Best Management Practices for Efficient Fertilization of Soybean in Lowland Soils

Nathan Slaton (nslaton@uark.edu)

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Discussion outline

- Arkansas USA production system traits
- Keys to successful soybean production on poorly drained soils
- Molybdenum, boron & pH
- Nodulation & N fixation
- Lime in the rice:soybean rotation
- P & K management
- Chloride management
- Summary

Arkansas Soybean Production

- 1.3 million ha
- 80-85% irrigated
  - Furrow irrigated
  - Flood irrigated
  - Center-pivot irrigated
- Most common rotation crop is flood-irrigated rice on poorly drained soils
- Soils <10 - 60% clay content with 1.0-2.5% organic matter
- Production systems
  - Early season (April)
  - **Full season (May)**
  - Double-crop following wheat (June planting)

Furrow-irrigated soybean on raised beds

Keys to successful production of soybean following rice

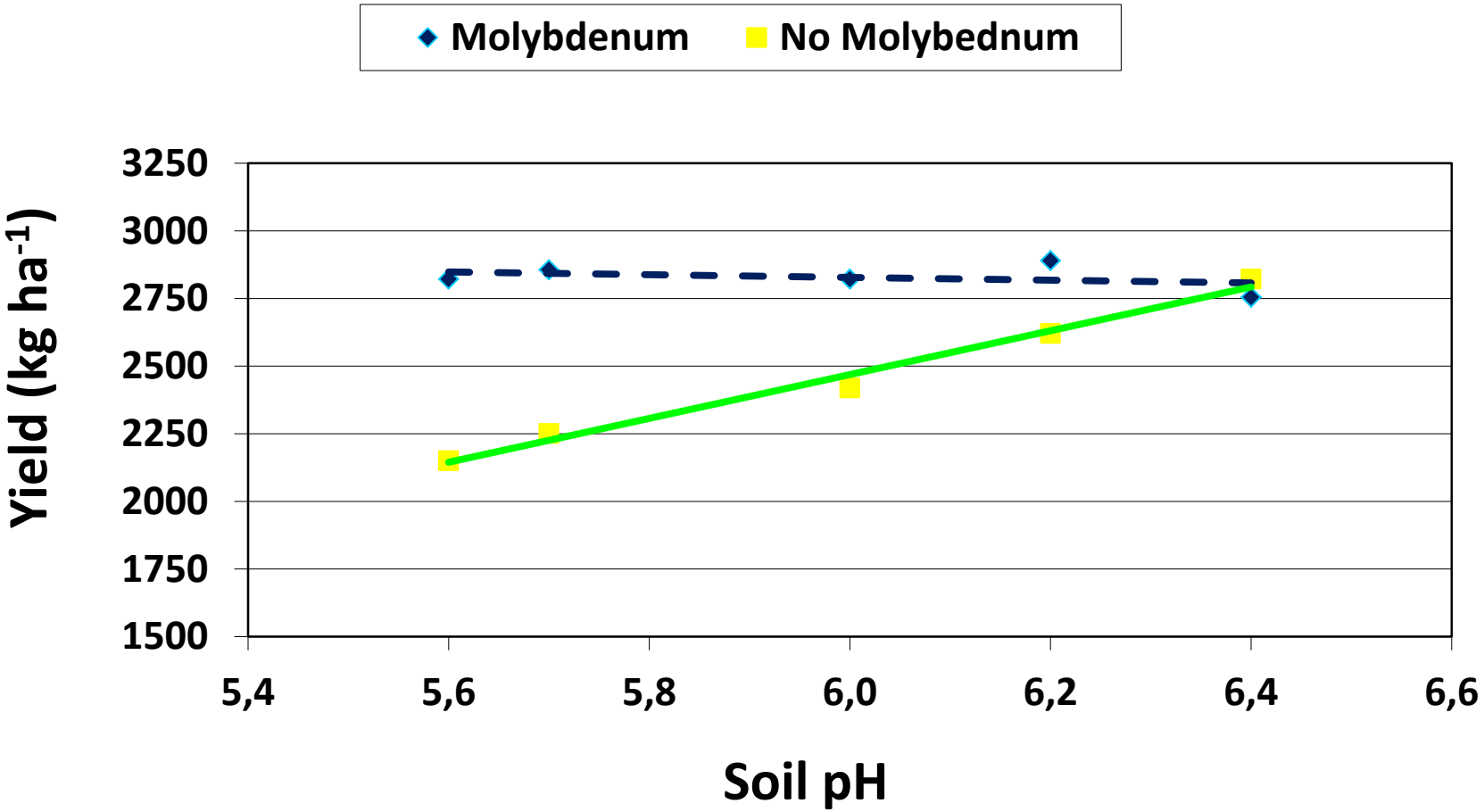
- **Need optimal soil pH**
  - Lime application to acidic soils
- **Surface drainage**
  - Beds and/or drain furrows
- **Irrigation and/or timely rainfall**
  - 80-85% ground water
  - 15-20% surface water
- **Variety selection**
- **Fertility**
  - Inoculate and apply Mo
  - P & K management
  - Micronutrients (Boron)
  - Chloride management

Boron deficiency of soybean near irrigation inlet following lime application

Observations on the production of soybean following rice (Arkansas, USA)

