A NEW ROADWAY TO IMPROVING PHOSPHOROUS MANAGEMENT IN CROP PRODUCTION

John D. Jones

The Foundation for Agronomic Research

Foundation for Agronomic Research (FAR)

"Enhance nutrient stewardship research, education, and outreach efforts."

- Agronomy research & education
- Public policy engagement
- Support public, private, and governmental collaborations

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4R Research Fund

Pre-2019

Companies Contributed	Funded Projects	Dollars Contributed	Total Dollars Allocated
84	25	$5.7M	$13M

Spring 2019 Projects

Proposals Submitted	Funded Projects	Dollars Contributed	Total Dollars Requested
72	5	$3.0M	$36M

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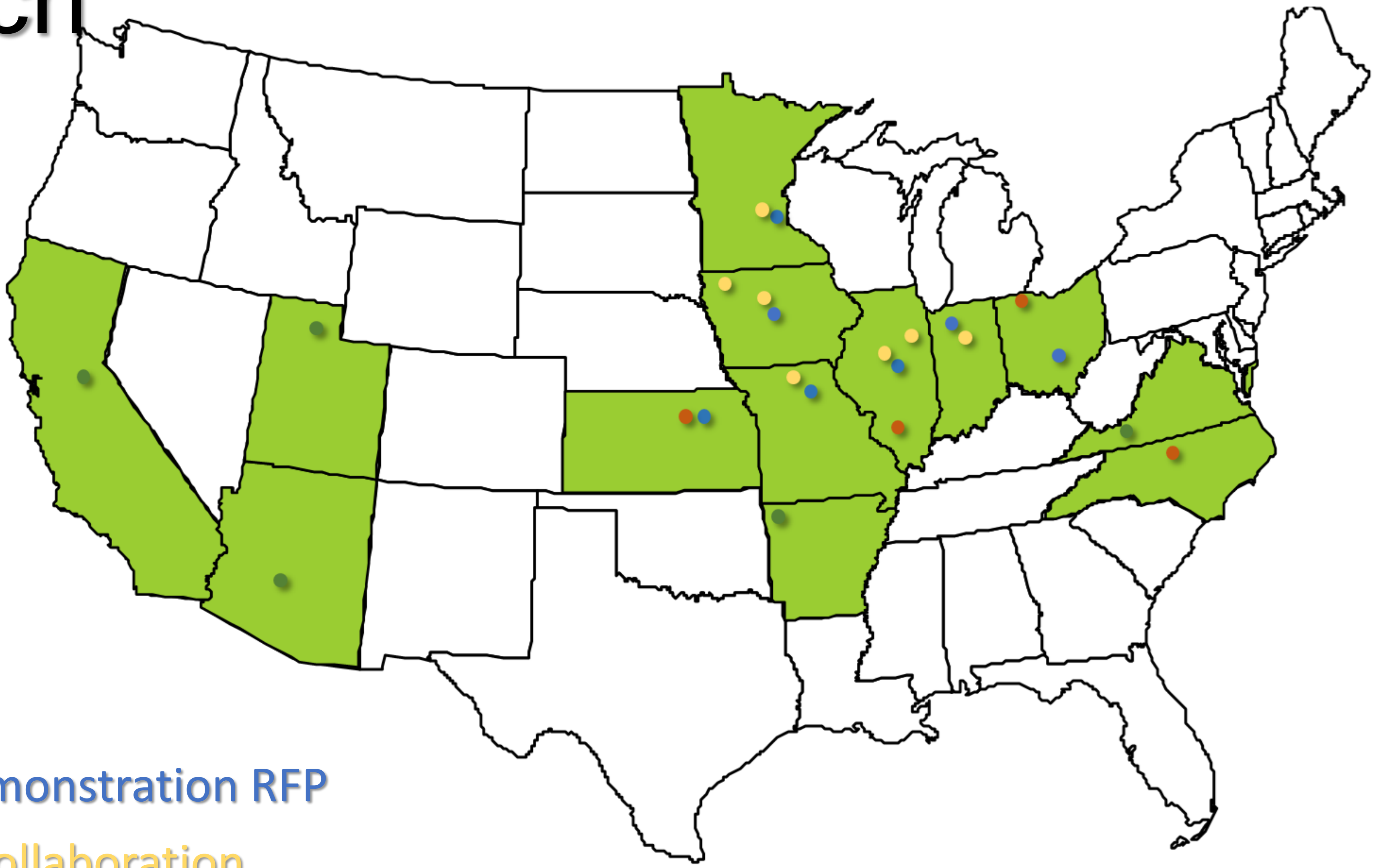
4R Research Fund



2013 Meta-analyses RFP

2013 4R Research and Demonstration RFP

2017 NutriNet five-state collaboration

2019 4R Research Awarded Projects

Phosphorus - Happy 350th!

Phosphoric Acid Determinations in Samples of Barley Soils from Hoos Field, Rothamsted.

Manure applied every year since 1852 (for quantities see pages 143 and 144).	Percentage of P_2O_5 in fine soil, calculated on dry state.	
	Total P_2O_5.	P_2O_5 *dissolved by 1 per cent. solution of citric acid.*
1 O. No manure	0·099	*0·0055*
2 O. Superphosphate	0·182	*0·0463*
3 O. Potash, &c. (no phosphates)	0·121	*0·0100*
4 O. Superphosphate, potash, &c.	0·189	*0·0538*
1 A. Ammonia salts	0·097	*0·0060*
2 A. Ditto and superphosphate	0·173	*0·0425*
3 A. Ditto, and potash, &c. (no phosphate)	0·102	*0·0084*
4 A. Ditto, superphosphate, and potash, &c.	0·182	*0·0500*

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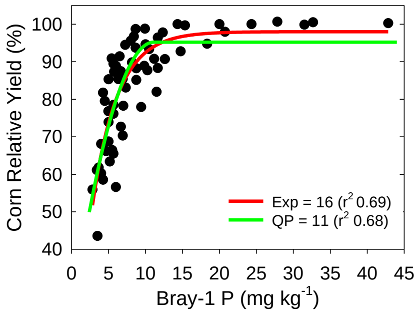
Dyer, Bernard. "VI.—A chemical Study of the phosphoric Acid and potash contents of the wheat Soils of broadbalk rothamsted." *Philosophical Transactions of the Royal Society of London. Series B, Containing Papers of a Biological Character* 194, no. 194-206 (1901): 235-290.

