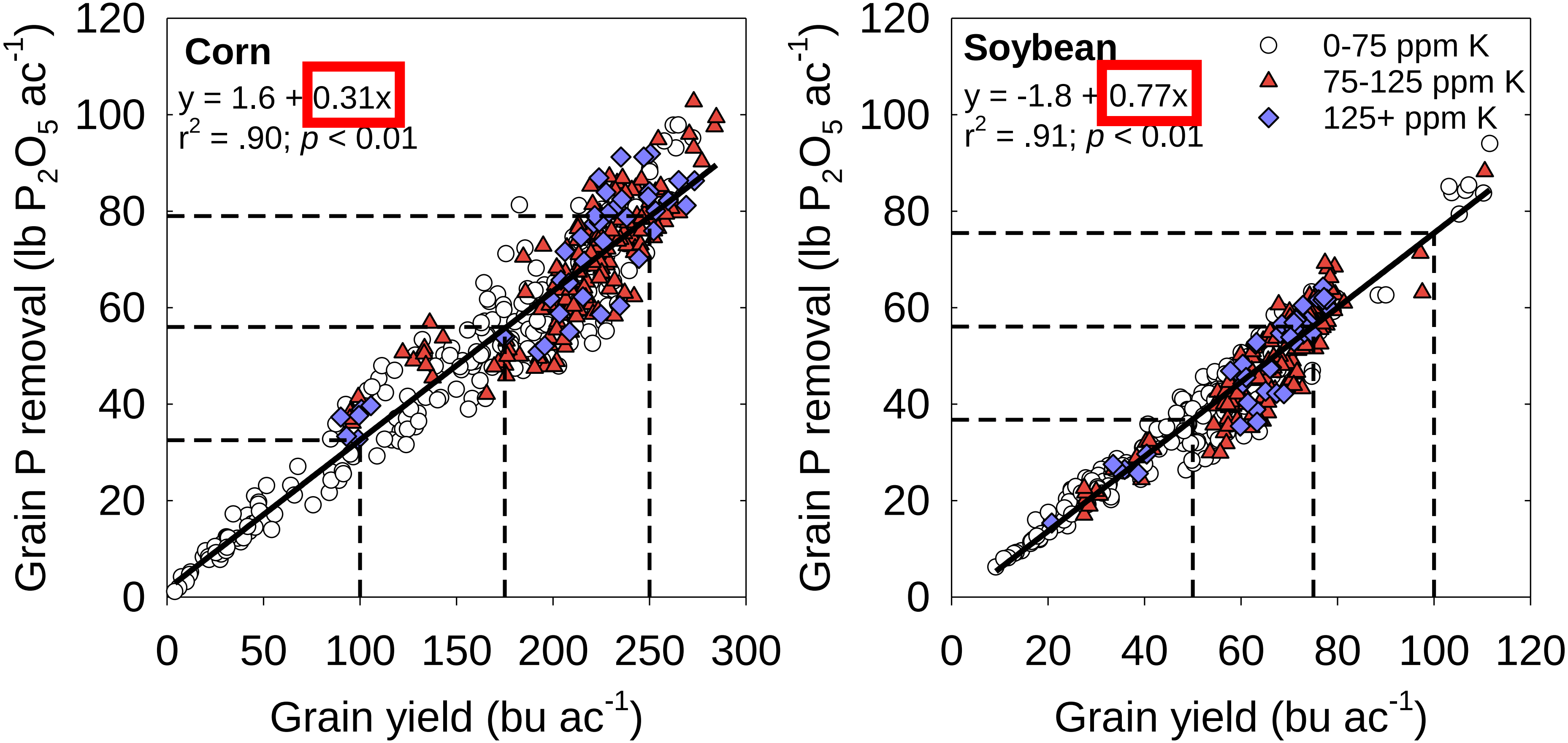
Soybean
1,748 samples
2011-2022
Nutrient concentration (%)
2.5
2.0
1.5
1.0
0.5
0.0
8
7
6
5
4
3
Phosphorus
Potassium
Nitrogen



Grain nutrient removal is the second largest nutrient distribution mechanism in the world, and drives nutrient balances

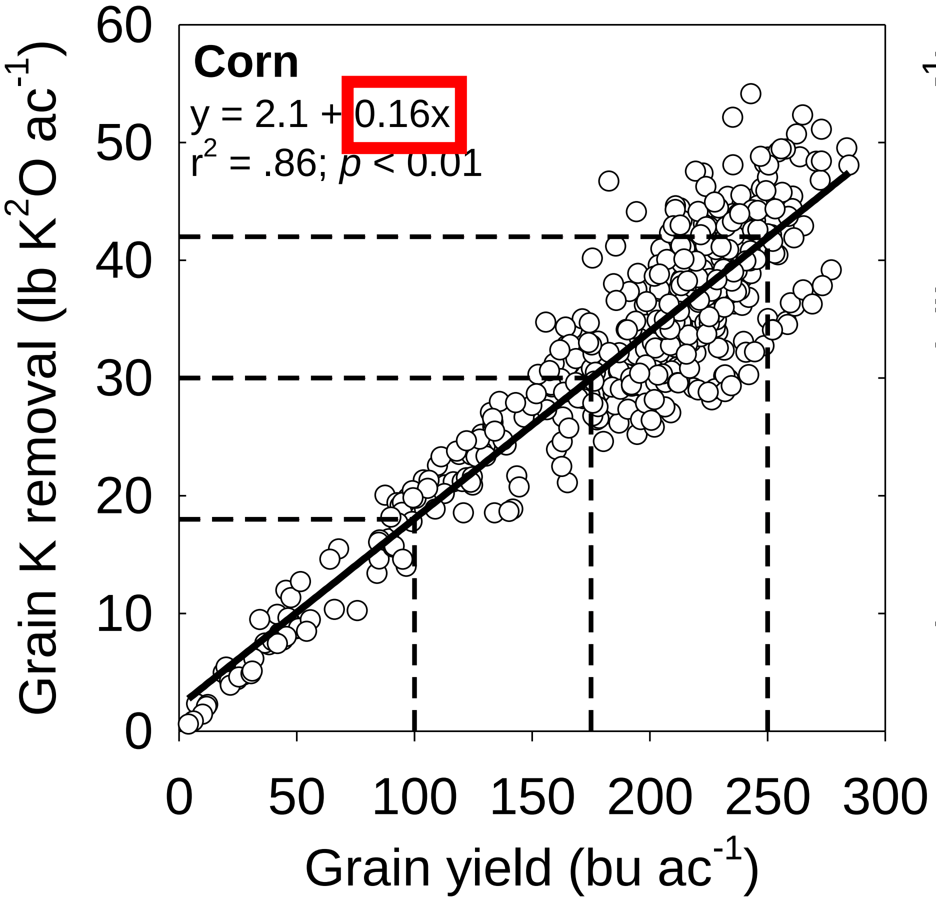
Jones, 2021

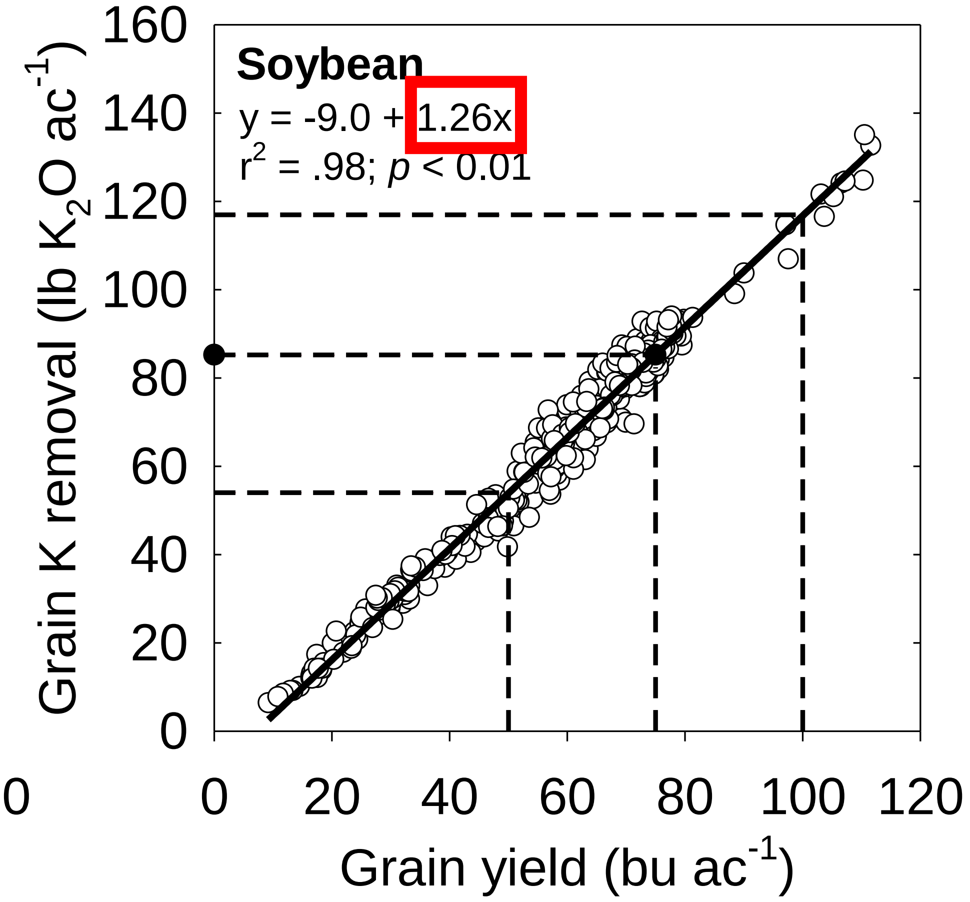
Yield level and P removal



Jones et al. (2022)