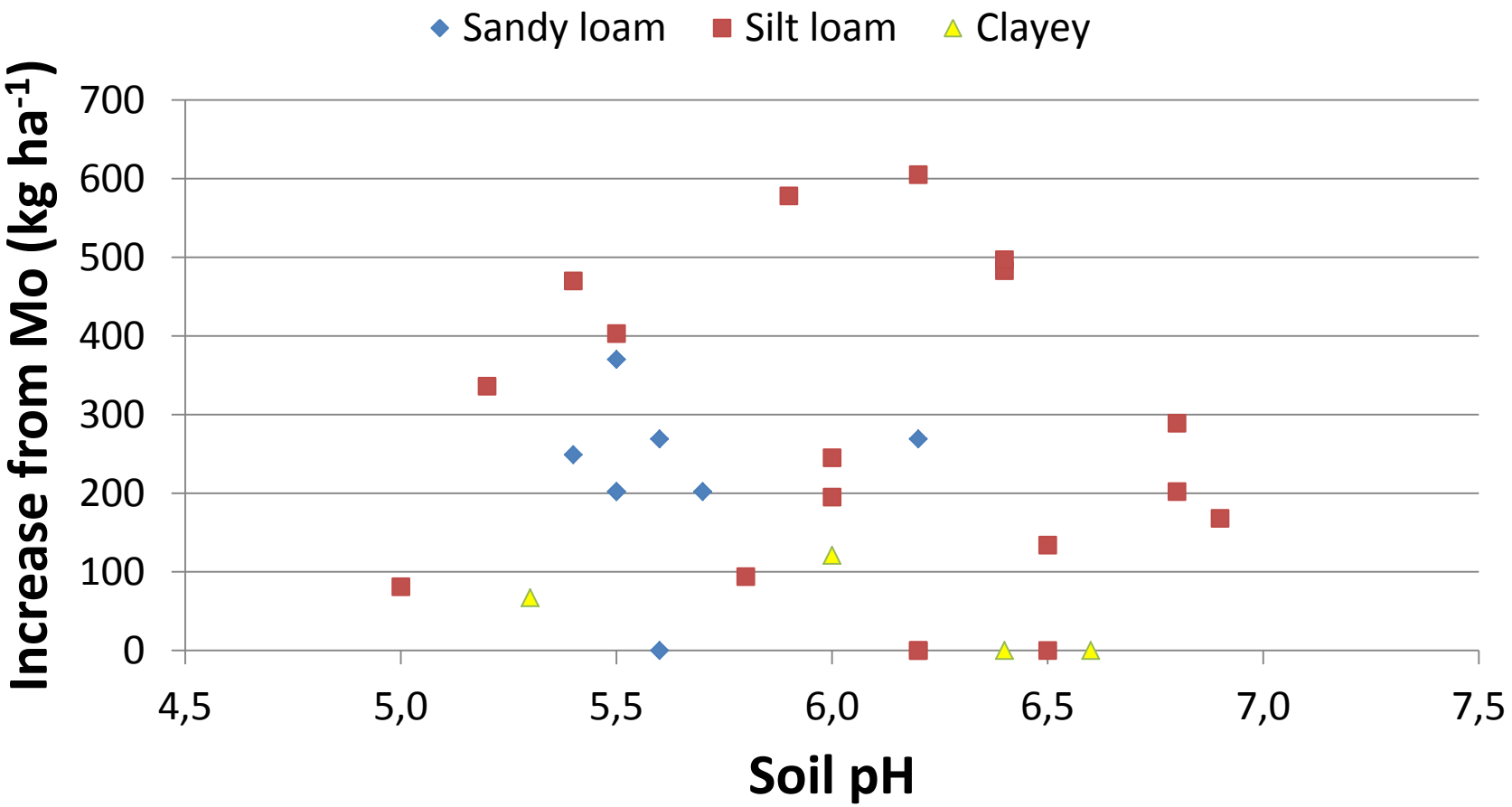
- Neutral to Alkaline soils
  - Infrequent response to P fertilization even when soil test P is Very Low
  - No problem with nodulation & N fixation
  - Some problems with micronutrient deficiencies
    - Boron deficiency is most common
- Acidic soils
  - Yields and vigor decrease rapidly when pH_{water} <5.5 on silt loam soils
    - Less influence of pH on clayey alluvial soils
  - Positive response to molybdenum
  - Benefit from P fertilization if pH is not too low!

Soybean response to molybdenum and soil pH



Source: Parker and Harris, 1962 (Agron. J., Univ. of Georgia)

Yield increase from molybdenum



Source: Arkansas Farm Research 1964-1966 13(1):2, 14(2):4, & 15(2):15

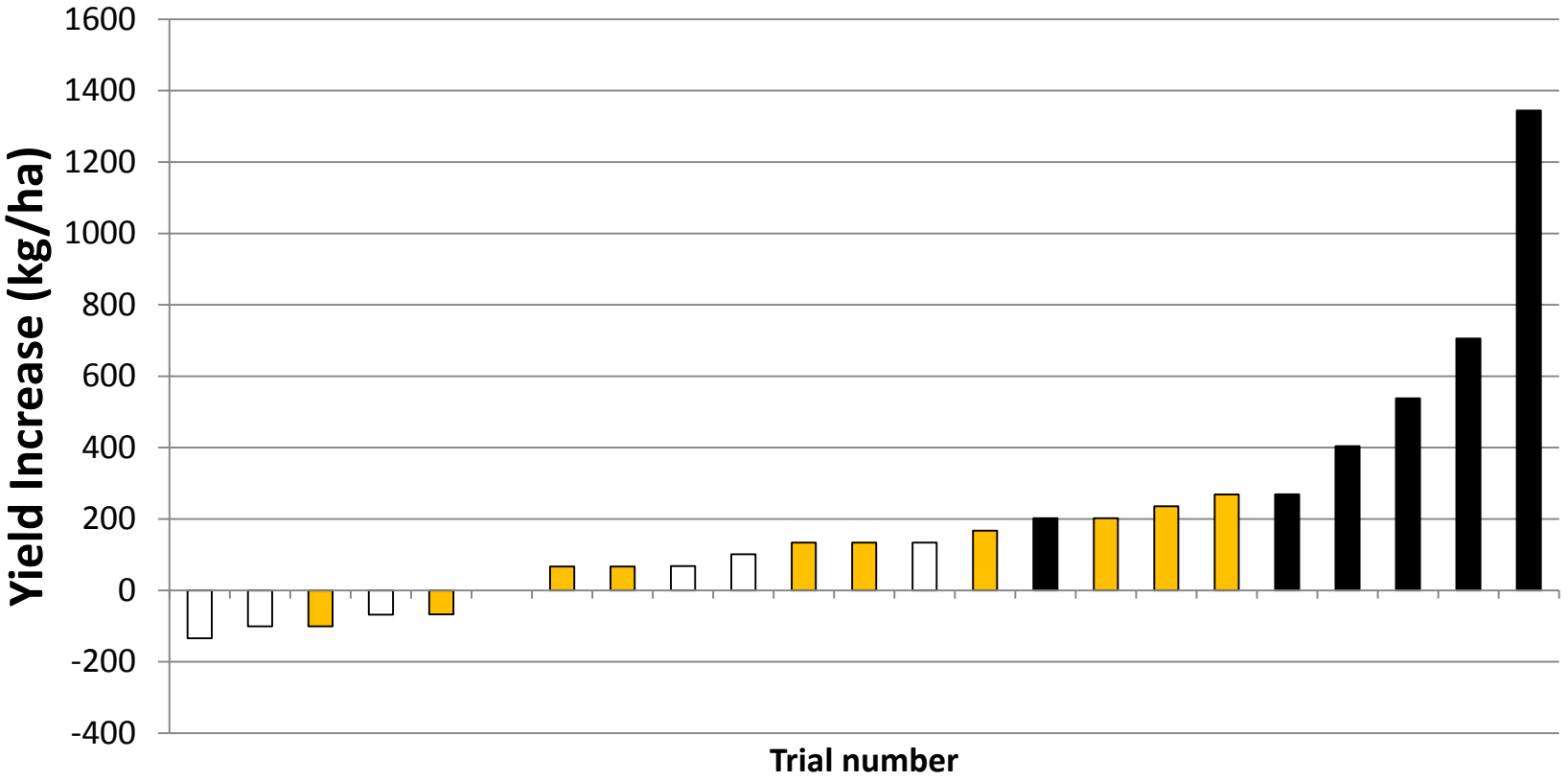
Lime application for rice-soybean rotation

- Use target pH of 6.0-6.2
- Monitor Zn status of soil
- Most common lime problems
  - Non-uniform distribution
  - Spatial variability in field