Today’s Discussion

- Phosphorus complexities in soil



- Management effects on soil and crop response to P

- Managing P within a system

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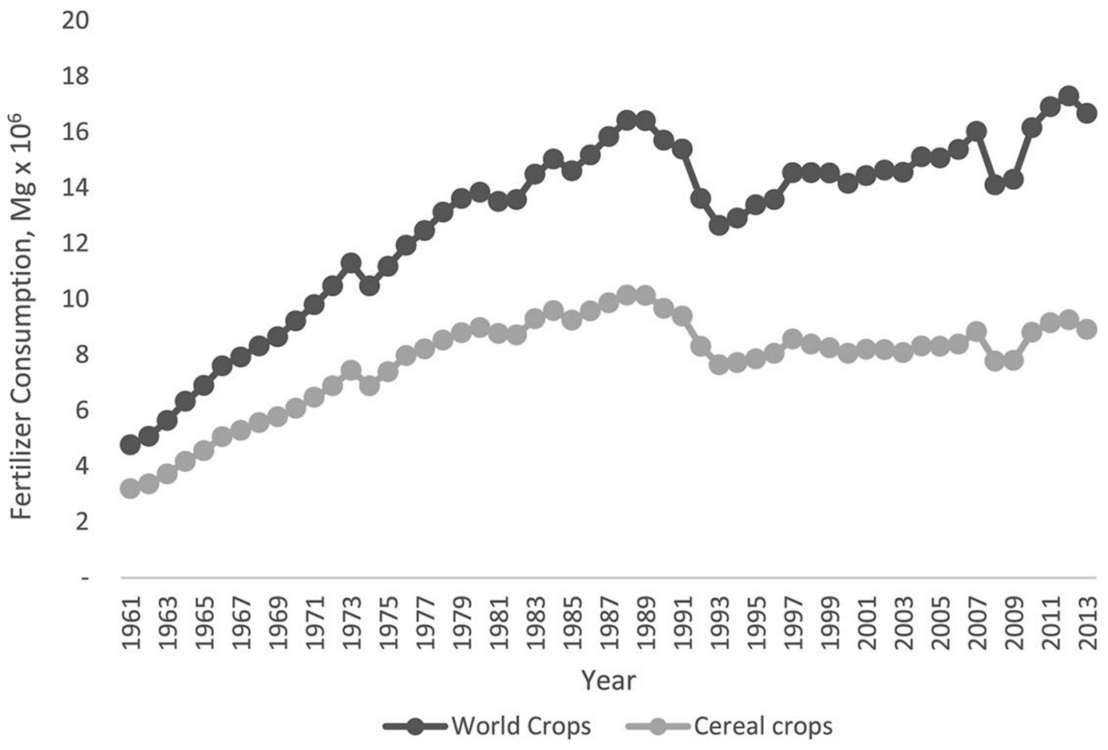
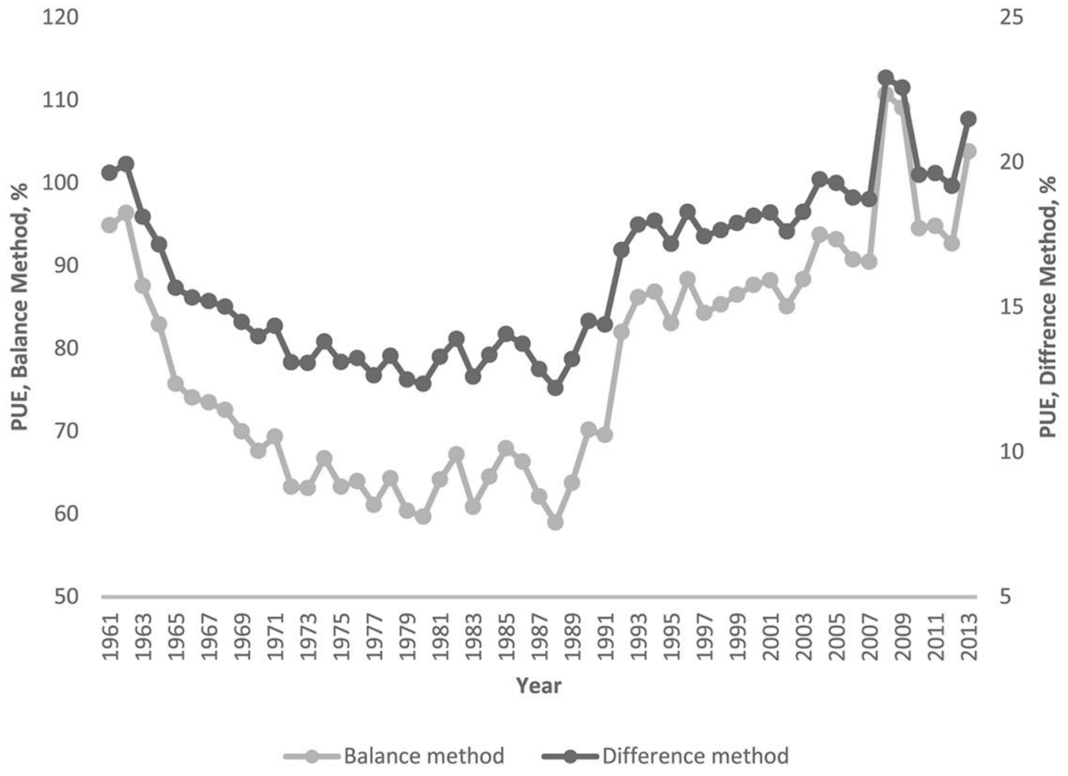
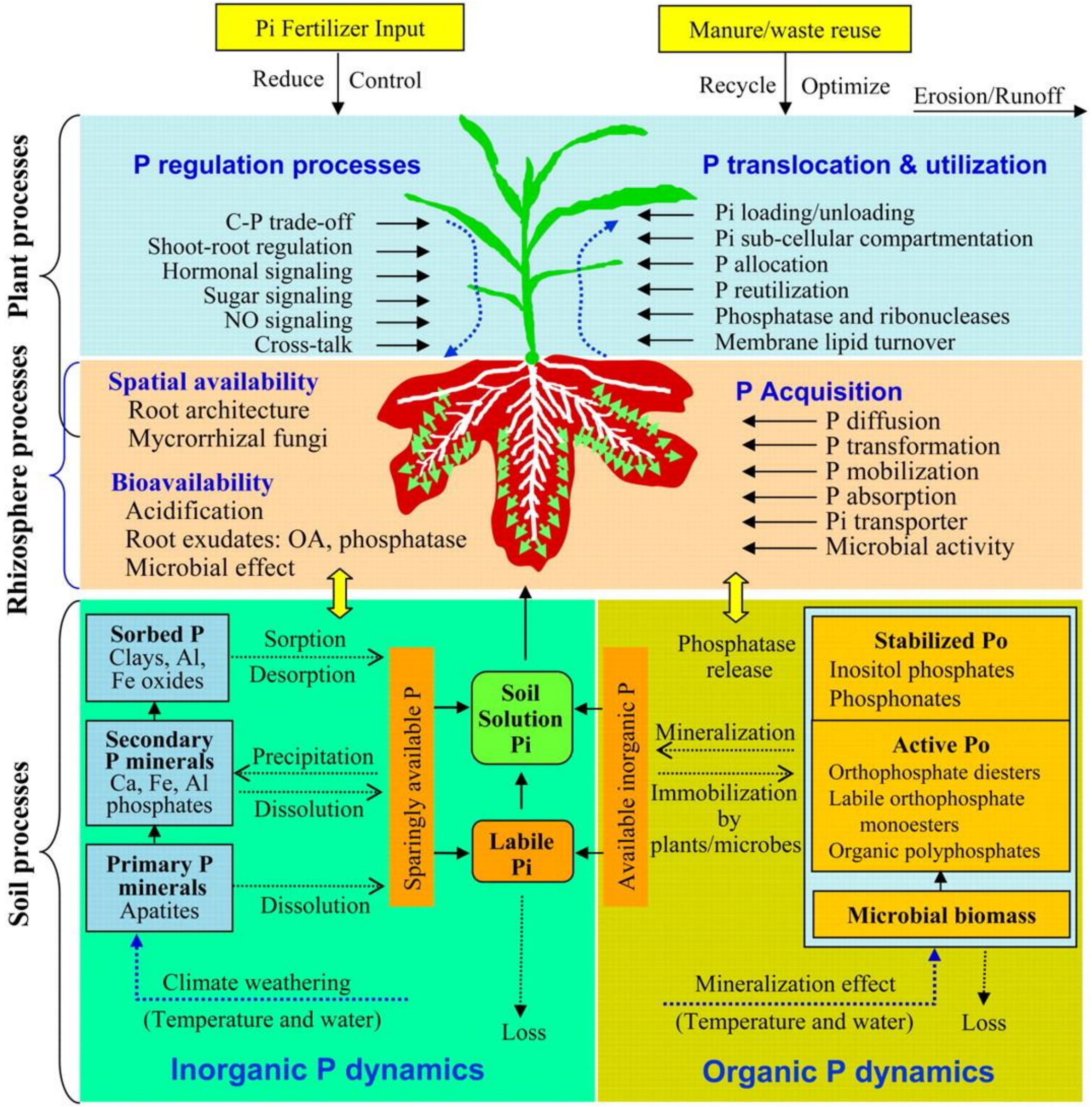
Phosphorus as a crop input…