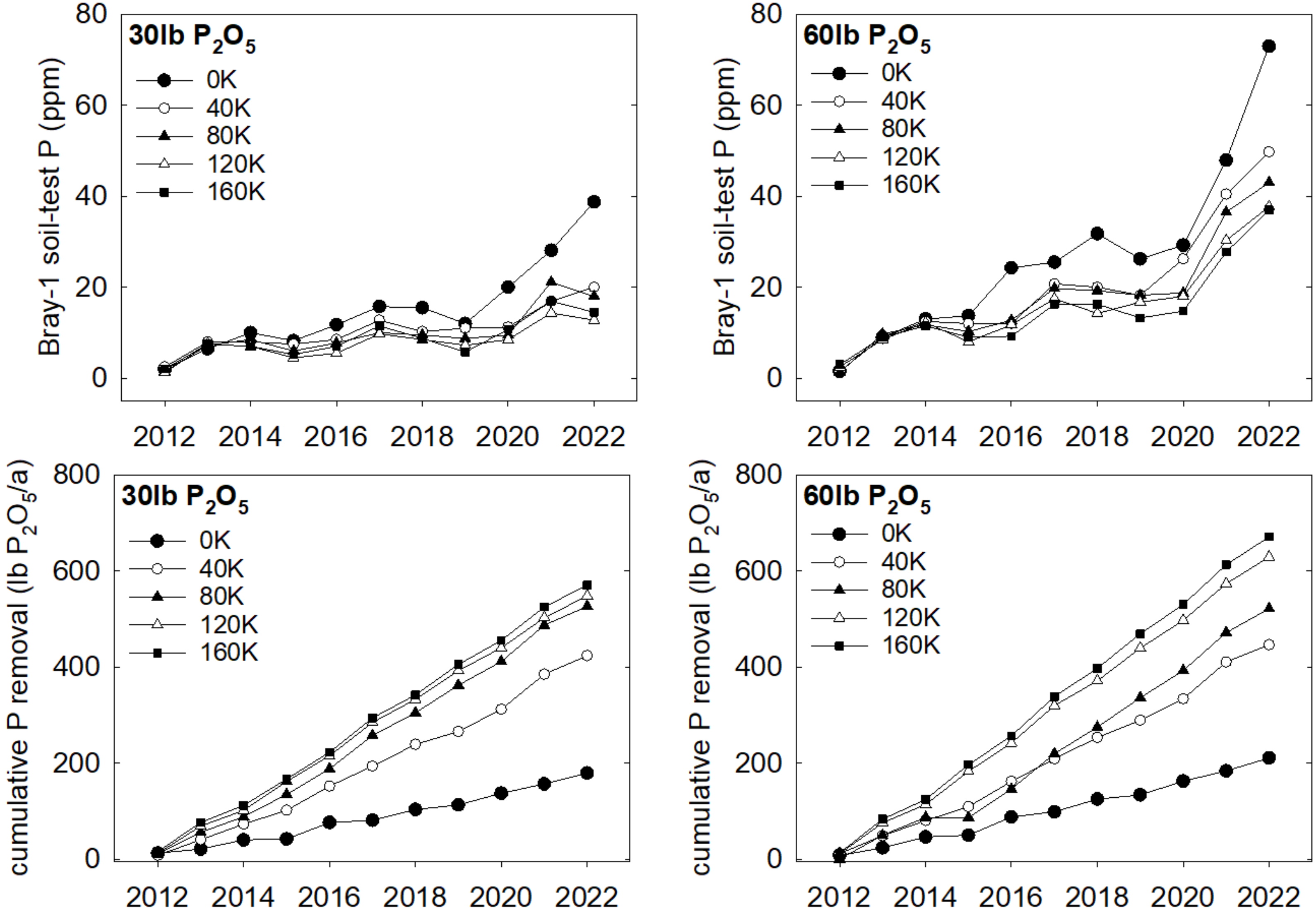
Yield level and K removal



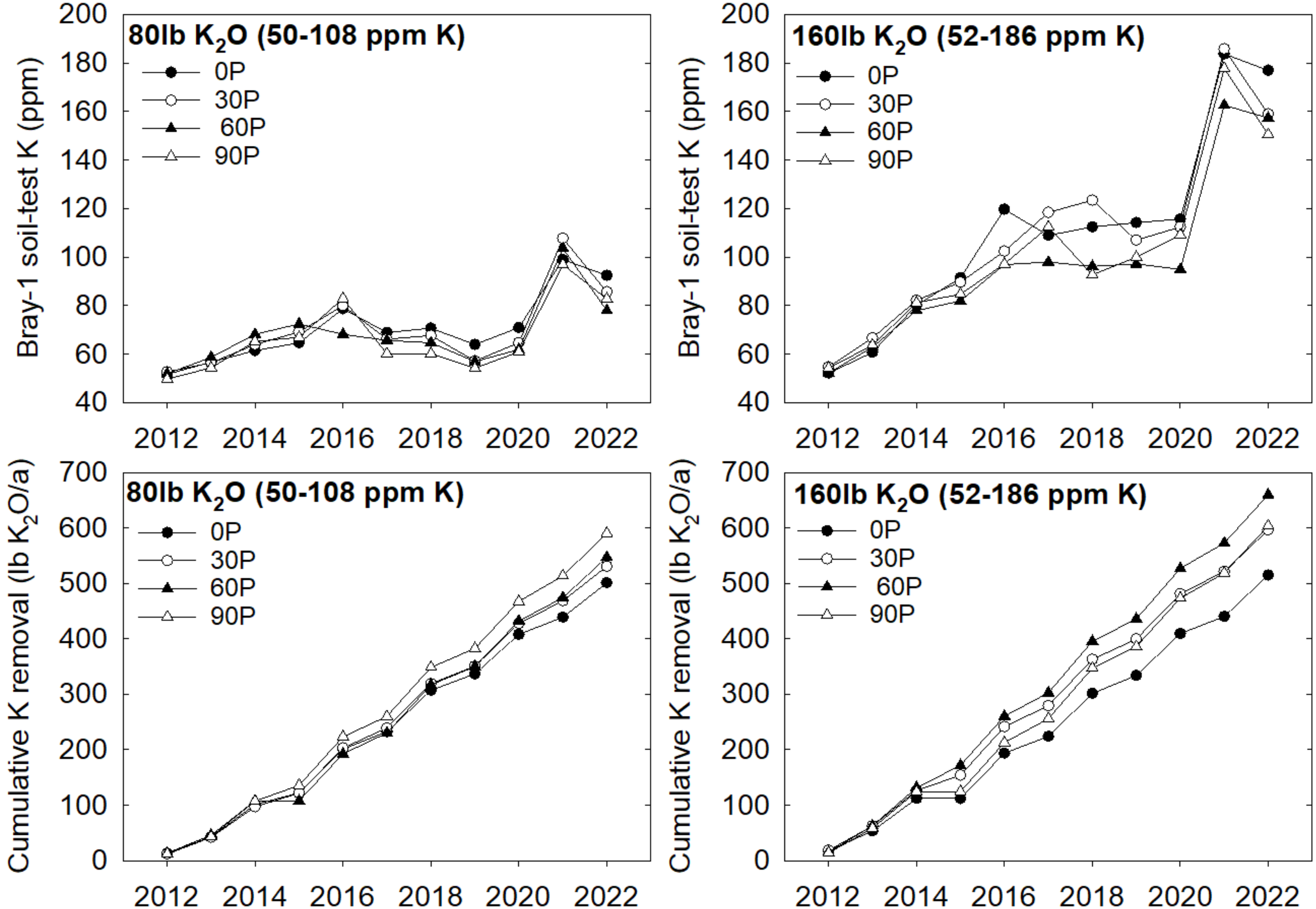


Jones et al. (2022)

STP level and removal



STK level and removal



New Soil Tests in State Recommendations

Why update Wisconsin P & K interpretations?

- Current guidelines provide interpretation only for the Bray-1 phosphorus and potassium
- No new supporting data in decades
- Improve response predictions & ease of use

"Pay no attention to that ~~man~~ agronomist behind the ~~curtain~~ nutrient recommendation"