Zinc deficiency of rice on alkaline soil

- Lime application
  - Grid soil sample & use variable rate application
  - Apply lime rate in two separate applications following rice in the rotation
    - To reduce 'streaking' or enhance uniform application
    - Minimize chance of increasing pH too much
  - Soil sample ~1 year after first lime application to monitor pH change before making second application

Boron deficiency of irrigated soybean



Black bars represent sites with pH > 7.0 & statistically significant increase
Orange bars represent sites with pH >7.0 & no significant difference
White bars represent sites with pH <7.0 & no significant difference

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Nutrient requirement of soybean

Nutrient	Seed Content	Total Uptake
	4700 kg ha^{-1} yield	
N	330	430
P_2O_5	71	94
K_2O	121	200
S	16	36

Source: http://extension.agron.iastate.edu/soybean/production_soilfert.html

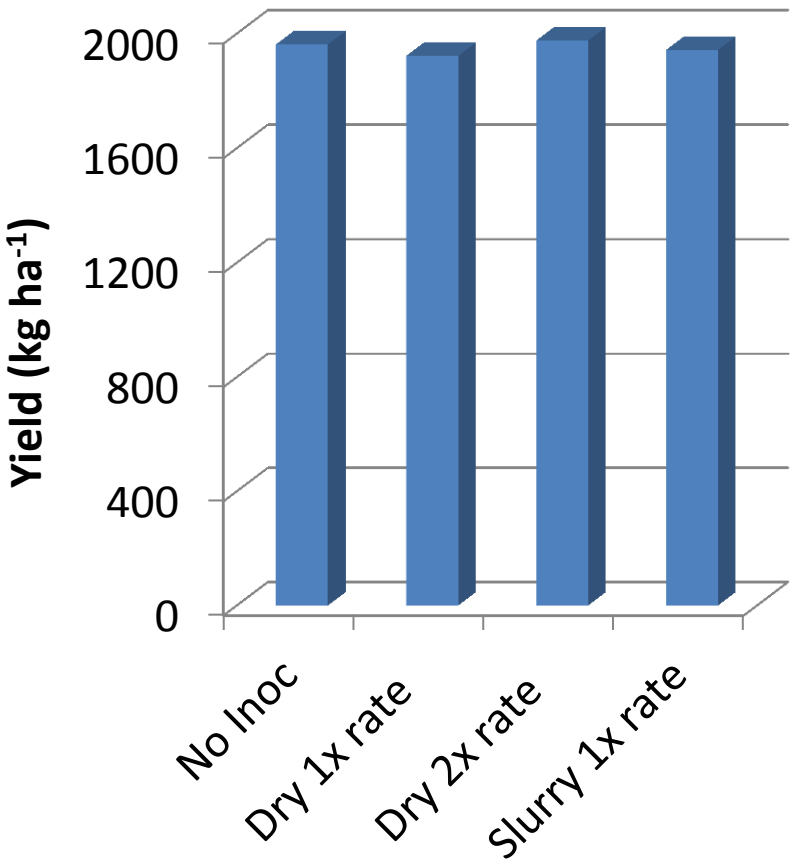
Inoculation of soybean seed

- **When to Inoculate soybean seed**
  - Sandy soils every year (Nebraska)
  - Inoculate if >3 to 5 years since last soybean crop
  - Add inoculum regularly on acid soils
  - Recently precision-graded soils
  - **Previously flooded fields (Wisconsin)**

Recommendations from multiple land-grant universities in the USA. From multiple sources.

Need for inoculation with Bradyrhizobium following rice?

- Stuttgart, AR trial
- Rotation
  - Soybean (1961) fb 2 years of rice (1962-63) fb soybean (1964)
- Dewitt silt loam, 6.8 pH
- No significant differences in seed yield, nodule number, or nodule weight



Arkansas Farm Research 15(6):12(Caviness, 1966)

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Factors influencing soybean nodulation

- Waterlogging or anoxic soil conditions are known to reduce N_2 fixation in soybean
  - Amarante and Sodek (2006)
  - Becanamwo and Purcell (1999)
- P nutrition plays a prominent role in nodulation (de Mooy and Pesek, 1966; Agron J 56:275-280)
- The effects of flooding/anoxic conditions, acidity, and organic acids on rhizobia may be additive (Osa-Afiana and Alexander, 1979; Agron J. 43:925-930)
- Prolonged anoxic conditions appear to be more damaging to soybean on acidic soils *(general observation in Arkansas)*

Poultry litter vs commercial fertilizer yield comparison (PK responsive sites)

Treatment	Average of 8 Trials	
	Low Rate	High Rate
	Yield (kg ha^{-1})	
No Fertilizer	4032	
N only	4166	3965
PK Fertilizer	4368	**4637**
NPK Fertilizer	4368	4435
Poultry Litter	**4502**	**4704**
LSD0.05	202 (compare Low vs High)	
LSD0.05	134 (compare to UTC)	

Source: Slaton et al. (2013, Agronomy Journal)

Is P or K more limiting to soybean yield?

- **Phosphorus**
  - Francisco (2013, Better Crops) showed both P & K limited soybean yield in Brazil and provided striking photos of positive soybean response to P
  - Below (Univ. of Illinois) suggested that P is a major yield limitation to soybean in Illinois/Midwest
    - http://cropphysiology.cropsci.illinois.edu/documents/2012%20Six%20Secrets%20of%20Soybean%20Success%20report.pdf
- **Potassium**
  - Soybean more responsive to K than P fertilization (Jones et al., 1977)
  - Generalization is true in Arkansas

Rice lodging & phosphorus
CL151 Variety (lodging prone variety)