Dhillon, J., G. Torres, E. Driver, B. Figueiredo, and W. R. Raun. 2017. World Phosphorus Use Efficiency in Cereal Crops. Agron. J. 109:1670-1677. doi:10.2134/agronj2016.08.0483

Soil Phosphorus



Shen, Jianbo, Lixing Yuan, Junling Zhang, Haigang Li, Zhaohai Bai, Xinping Chen, Weifeng Zhang, and Fusuo Zhang. "Phosphorus dynamics: from soil to plant." *Plant physiology* 156, no. 3 (2011): 997-1005.

Phosphorus Losses

- Tradeoffs with erosion (particulate P) & soluble P loss prevention
- Efficient agronomic P use = less P susceptible to losses
- Watershed, field, and subfield variability cause difficulties

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Phosphorus Losses

- Erosion and tile drainage provide main mechanisms in Iowa
- Dissolved P
  - Important short-term effect on water quality
  - High proportion in tile drainage
  - Amount in surface runoff is variable
- Particulate P (sediment-bound)
  - Long-term effect on water quality
  - Source for "legacy" P
- Different management systems will lead to varying proportions of each

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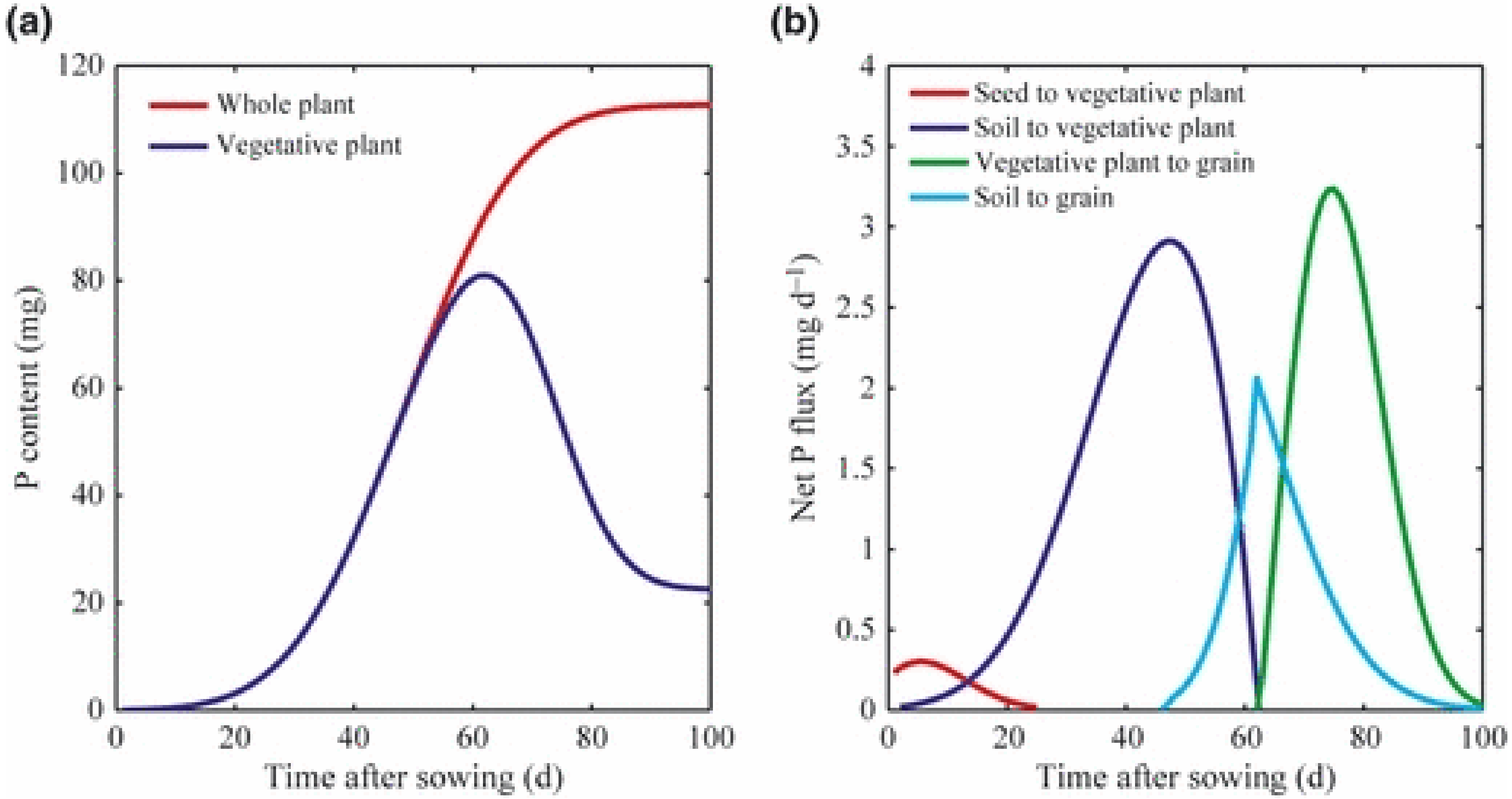
Phosphorus Uptake & Partitioning