What's old is "new" again…

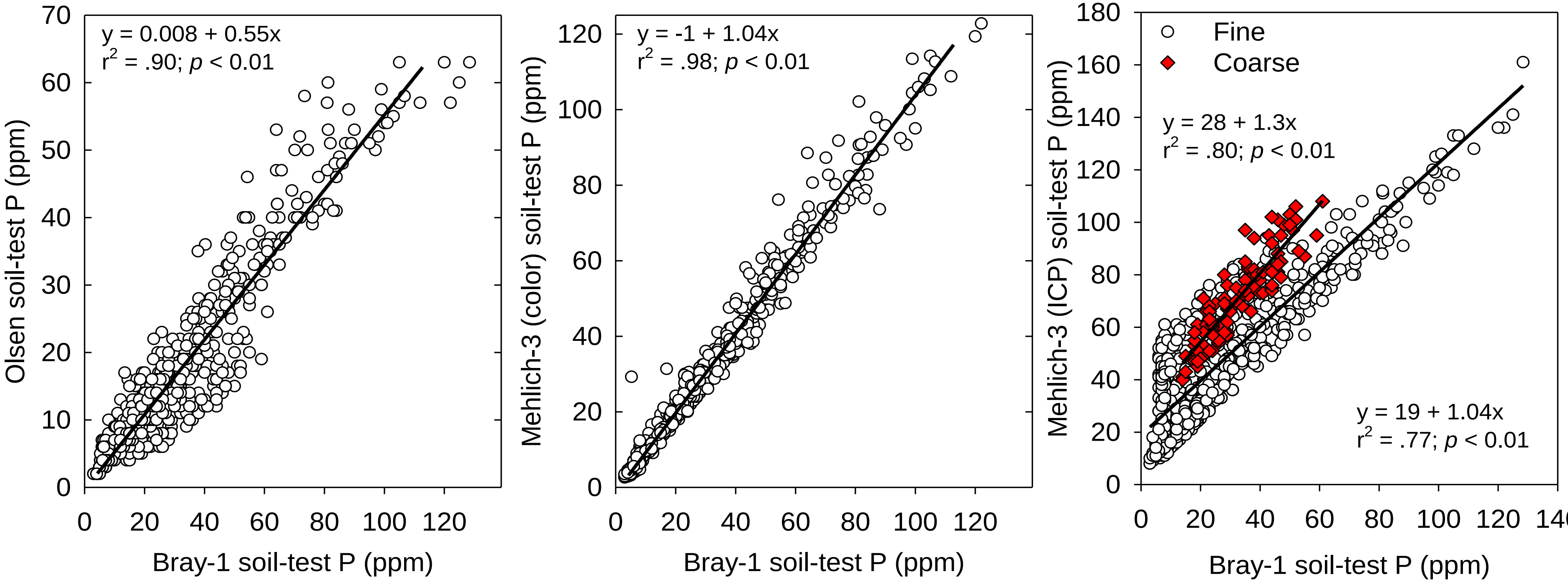
Relationship to Bray-1 P or K (760 samples)

Soil test	Regression equation	r^2
Mehlich-3 P colorimetric	y = -1 + 1.04*BP	0.98
Mehlich-3 ICP	fine: y = 28 + 1.3*BP; coarse: y = 19 + 1.04*BP	0.80; 0.77
Olsen P	y = 0.008 + 0.55*BP	0.90
H3AP colorimetric	fine: y = -.62 + .59*BP; coarse: y = -2.2 + .3*BP	0.86; 0.93
H3AP ICP	fine: y = 5.8 + .64*BP; coarse: y = 6.1 + .37*BP	0.86; 0.91
Mehlich-3 K	y = 8.9 + 1.14*BK	0.95
Ammonium acetate K	y = 0.76 + 1.18*BK	0.86
H3AK	fine: y = -3.1 + .44*BK; coarse: y = -17 + .73*BK	0.92; 0.92

Jones et al. (2022)

- Olsen (1954), Mehlich-3 (1984), ammonium acetate (pre-1965), H3A – Europe and S. America have used organic acids since late 1800s to mid 1950s.
- Linear regressions between tests may hide true, more complex relationship

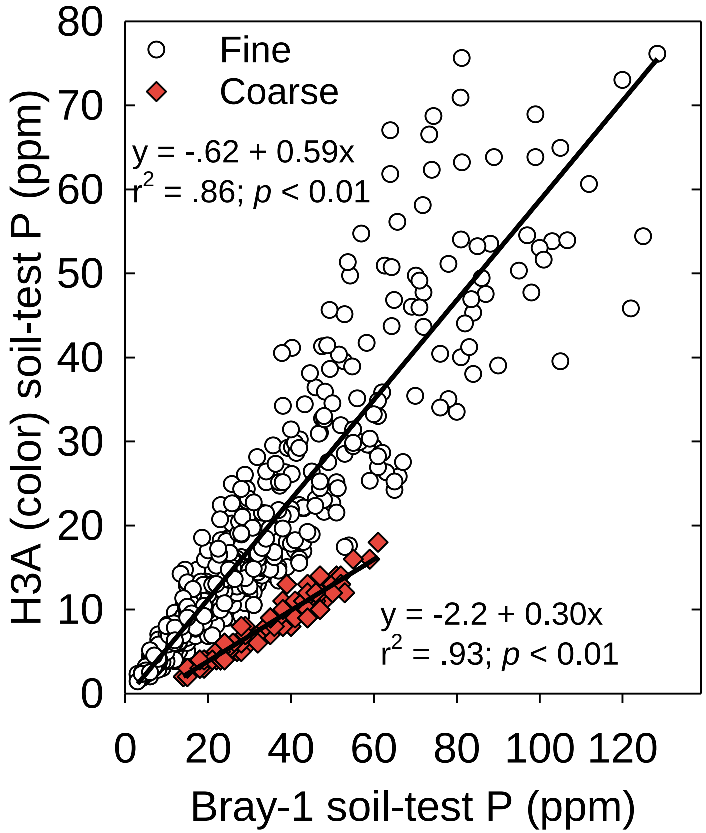
Comparing measured soil P

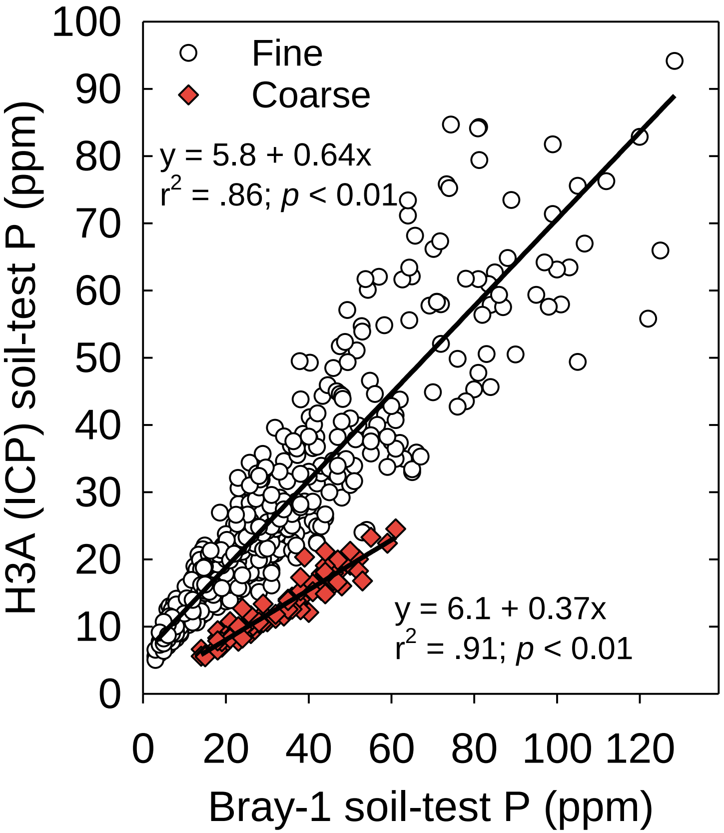


Strong linear relationships between BP and M3P (color), BP-OP relationship more variable. Large variation in BP and M3P (ICP) relationship in fine texture sites. Site variations.

Jones et al. (2022)

Comparing measured soil P



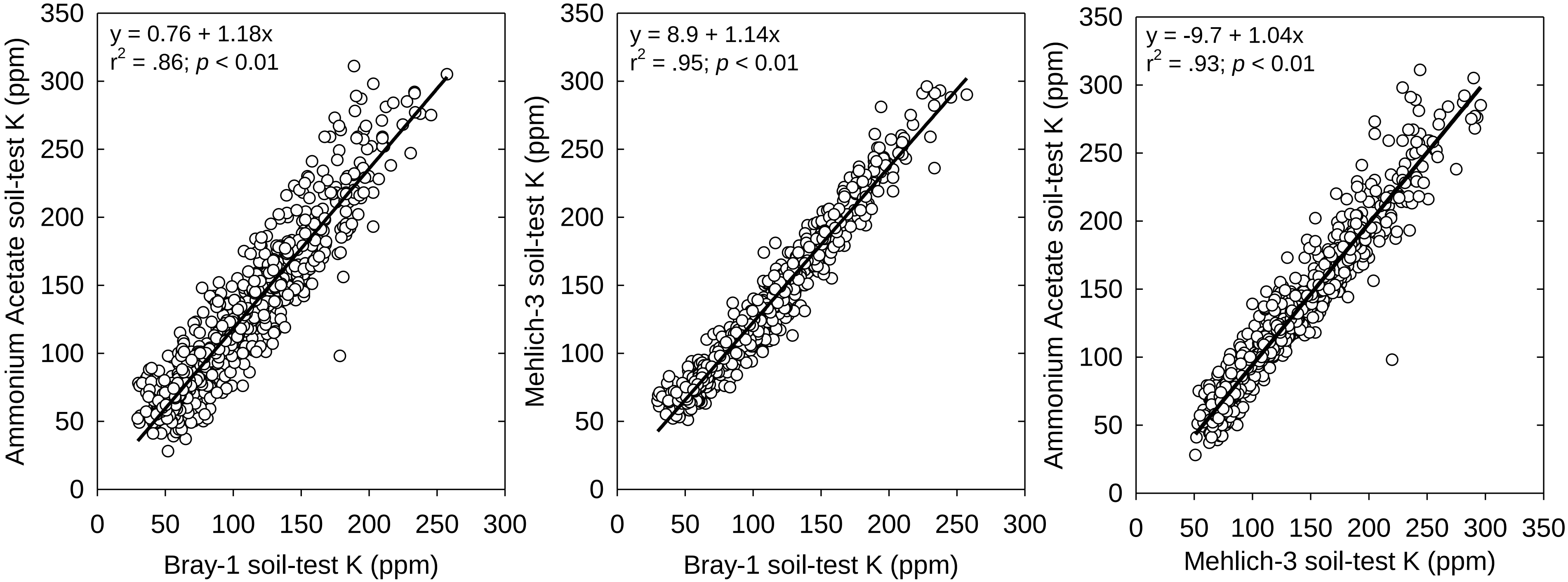


Linear relationships between soil health P tests and Bray.