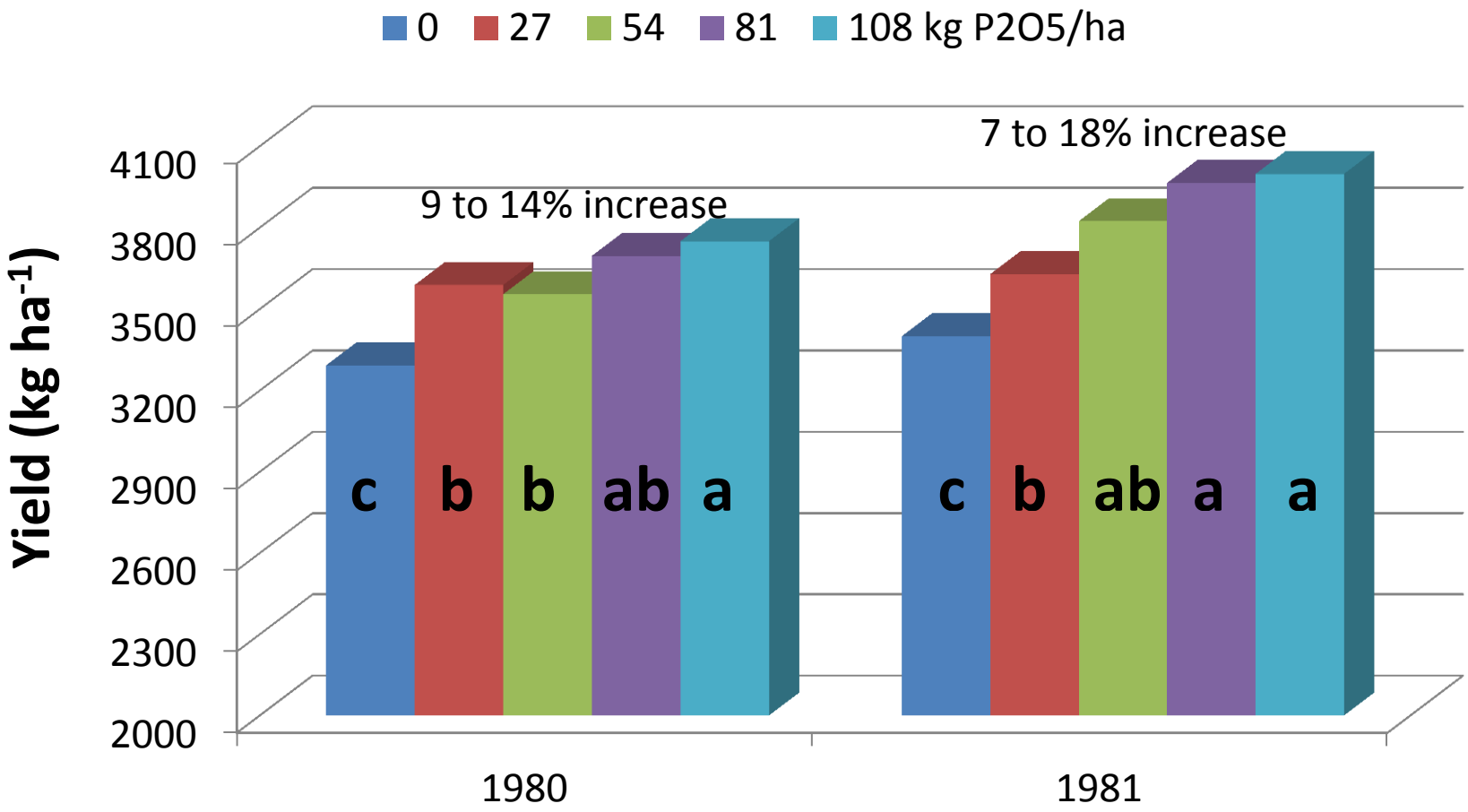
P-fertilizer rate	PTRS-2011†		PTRS-2012‡	
	Lodging	Grain Yield	Lodging	Grain Yield
kg P_2O_5 ha^{-1}	% lodged	kg ha^{-1}	% lodged	kg ha^{-1}
0	20	9425	1	9778
45 – 50	42	9022	15	9173
90 – 100	59	9122	9	8921
135	--	--	29	9374

Primarily a problem with lodging prone rice varieties/hybrids

2011: Calloway silt loam w/ soil test P (Mehlich-3) 6 ppm & soil pH 6.5
2012: Calloway silt loam w/ soil test P (Mehlich-3) 18 ppm & soil pH 7.4.

Unpublished data (Slaton)

Soybean response to P following flood-irrigated rice in rotation



Griffin and Brandon (1983, Field Crops Research Vol. 7)
Crowley silt loam, pH 6.8-7.1

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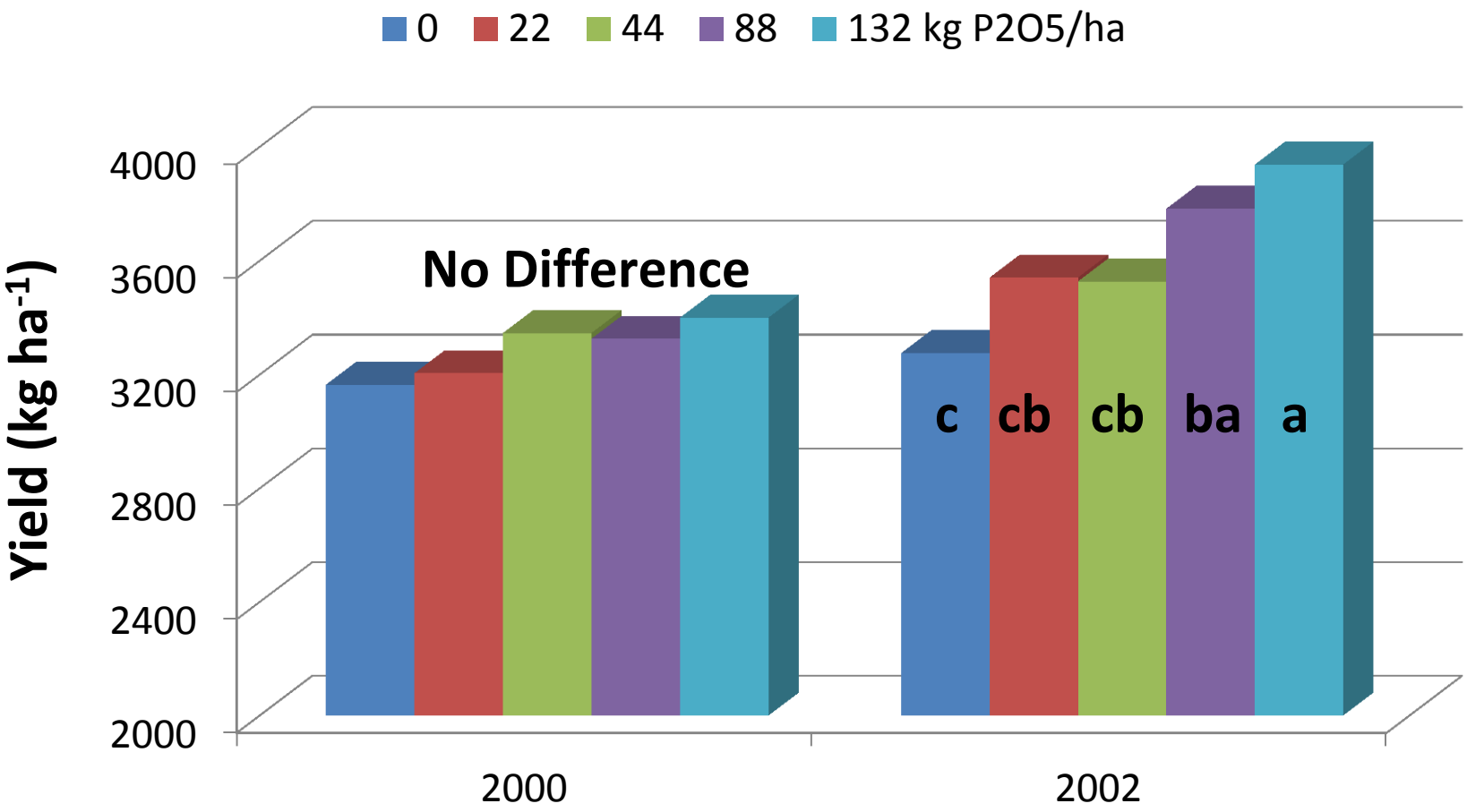
Soybean response to P Following rice
P rate effect