Veneklaas, Erik J., Hans Lambers, Jason Bragg, Patrick M. Finnegan, Catherine E. Lovelock, William C. Plaxton, Charles A. Price et al. "Opportunities for improving phosphorus-use efficiency in crop plants." *New Phytologist* 195, no. 2 (2012): 306-320.

Phosphorus Removal

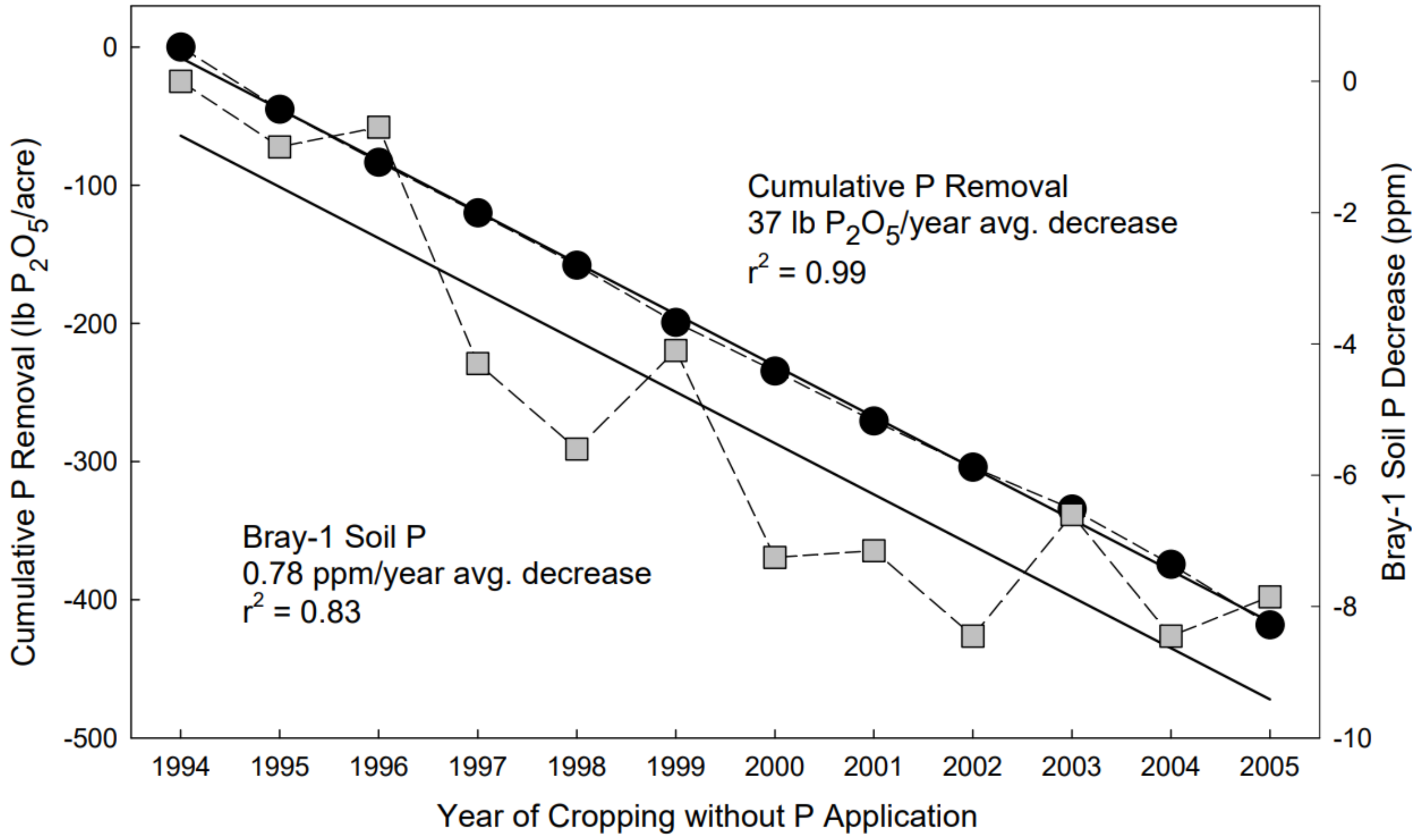
- Crop removal for N, P, and K doesn't increase equally with yield
- Grain content & yield dictate P removal

Table 2. Nutrient concentrations to calculate removal amounts of P_2O_5 and K_2O in the optimum soil-test category.

Crop †	Unit of Yield and Moisture Basis	Pounds per Unit of Yield ‡	
		P_2O_5	K_2O
Corn	bushel, 15%	0.32	0.22
Corn silage	bushel grain equiv., 15%	0.44	1.10
Corn silage	ton, 65%	3.5	9.0
Corn stover	ton, 15%	4.8	18
Soybean	bushel, 13%	0.72	1.2
Soybean residue	ton, 10%	4.7	23
Oat	bushel, 13%	0.29	0.19
Oat straw	ton, 10%	6.4	36
Wheat	bushel, 12%	0.55	0.27
Wheat straw	ton, 10%	3.7	23
Sunflower	100 pounds, 10%	0.75	0.65
Alfalfa, alfalfa-grass	ton, 15%	13	43
Red clover-grass	ton, 15%	11	31
Trefoil-grass	ton, 15%	11	31
Smooth bromegrass	ton, 15%	7.9	41
Orchardgrass	ton, 15%	12	60
Tall fescue	ton, 15%	11	58
Timothy	ton, 15%	7.9	28
Perennial ryegrass	ton, 15%	11	30
Sorghum-sudan	ton, 15%	11	33
Switchgrass	ton, 15%	11	58
Reed canarygrass	ton, 15%	7.9	41

Mallarino, A. P., J. E. Sawyer, and S. K. Barnhart. "A general guide for crop nutrient and limestone recommendations in Iowa, Iowa state university extension and outreach, PM 1688." *Iowa State Univeristy (IOWA) pp* 18 (2013).