Site variability

Jones et al. (2022)

Comparing measured soil K

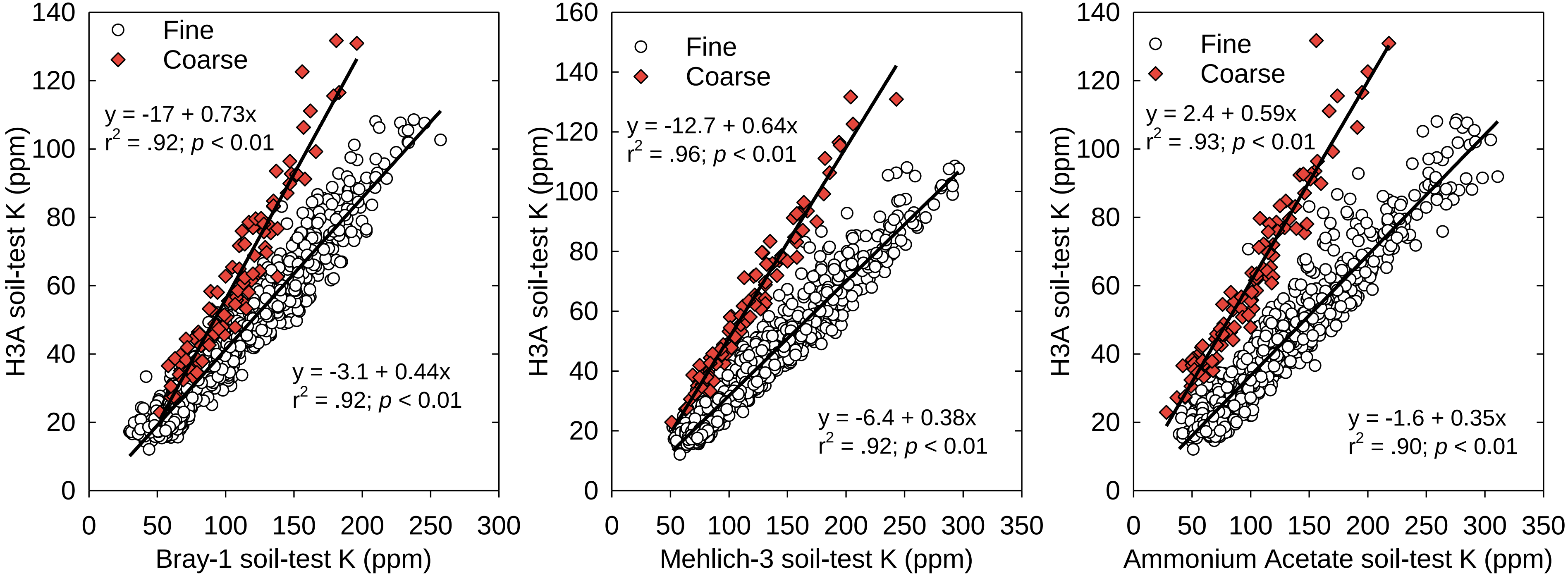


Linear relationships between all routine tests. On average…

- BK measured 81% of M3K; 24 ppm K less (all samples)
- BK measured 87% of AAK; 20 ppm K less (all samples)

Jones et al. (2022)

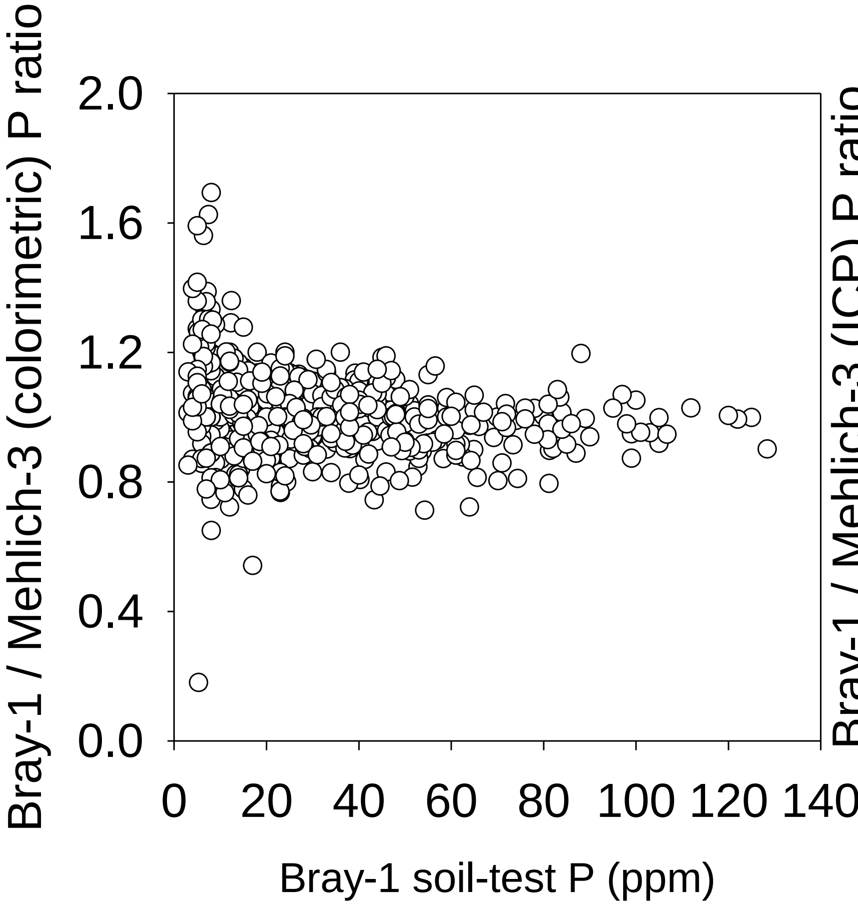
Comparing measured soil K

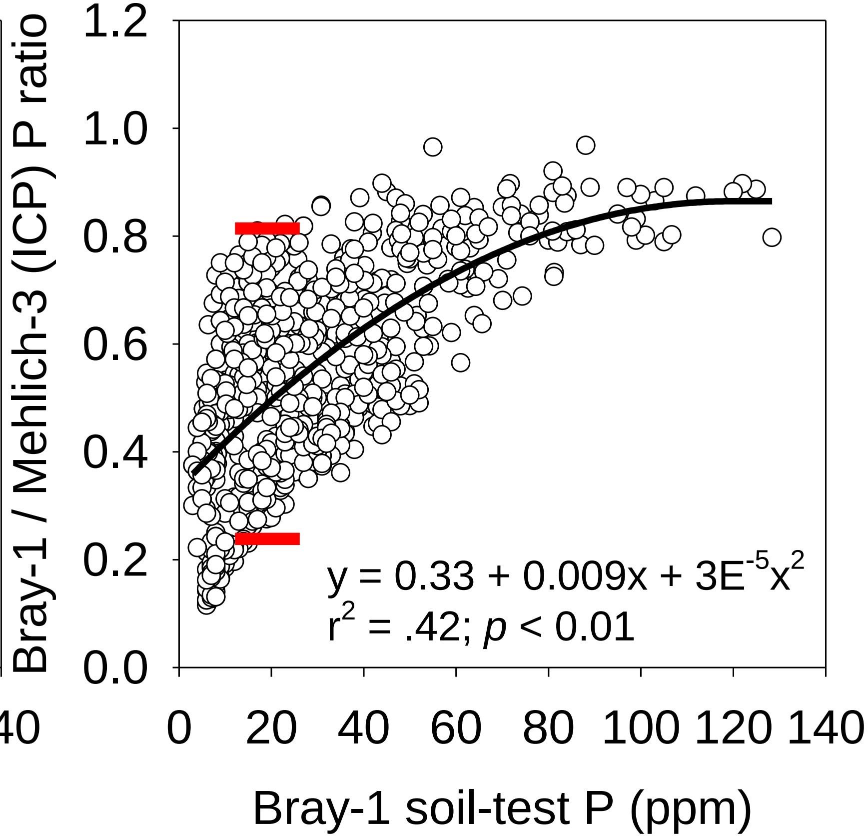


Strong linear relationships between H3A K and routine tests, however site variations significantly affected relationship.

Jones et al. (2022)

Is linear regression enough?