Dewitt silt loam pH 5.6 - 6.1
Averaged across application frequency

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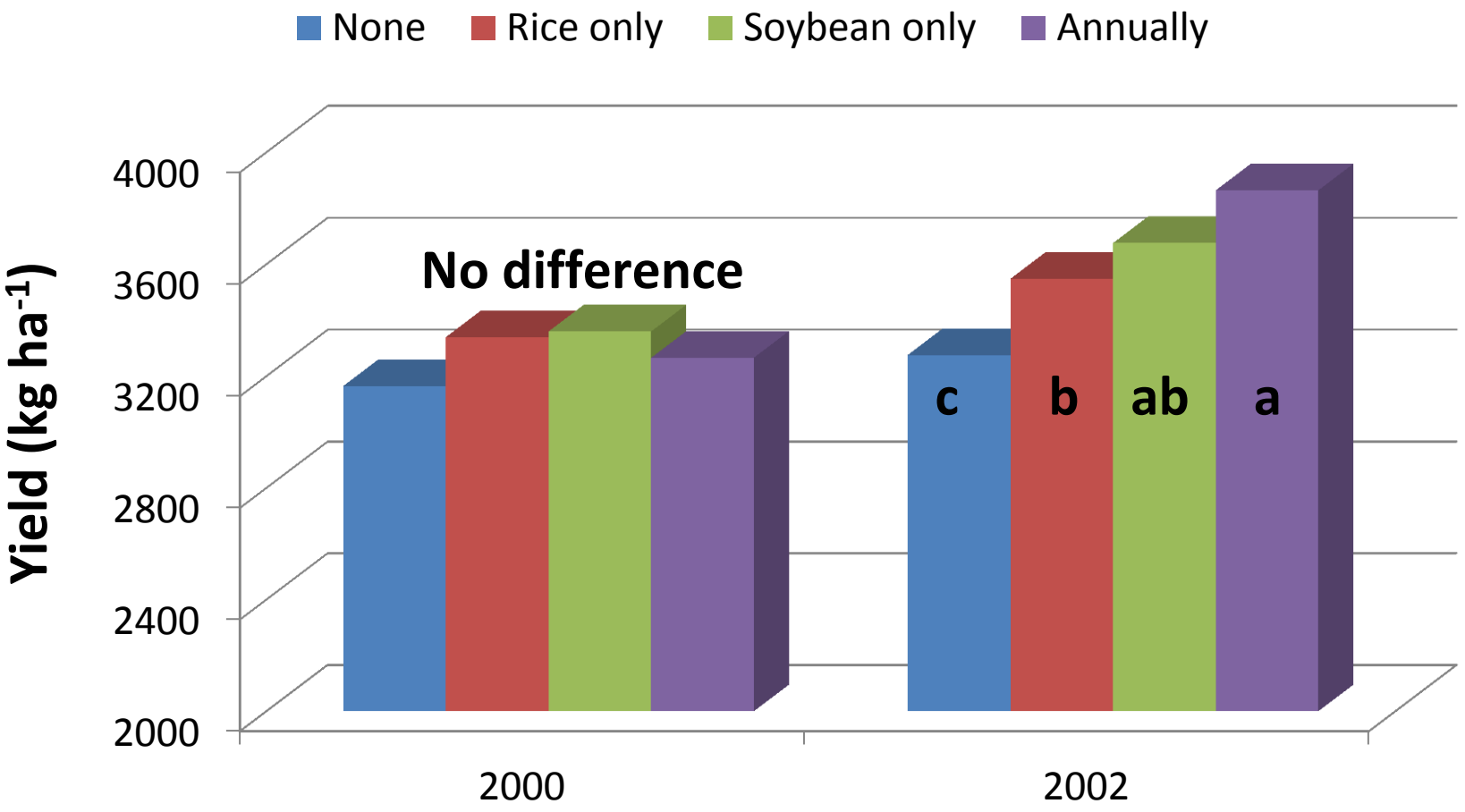
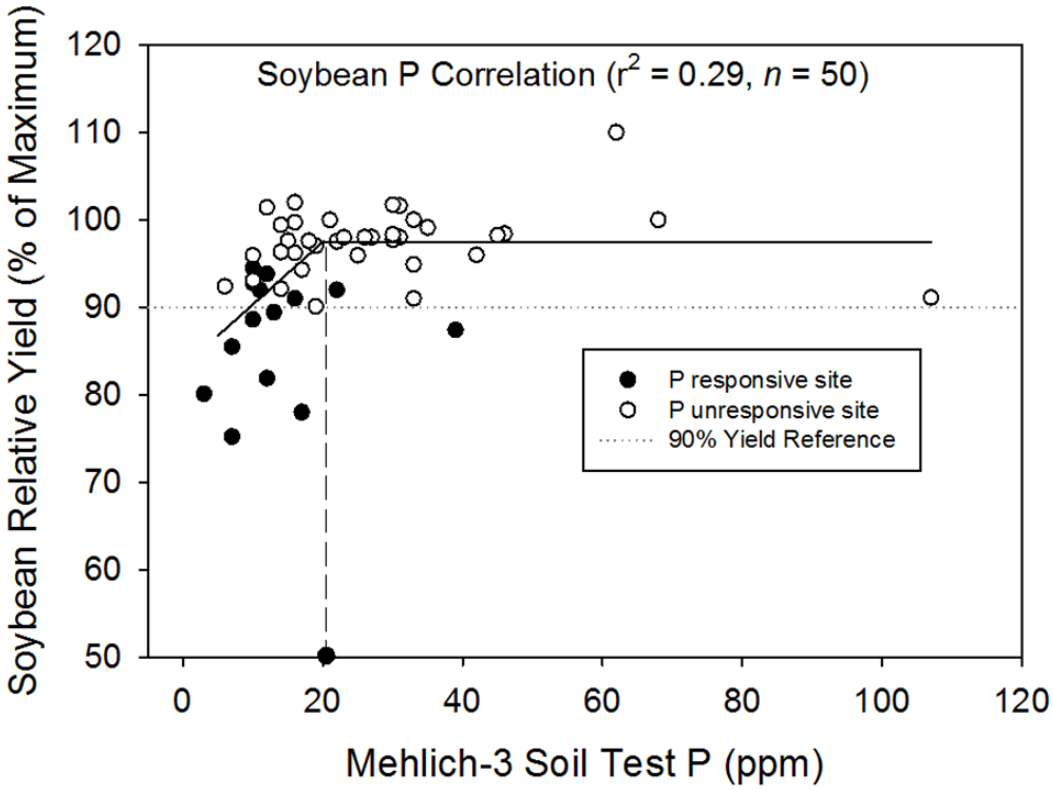
Soybean response to P following rice
Frequency of P application



Dewitt silt loam pH 5.6 - 6.1
Averaged across application rates

Soybean and P fertilization

- Arkansas research indicates that the critical Mehlich-3 soil test P value for soybean production is ~20 ppm (95% CI 13-27 ppm).