Phosphorus Removal



Mallarino, Antonio P. and Prater, Jacob, "Corn and Soybean Grain Yield, Phosphorus Removal, and Soil-Test Responses to Long-Term Phosphorus Fertilization Strategies" (2007). Proceedings of the Integrated Crop Management Conference. 35. https://lib.dr.iastate.edu/icm/2007/proceedings/35

Phosphorus Placement

- North Central Region studies have found little yield differences (Preston et. al, 2019; Mallarino et. al, 2018)
- Reductions in water quality impairment with subsurface banded P is common
- Different application, soil sampling, and tillage systems may need adjusted to reflect optimum P availability

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Phosphorus Placement

Table 1. Phosphorus placement and application rate effects on crop yield.

	Period	Tillage	Control	Broadcast 28	Broadcast 56	Broadcast 56x2 ‡	Planter band 28	Planter band 56
			Placement method and rate (lb P_2O_5/acre)†					
			------------------ Corn yield (bu/ac) ------------------					
High STP	1994-2016	Chisel	186b	188ab	190a	190a	188ab	189ab
		No-till	175b	180a	181a	181a	179ab	181a
Optimum/Low STP	2013-2016	Chisel	206b	214ab	217a	217a	212ab	219a
		No-till	188b	199a	207a	204a	205a	205a
			------------------ Soybean yield (bu/ac) ------------------					
High STP	1994-2016	Chisel	58.7b	60.2ab	60.4a	60.2ab	60.0ab	60.4a
		No-till	58.9a	59.4a	59.1a	59.4a	59.3a	59.3a
Optimum/Low STP	2013-2016	Chisel	58.5b	62.5a	62.0ab	60.7ab	59.1ab	61.4ab
		No-till	61.6c	63.5abc	65.3a	63.0abc	65.1ab	62.7bc

†Yield values in a row followed by the same letter(s) do not differ ($P \leq 0.05$).
‡56x2, twice the annual 56 lb-rate applied once for the 2-year rotation before corn or soybean.

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Mallarino, Antonio, and Kenneth Pecinovsky. "Phosphorus and Potassium Placement for Corn and Soybean Managed with Tillage or No-Tillage." *Farm Progress Reports* 2016, no. 1 (2017): 76.

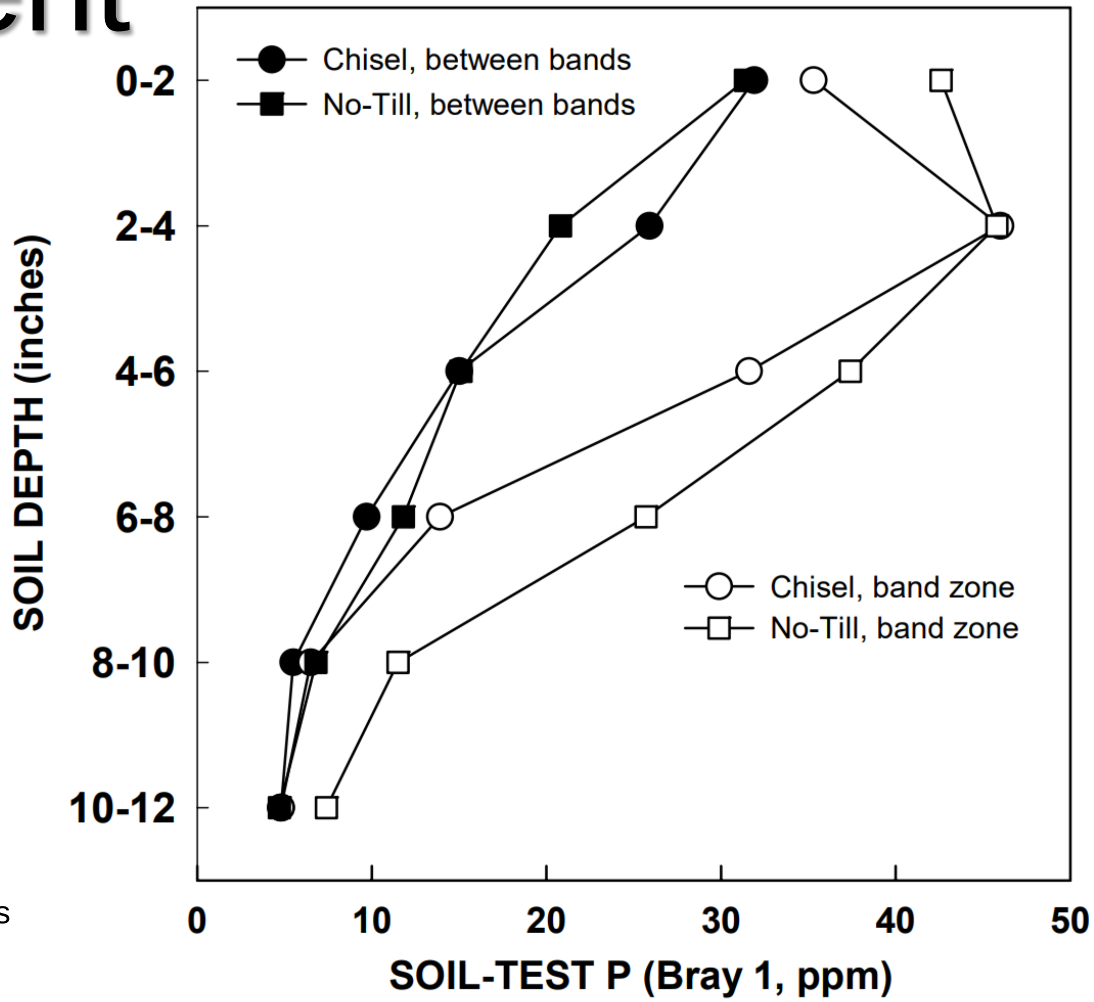
Phosphorus Placement

Responses to starter fertilizer (NPK or NP)

Location	Reference	Response frequency	Response
Illinois	Ritchie et al. (1996)	8 of 9 trials	14 bu/acre average
Iowa	Buah et al. (1999)	7 of 9 trials	4 to 18 bu/acre
Iowa	Bermudez & Mallarino (2002)	5 of 7 trials ‡	2 to 8 bu/acre ‡
Iowa	Mallarino (2003)	3 of 8 trials	5 bu/acre average
Iowa	Kaiser et al. (2005)	1 of 2 ‡	15 bu/acre ‡
Missouri	Scharf (1999)	6 of 6 trials	13 bu/acre average
Wisconsin	Bundy & Widen (1992)	8 of 12 trials	15 bu/acre average

† Soils tested medium, optimum, or higher in P and K according to local interpretations

Bundy, Larry G., Hubert Tunney, and Ardell D. Halvorson. "Agronomic aspects of phosphorus management." *Phosphorus: Agriculture and the environment* 46 (2005): 683-727.