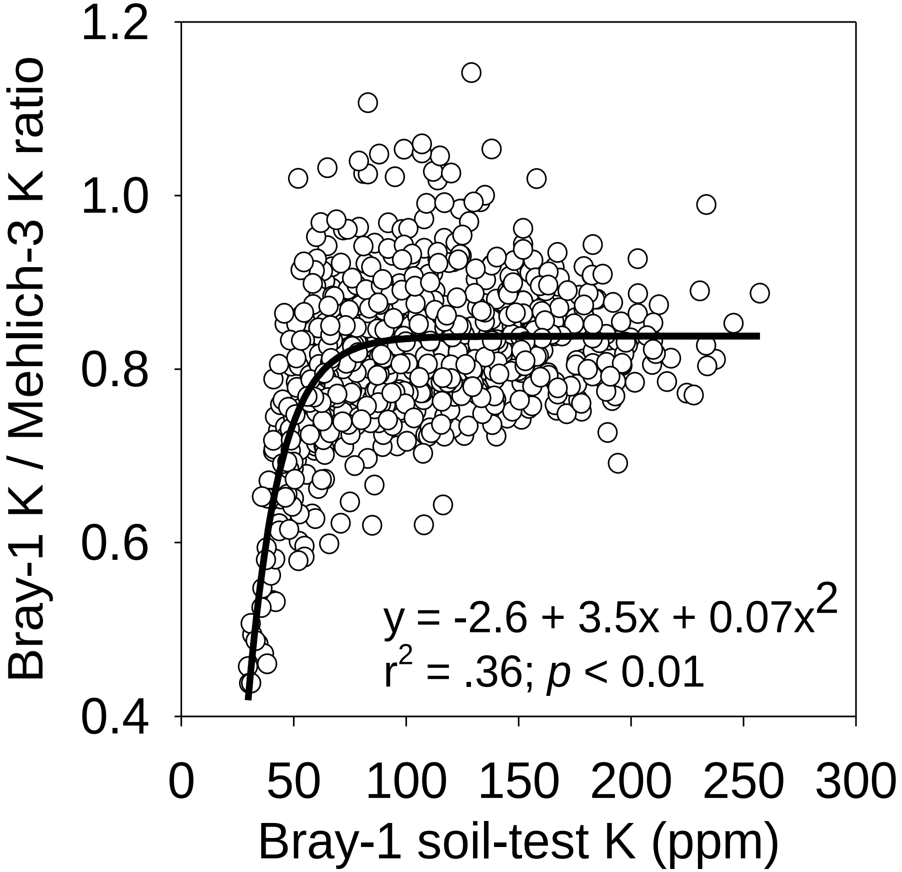


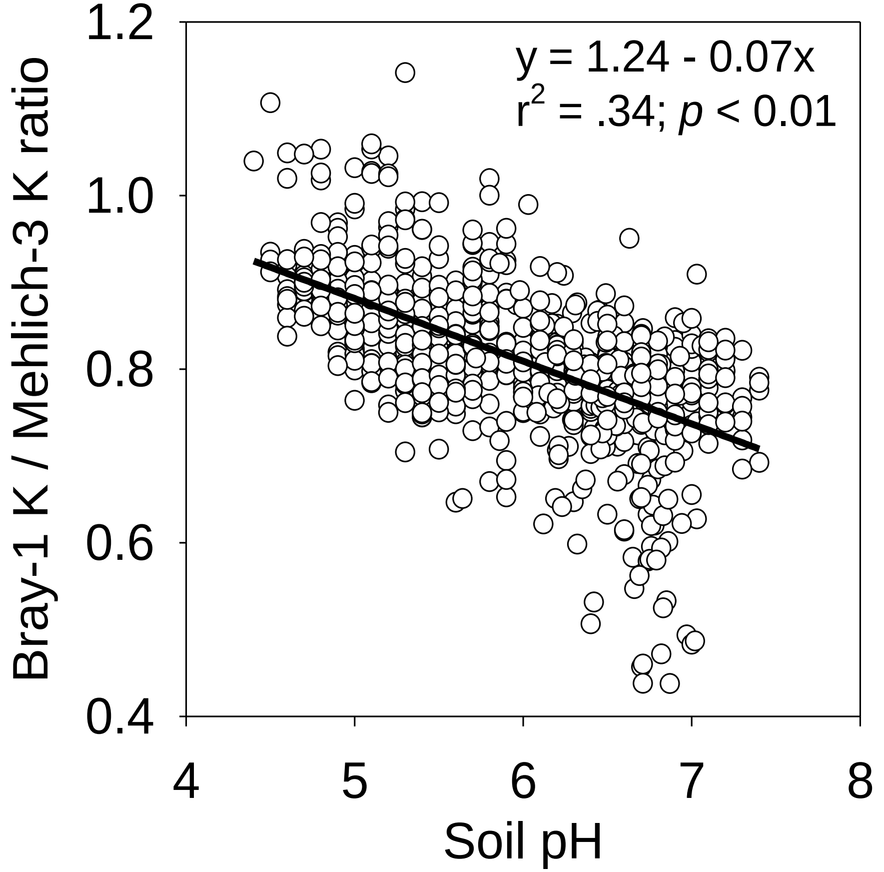


BP / M3P (color) equal variation around 1.0.

BP / M3P (ICP) extremely wide range in low P soils.

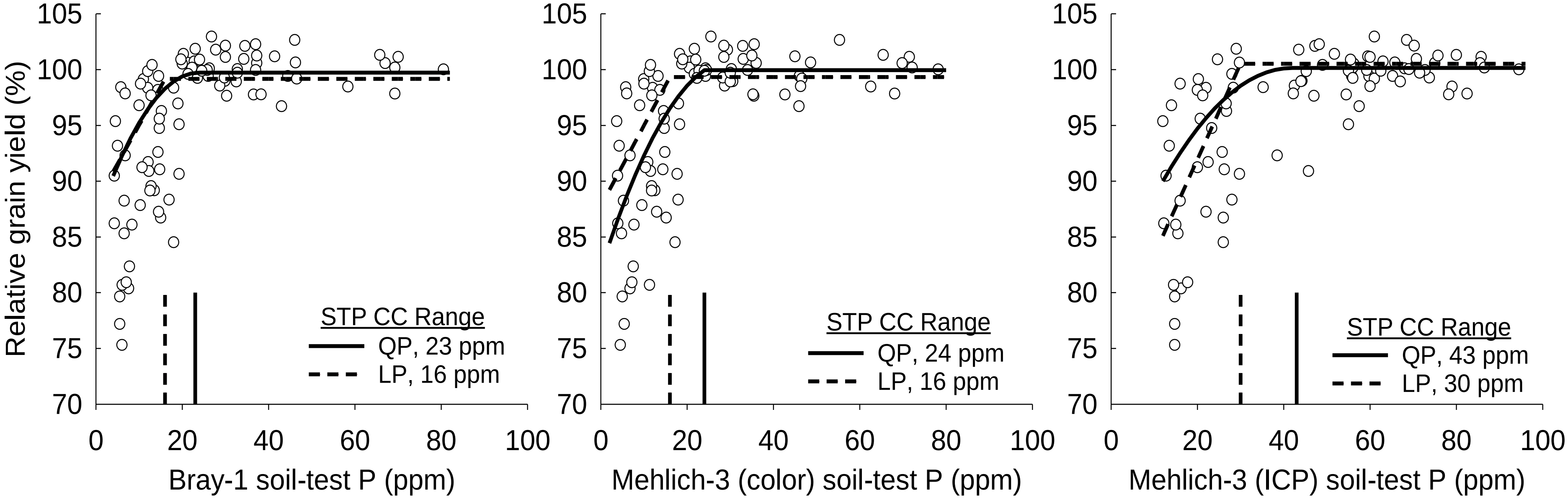
Is linear regression enough?





BK / M3K ratio very difference above/below 60 ppm K; indication of pH affecting ratio.

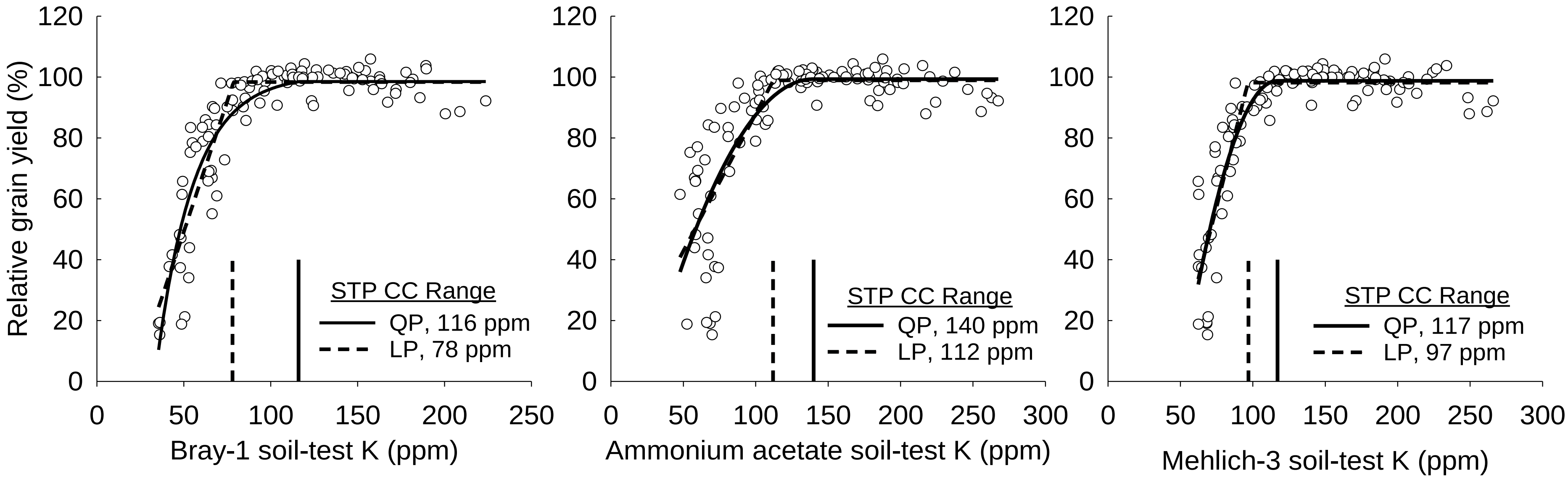
Updating STP interpretation



Interpretation of Mehlich-3 colorimetric (VL, L, O, H, VH) is similar to Bray, but an ICP determined soil P test needs separate calibration.