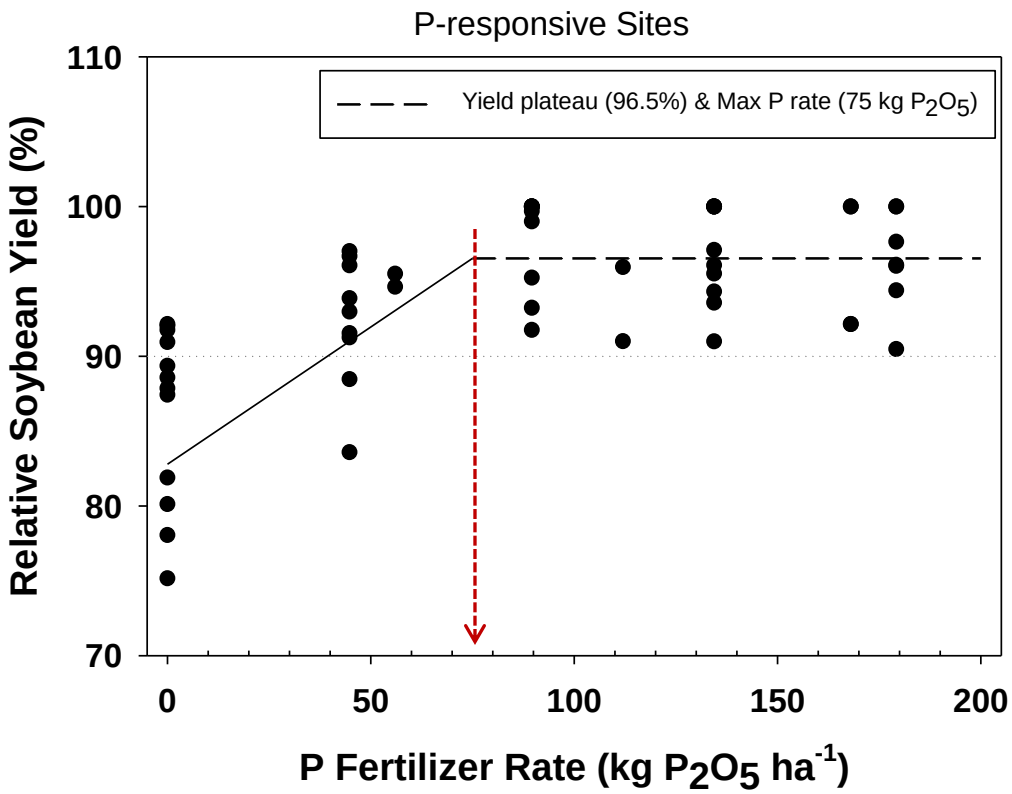
Soybean response to phosphorus

Soil Test Level	Soil Test P	Total Sites	Responsive	P Responsive Sites		Yield Loss	
				No P	Fertilized		
	ppm	#	%	- - - - - - - kg ha^{-1} - - - - - -			%
Very Low	≤15	18	56	3494	3965	471	12
Low	16-25	14	21	3562	4099	537	13
Medium	26-35	11	0	--	--	--	--
Optimum	36-50	4	25†	3629	4166	537	13
Above Optimum	≥51	3	0	--	--		--

Summary of soybean P correlation calibration research
Soil test P method is Mehlich-3
10 cm soil sample depth

Soybean and P fertilization

- Arkansas research suggests that on P responsive soils, soybean yield does not benefit from fertilizer rates > 75 kg P_2O_5 ha^{-1}



Soybean - P and K fertilization

Treatment Comparison	Treatment Comparison	Yield	P-value
		kg ha^{-1}	sdf contrast
1	No P or K vs	4207 b	0.0477
	K only	4435 a	
2	**K only vs**	**4435 a**	**0.0010**
	P only	**4086 b**	
3	**K only vs**	**4435 a**	**0.4517**
	Both P and K	**4502 a**	
4	No P or K vs	4207 a	0.2422
	P only	4086 a	

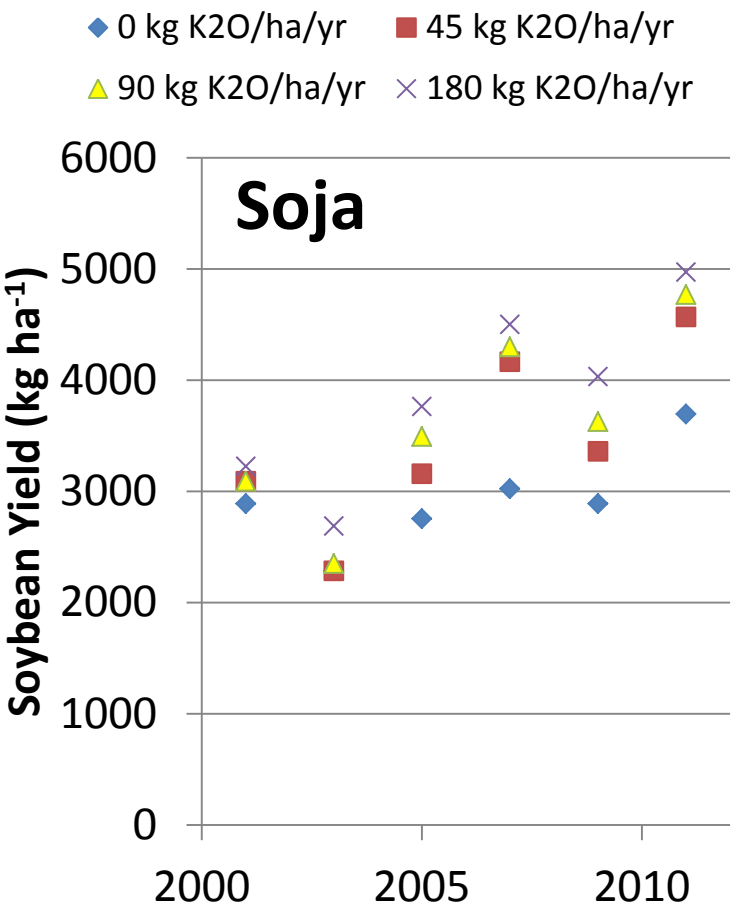
Calhoun silt loam
pH = 7.3 , Mehlich-3 P = 10 ppm& K = 71 ppm