Mallarino, Antonio P., and Rogerio Borges. "Phosphorus and potassium distribution in soil following long-term deep-band fertilization in different tillage systems." *Soil Science Society of America Journal* 70, no. 2 (2006): 702-707.

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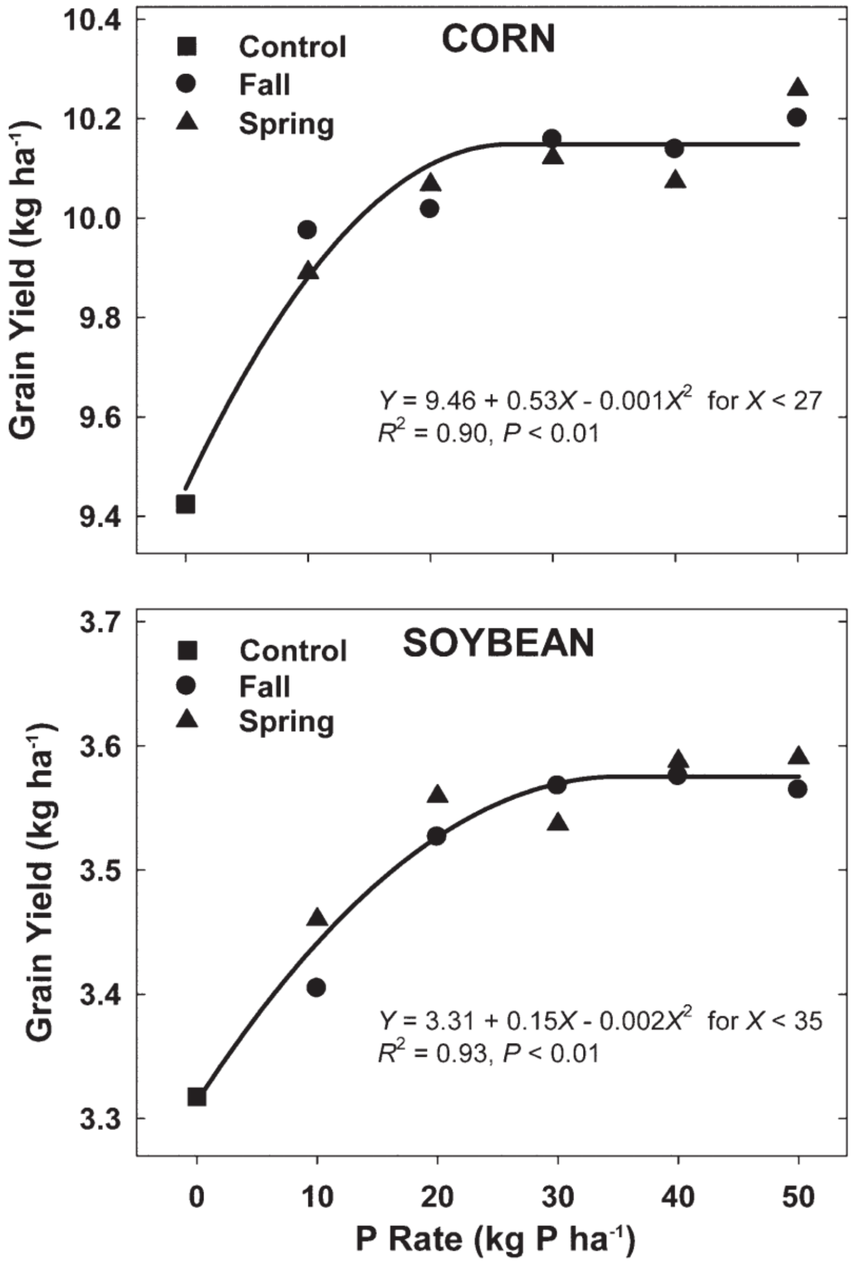
Application Timing

- Broadcasting fall vs spring P showed no yield differences in Iowa.
- Potential of runoff loss & spring logistics