Jones et al. (2022)

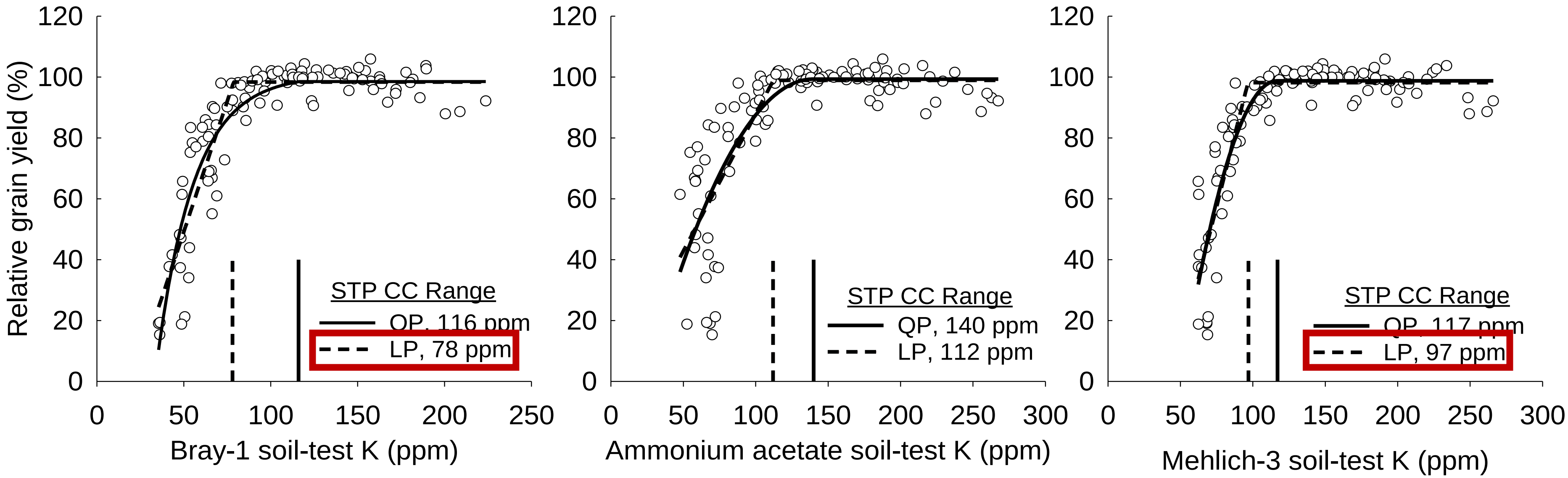
Updating STK interpretation

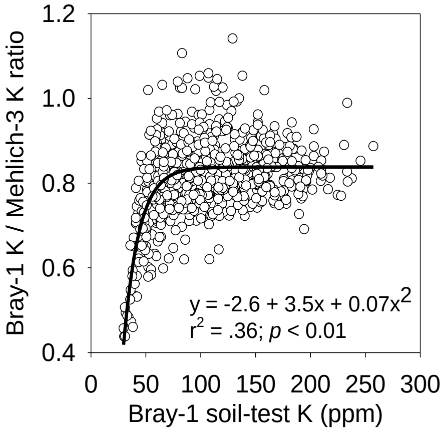


Bray and Mehlich K tests have similar upper limits for critical range, <u>but variation in extraction at low STK levels</u> prohibits using similar interpretation. Why the discrepancy?

Jones et al. (2022)

Updating STK interpretation

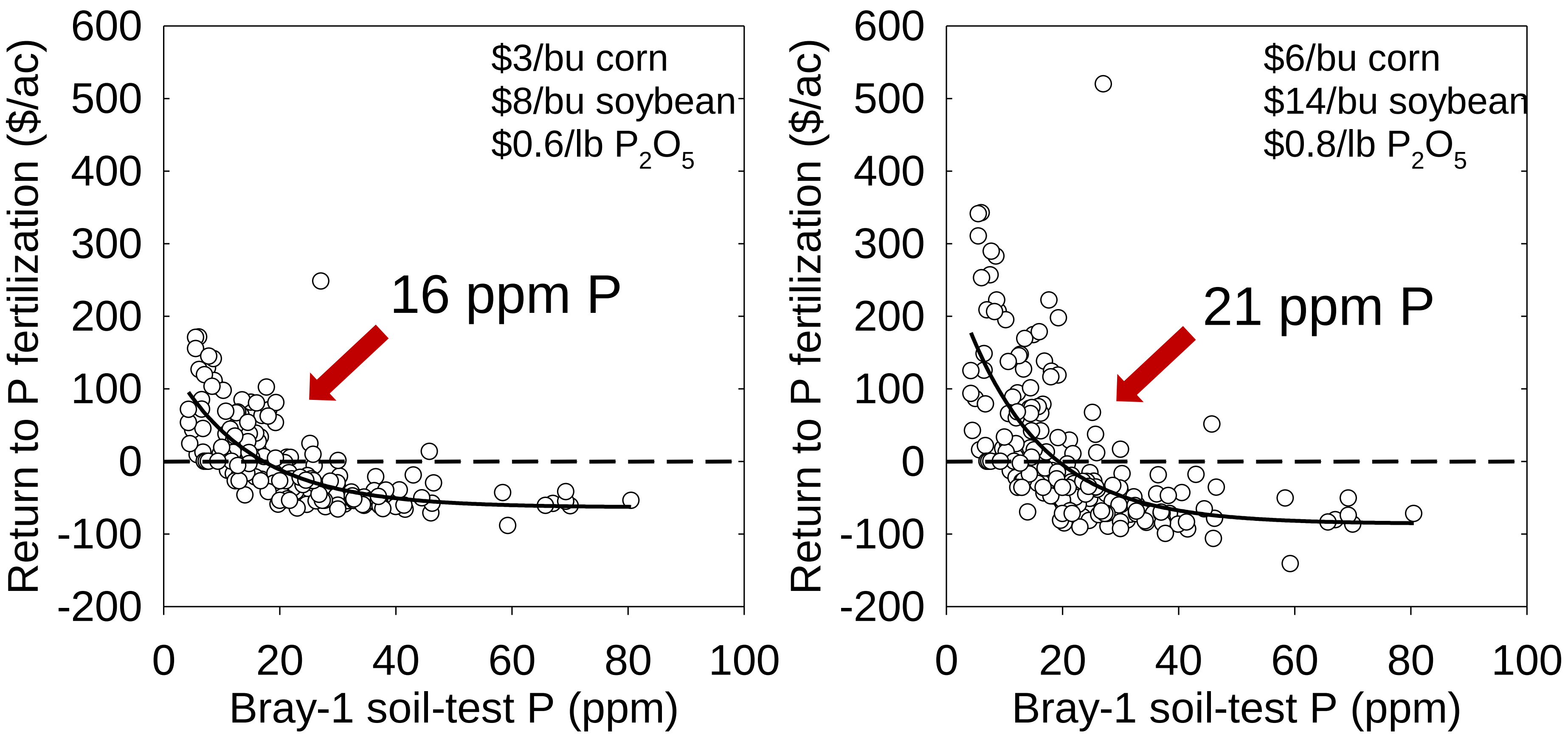




From slide 30, Bray K measured relatively less K in lower K soils – under ~75 ppm K. Reasoning for necessary individual calibration!

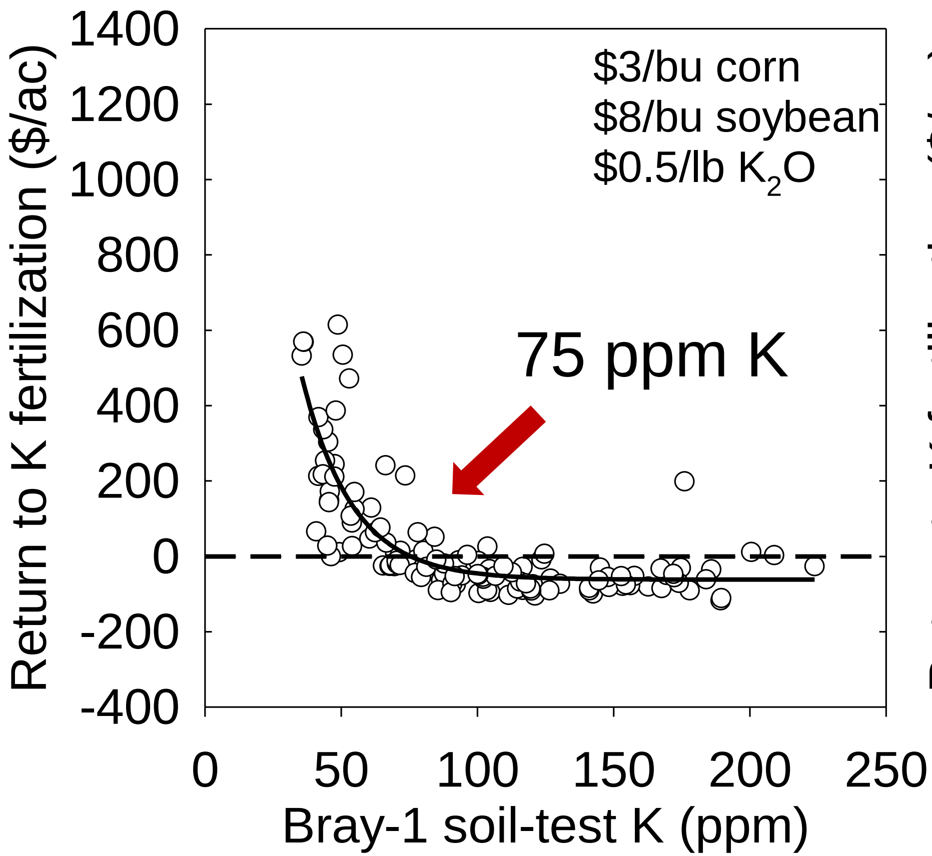
Jones et al. (2022)