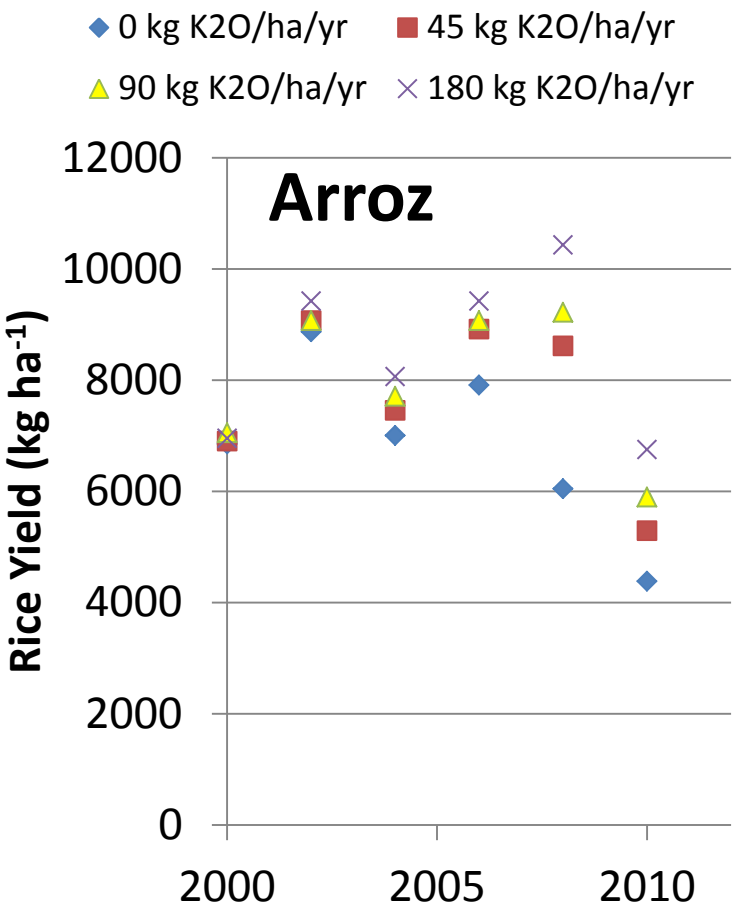
Soybean response to potassium

Soil Test Level	Soil Test K	Total Sites	Responsive	K Responsive Sites		Yield Loss	
				No K	Fertilized		
	ppm	#	%	- - - - - - - kg ha^{-1} - - - - - -			%
Very Low	≤60	4	100%	1949	3091	1142	37
Low	61-90	13	92%	2957	4032	1075	27
Medium	91-130	22	41%	3427	3965	538	14
Optimum	131-175	6	0	--	--	--	--
Above Optimum	≥176	2	0	--	--	--	--

Summary of soybean P correlation calibration research
Mehlich-3 soil test
10 cm soil sample depth

Yield response to annual potassium rate rice:soybean rotation





Source: N.A. Slaton (Calhoun silt loam, Pine Tree AES)

K Fertilization Decisions

Mehlich-3 Soil Test K	Rice			Soybean		
	Fertilizer rate, kg K_2O ha^{-1}			Fertilizer rate, kg K_2O ha^{-1}		
	0	45	90	0	45	90
ppm	% Yield Loss			% Yield Loss		
45	22	16	11	32	23	15
60	17	12	7	27	18	11
75	13	9	5	21	14	8
90	10	6		17	10	6
105	7			12	7	
120				9	5	
135				5		

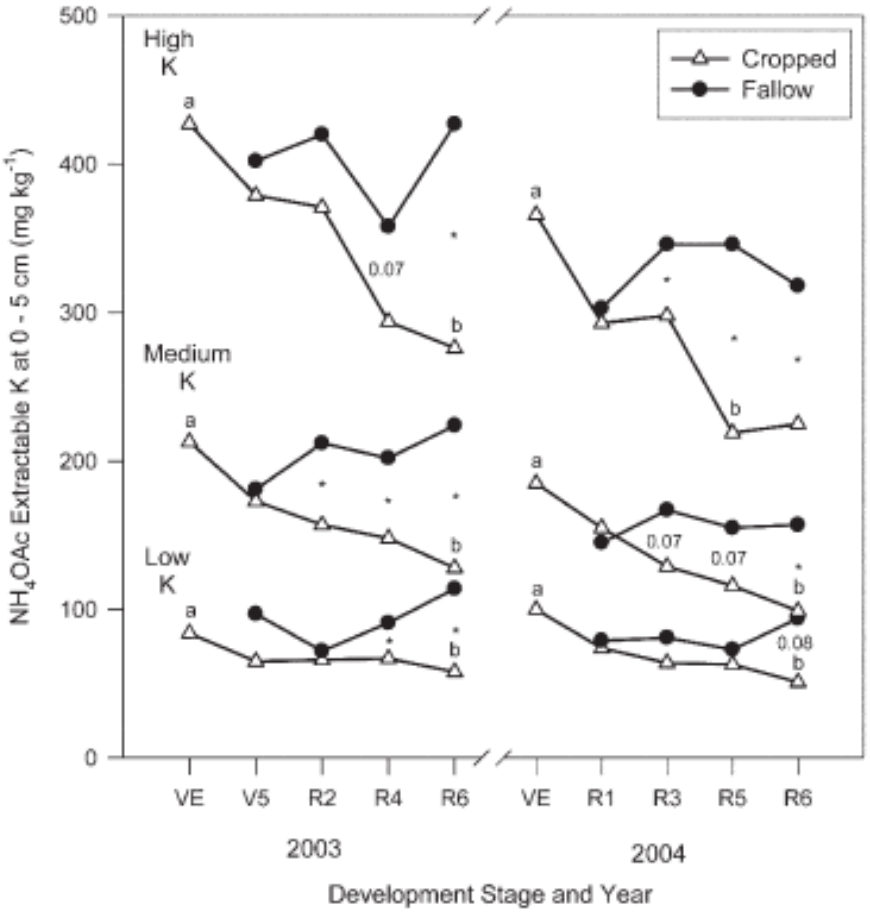
From Slaton et al. (2011) UACES Fact Sheet 2165

Soil testing issues in rice:soybean rotation

- Soil sample depth
  - What soil sample depth is most accurate?
- Field variability
  - Spatial - accounted for by grid sample collection
  - **Temporal** - **Significant problem for K**
- Soil test accuracy
  - How much yield variation (e.g., r^2) is accounted for by the soil test availability index?
  - Potassium
    - 75% (Arkansas)
    - 26 (dry) – 56% (moist, Iowa)
  - Phosphorus
    - 30% (Arkansas)
    - 60% (Iowa)