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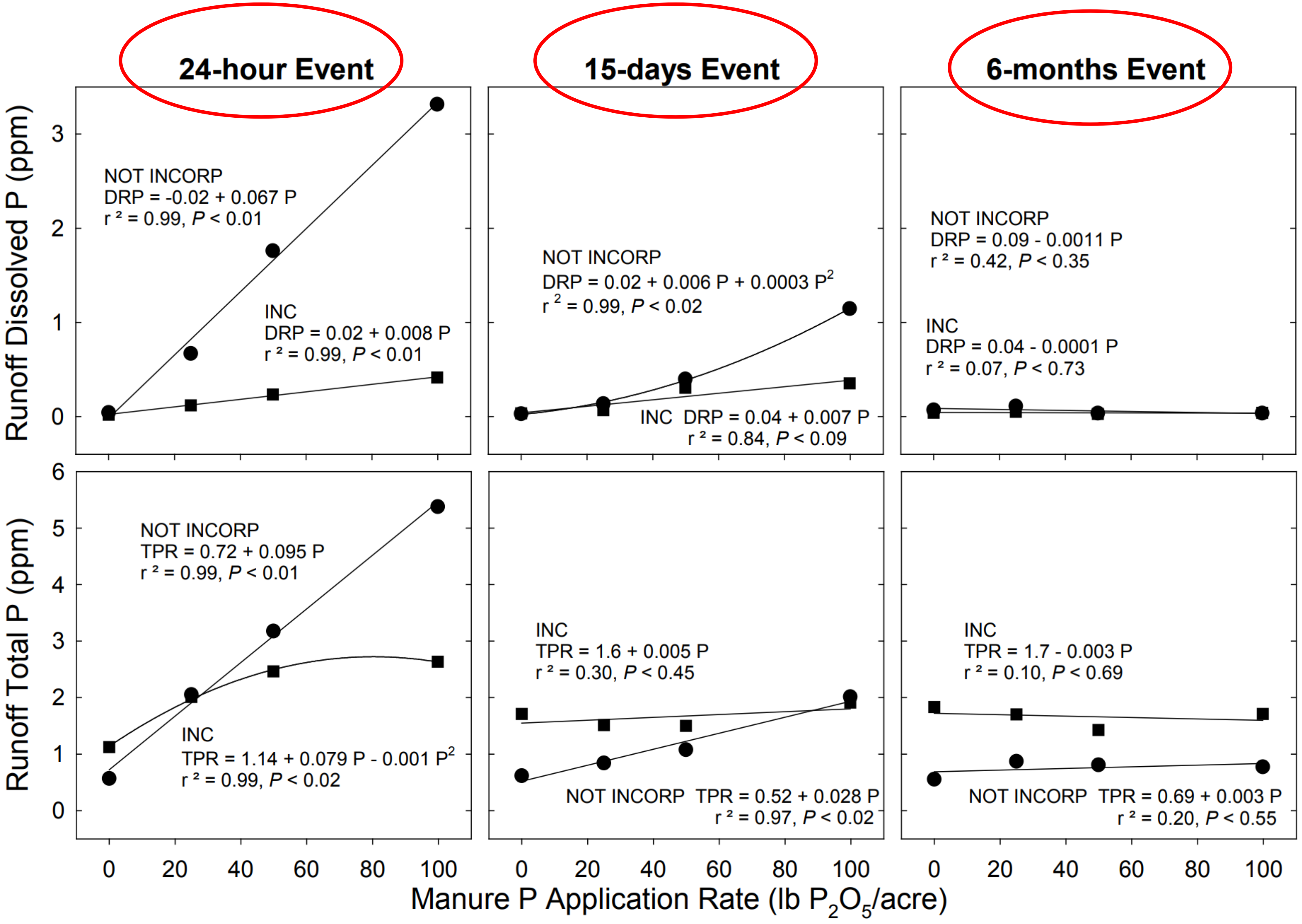
Mallarino, A. P., S. R. Barcos, J. R. Prater, and D. J. Wittry. 2009. Timing of Broadcast Phosphorus Fertilization for No-Till Corn and Soybean Research supported in part by the Iowa Soybean Association.. Soil Sci. Soc. Am. J. 73:2143-2150. doi:10.2136/sssaj2008.0383

Application Timing



Allen, B. L., and A. P. Mallarino. 2008. Effect of Liquid Swine Manure Rate, Incorporation, and Timing of Rainfall on Phosphorus Loss with Surface Runoff. J. Environ. Qual. 37:125-137. doi:10.2134/jeq2007.0125

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Soil health phosphorus tests

- Concepts based in microbial influence on P
- "availability factors" applied to routine tests (mineralization or residue decomposition)
- Amount extracted has been correlated
- Crop response has been field-calibrated
- Ability to detect sufficiency ranges, but variable predictability compared to Bray-1, Mehlich-3, or Olsen

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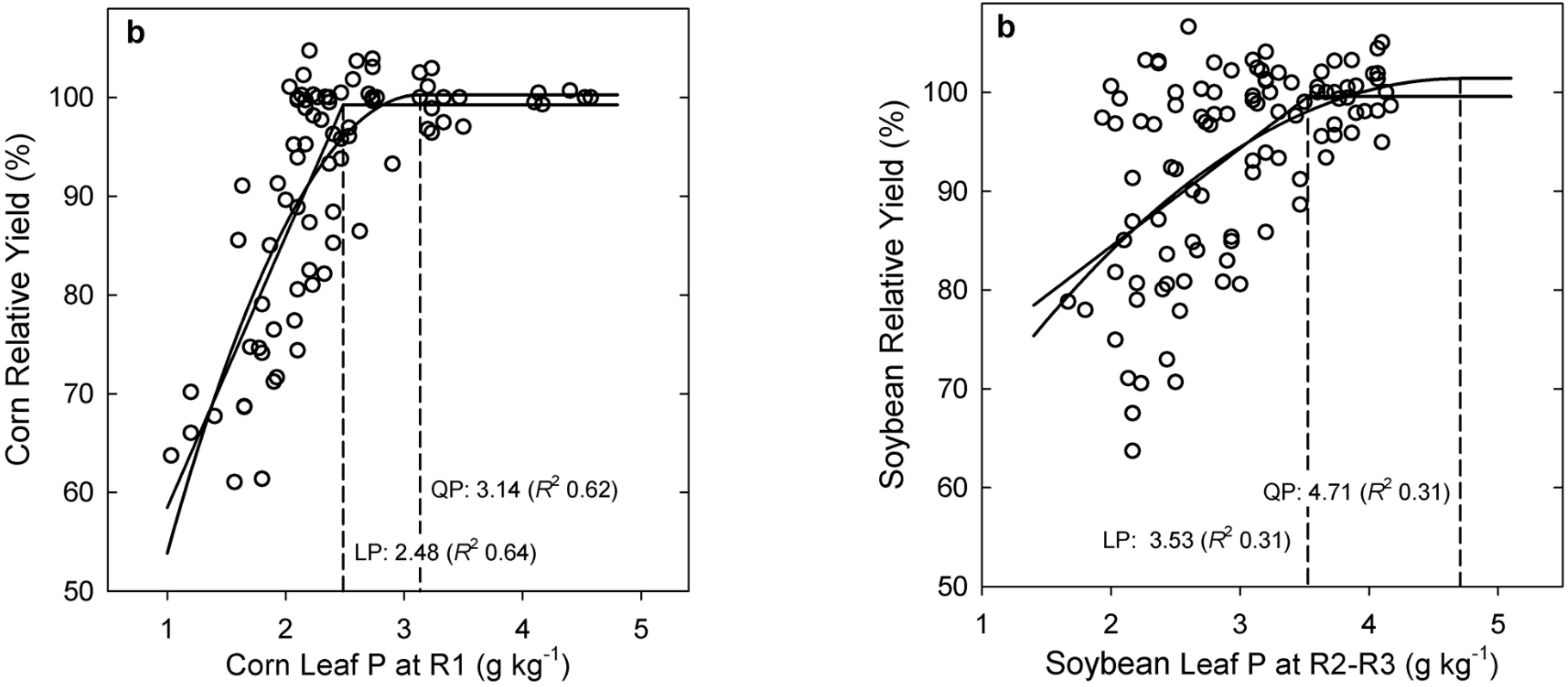
Tissue Sampling for Phosphorus

- Diagnosis vs Prescription
- Some disagreement on critical concentration and ideal sampling stage
- Importance of early season P supply may negate a V5 (corn) or (R1) soybean sample

IPNI, NutriFacts. No. 2

Tissue Sampling for Phosphorus



Stammer, Andrew J., and Antonio P. Mallarino. "Plant tissue analysis to assess phosphorus and potassium nutritional status of corn and soybean." *Soil Science Society of America Journal* 82, no. 1 (2018): 260-270.