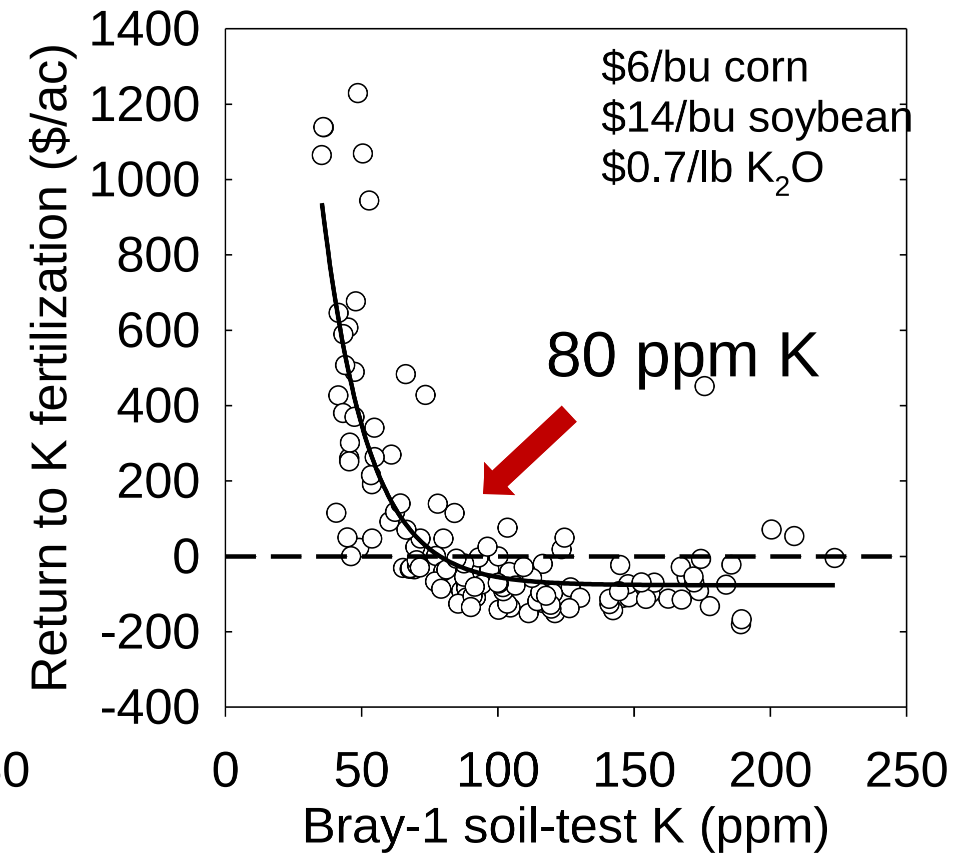
Economics and Interpretation Class



Intersection point aligns with optimum STP range (16-23 ppm)

Economics and Interpretation Class



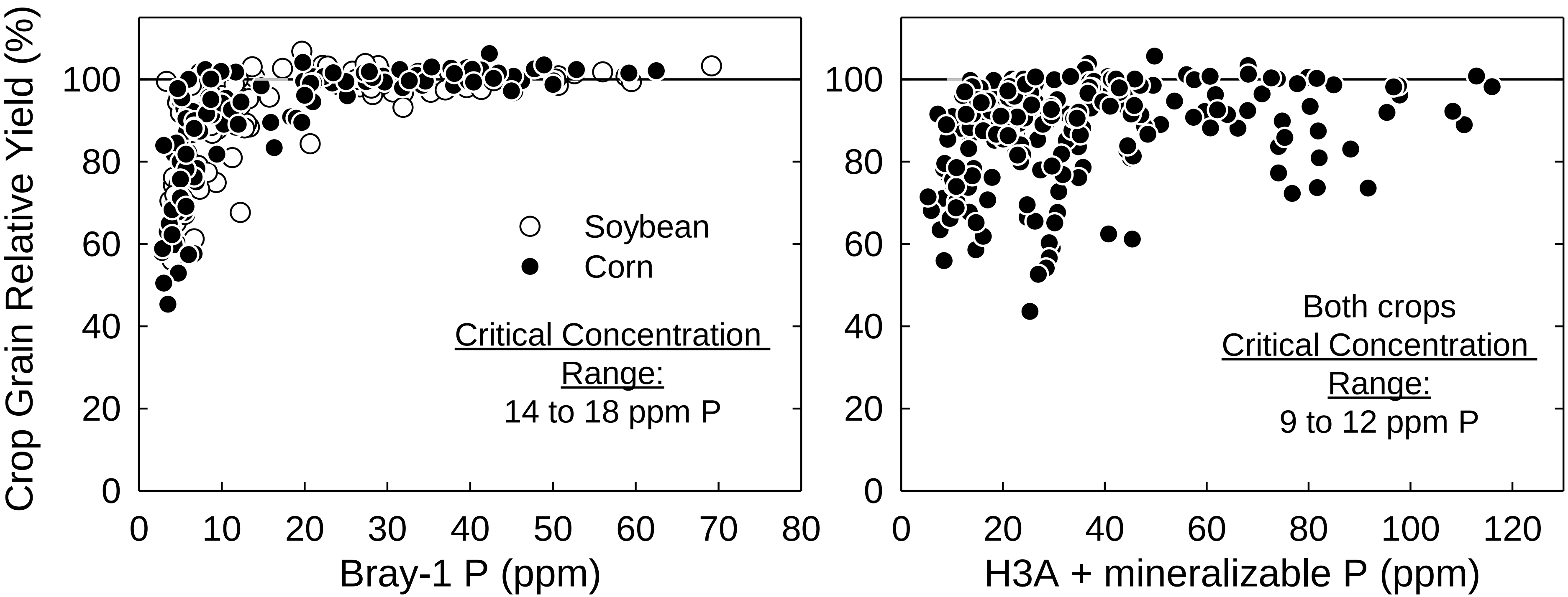


Preliminary optimum classes

- Ranges where harvest removal rates are recommended
- Probability of fertilization response increases from 65 to 85% below the range.
- Additional years, trials to aggregate

Soil test	CC Range (ppm)
Bray-1 P	16-23
Mehlich-3 (COL)	16-24
Mehlich-3 ICP	30-43
Olsen P	13-18
H3AP (COL)	10-17
H3AP ICP	23-29
Bray-1 K	78-116
Mehlich-3 K	97-117
Ammonium acetate K	112-140
H3AK	30-37

Note on P mineralization



Including a mineralization factor based on CO_2 respiration could not improve the performance

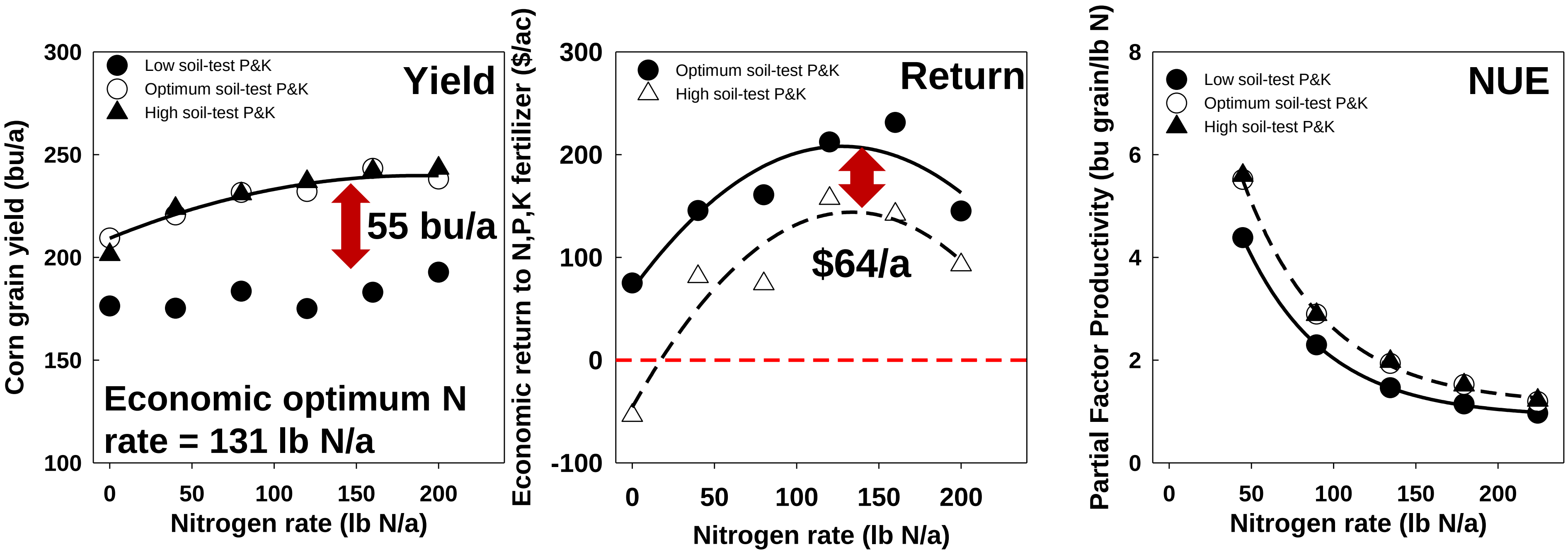
27% below & 73% above

Jones and Mallarino, (2019)

Nitrogen demand at high soil-test levels?

- What about…
  - High yield level?
  - K x N interactions?
  - Supplemental soybean N?
- Single site study (2018-present)
  - Low, optimum, high P & K levels
  - Six N rates
  - Conventional tilled corn-soybean rotation
  - Plano silt loam (typic argiudoll), 5% SOM, 6.5 pH, supplemental S for corn
  - Most productive soil in south central WI (Empire Prairie)

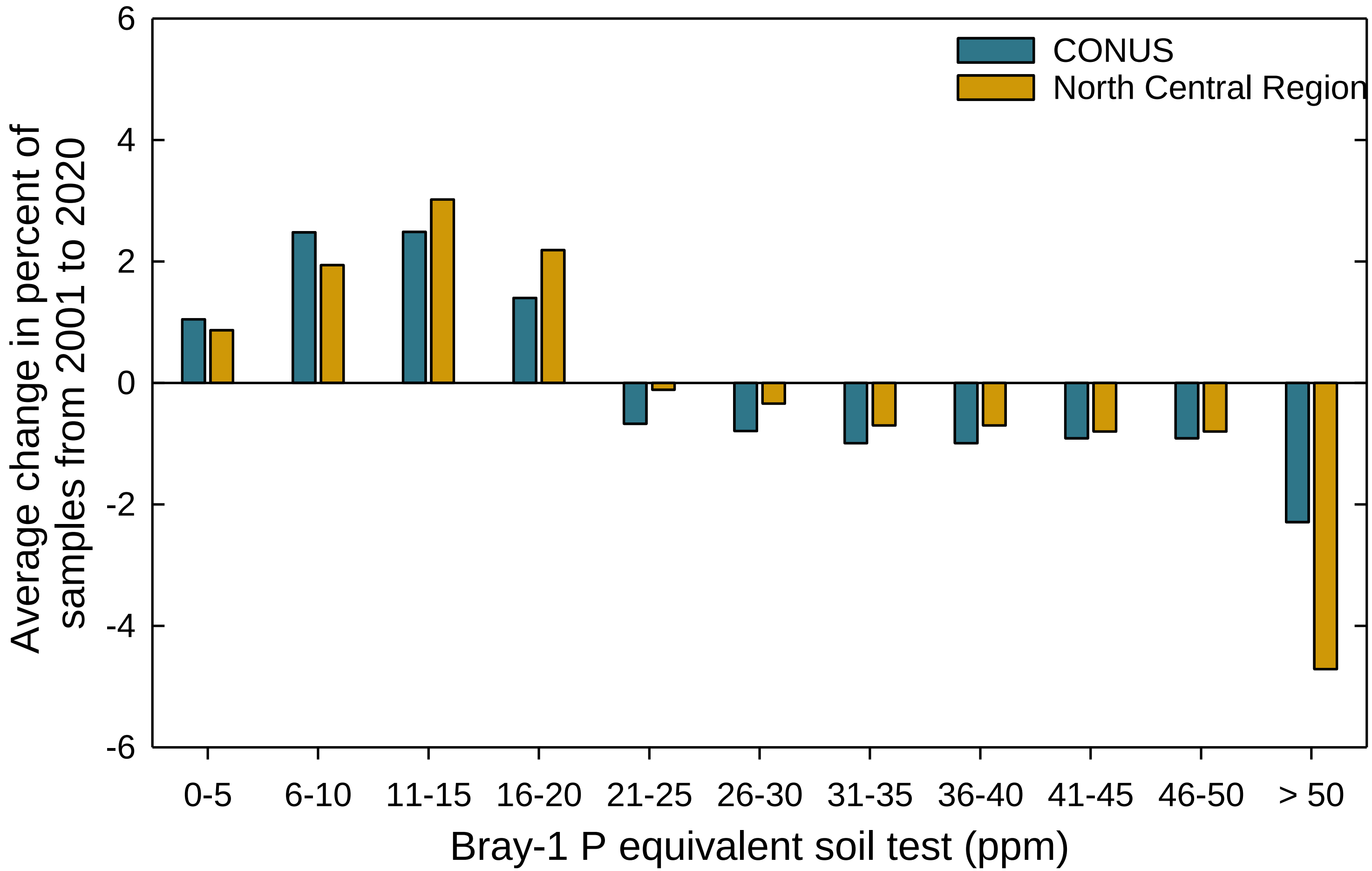
Interaction of P, K, and nitrogen



Optimum soil-test P & K level required to achieve N response, ROI, and efficient N use

Jones et al. (2022)

North Central region STP trend

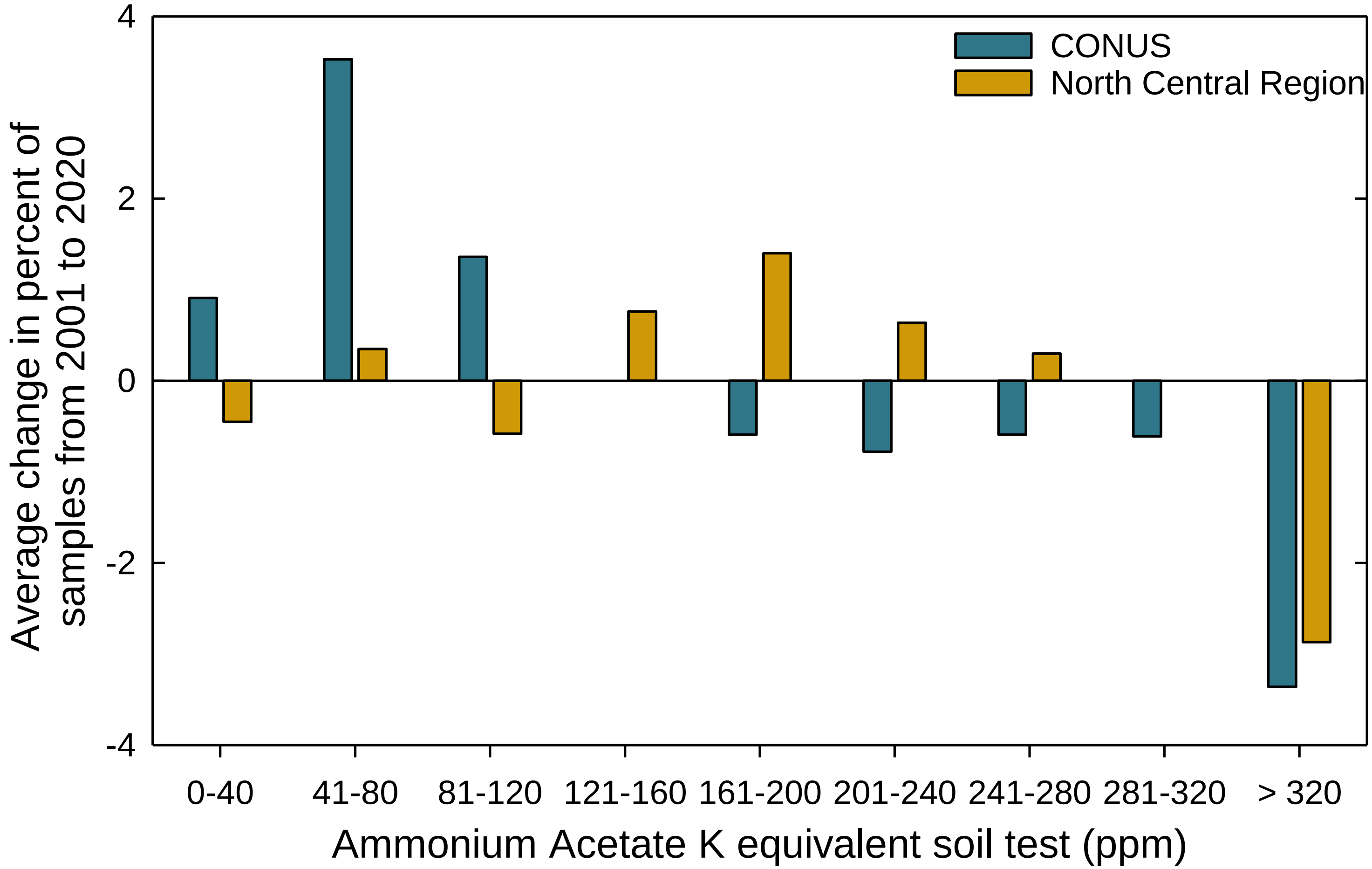


2020 North American Soil Test Summary

TFI, FAR, PNC, PAQ, and IPNI

Jones et al. (2021)

North Central region STK trend



2020 North American Soil Test Summary

TFI, FAR, PNC, PAQ, and IPNI

Jones et al. (2021)

Key takeaways

- Expected yield responses to soil-test level need to consider both P & K.
- Soil testing is the priority to capture fluctuation in available nutrients, tissue tests have limitations
- Prioritizing STP & STK levels can safeguard N investment
- Estimating removal values needs more attention with higher yield levels – static values may underestimate

Lingering questions…

- Potassium cycling across WI soils
  - Improved representation of soil diversity
  - Stable isotope field work beginning 2023
  - Alfalfa vs corn silage dominant forage systems
  - K^+ (Cl^-) leaching concerns – WI central sands region
- Phosphorus mineralization & movement
- N rate recommendations in low vs high PK

Thank you!

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Collaborating laboratory: AGVISE Laboratories