The value of a trend…

- Long-term phosphorus rate, tillage, & placement trials determined many of the recommendation systems in the North Central Region
- Difficult for replicated research to capture all P management options, especially with long-term studies
- Will soil sampling every 3 to 4 years catch annual fluctuations?

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Practical Considerations

- Fertilizer placement, tillage, and previous crop effects
- Balance the choice of tillage operation and P fertilizer placement for specific landscape and environment
- Convenient and effective P fertilizer applications are prioritized
- Yield reductions not synonymous with reduced P loss

For comparison, IA Reduction Strategy…

- P reduction practices includes large variability
- Assessing confounding practices
- Practices are cumulative, not additive to reduce P loss

	Practice	Comments	% P Load Reduction[a]	% Corn Yield Change[b]
			Average (SD[c])	Average (SD[c])
Phosphorus Management Practices	Phosphorus Application	Applying P based on crop removal – Assuming optimal STP level and P incorporation	0.6[d]	0
		Soil-Test P – No P applied until STP drops to optimum or, when manure is applied, to levels indicated by the P Index[f]	17[e]	0
	Source of Phosphorus	Liquid swine, dairy, and poultry manure compared to commercial fertilizer – Runoff shortly after application	46 (45)	-1 (13)
		Beef manure compared to commercial fertilizer – Runoff shortly after application	46 (96)	
	Placement of Phosphorus	Broadcast incorporated within 1 week compared to no incorporation, same tillage	36 (27)	0
		With seed or knifed bands compared to surface application, no incorporation	24 (46)	0
	Cover Crops	Winter rye	29 (37)	-6 (7)
	Tillage	Conservation till – chisel plowing compared to moldboard plowing	33 (49)	0 (6)
		No till compared to chisel plowing	90 (17)	-6 (8)
Land Use Change	Perennial Vegetation	Energy Crops	34 (34)	
		Land Retirement (CRP)	75	
		Grazed pastures	59 (42)	
Erosion Control and Edge-of-Field Practices	Terraces		77 (19)	
	Buffers		58 (32)	
	Control	Sedimentation basins or ponds	85	

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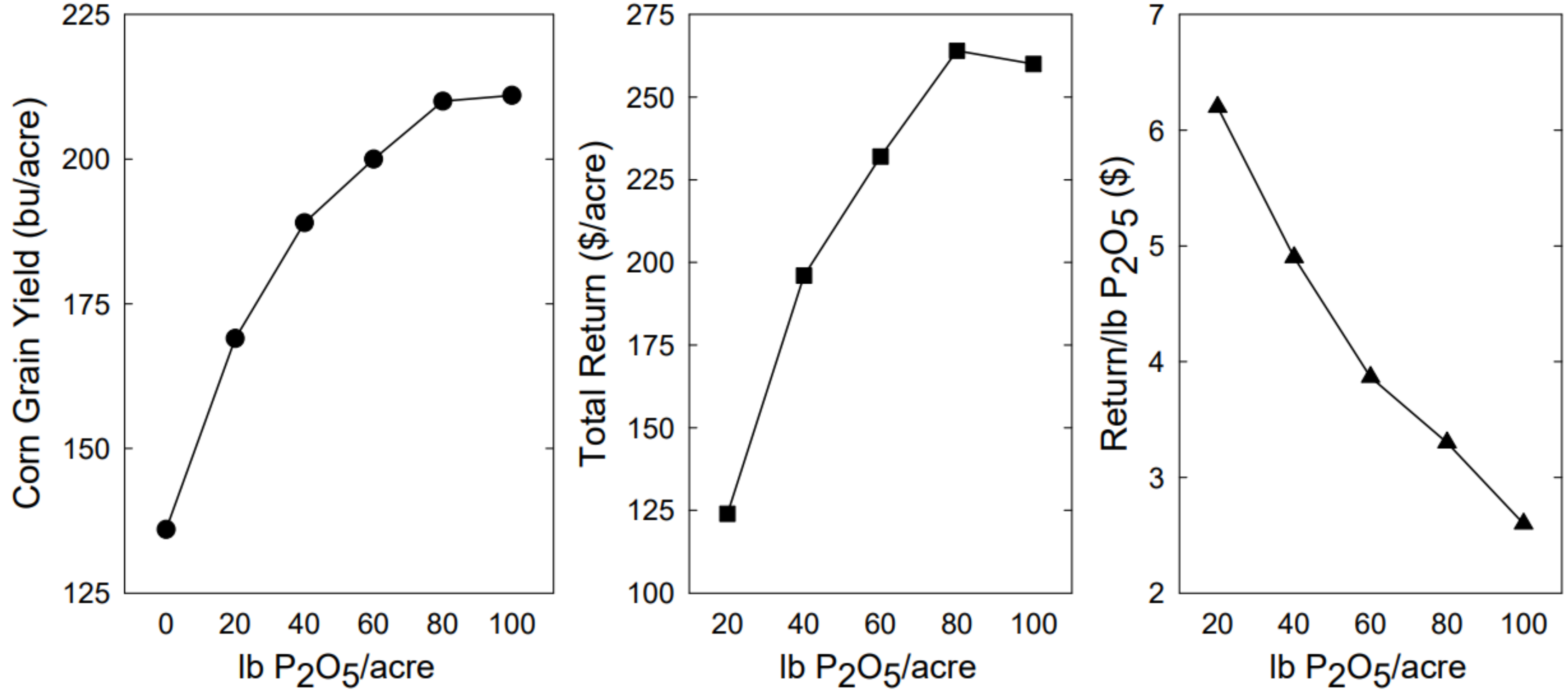
Changing P Management Strategy

- What constitutes an "improvement"?
- Combination of yield, loss reduction, and ROI?



*Assumes $4/bu corn & $0.40/lb P_2O_5

Mallarino, Antonio P. "Long term phosphorus studies and how they affect recommendation philosophies." In *North-Central Extension-Industry Soil Fertility Conf. Proceedings. Nov*, pp. 14-15. 2009.