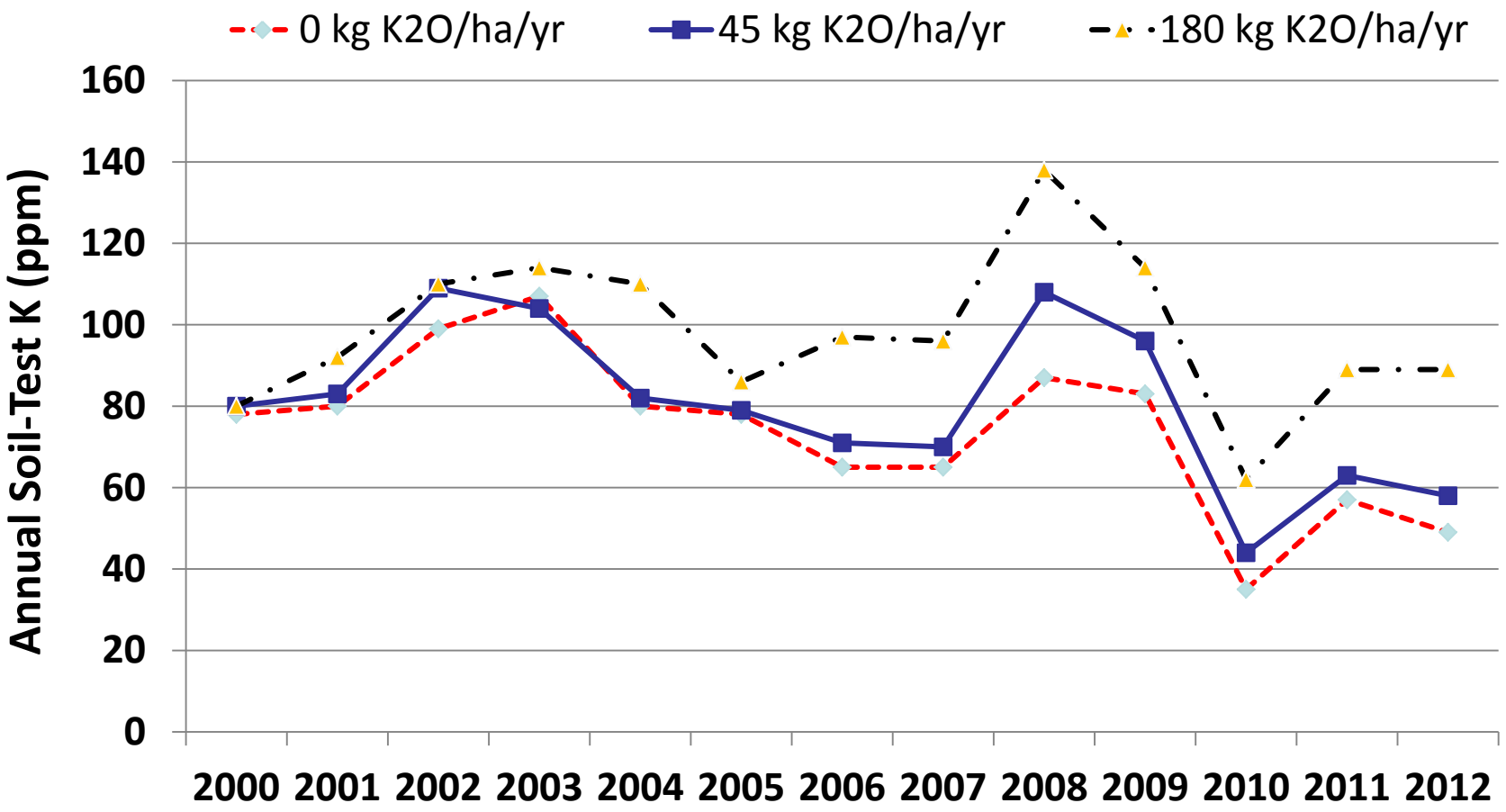
What is best soil sample depth for Soybean?

- Fernandez et al. (2008) reported that 0-10 cm depth provided better estimates of available K than 0-20 cm depth on a poorly drained soil and K (0-5 cm) was very dynamic (i.e., change during season).
  - Soil Sci Soc. Am. J. 72:1085-1095.



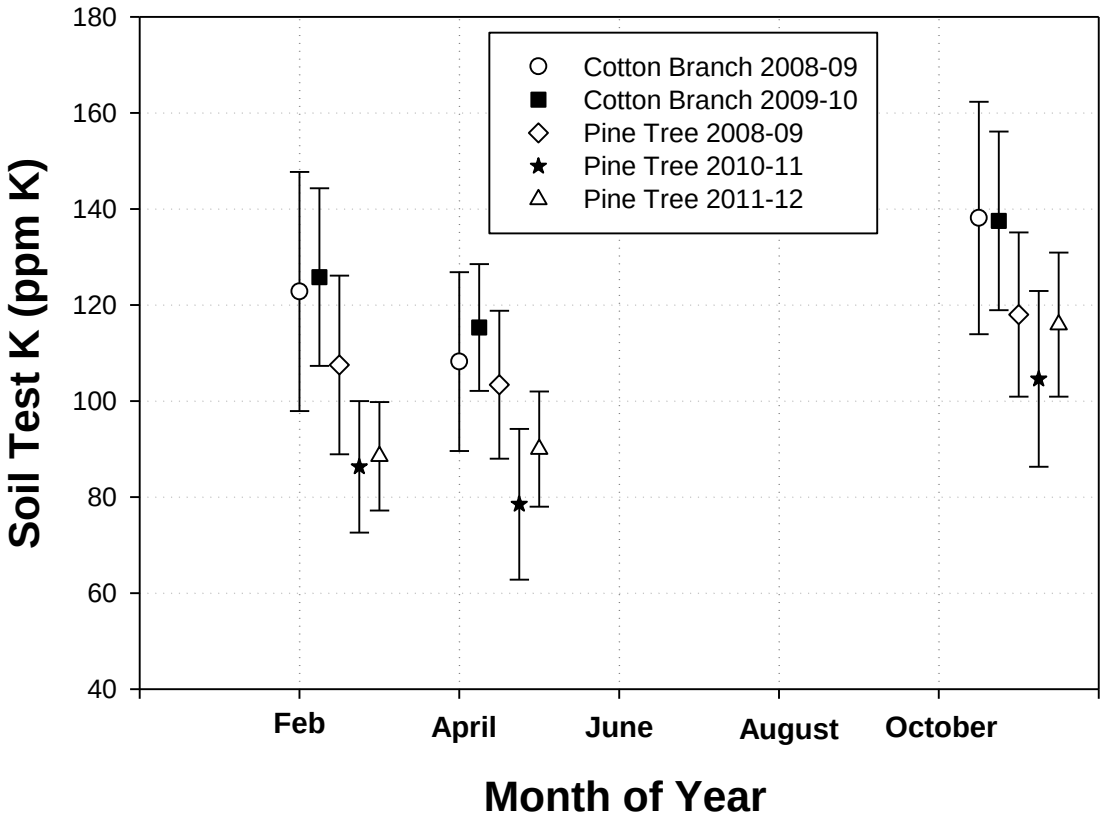
Annual Soil Test K Fluctuation

Environmental Influences



Source: Slaton, Calhoun silt loam at Pine Tree 2000-2012

Temporal variation in soil test K



Each point represents the mean of 12-24 composite samples (4-5 cores/sample) collected from a ~0.25 ha research area.

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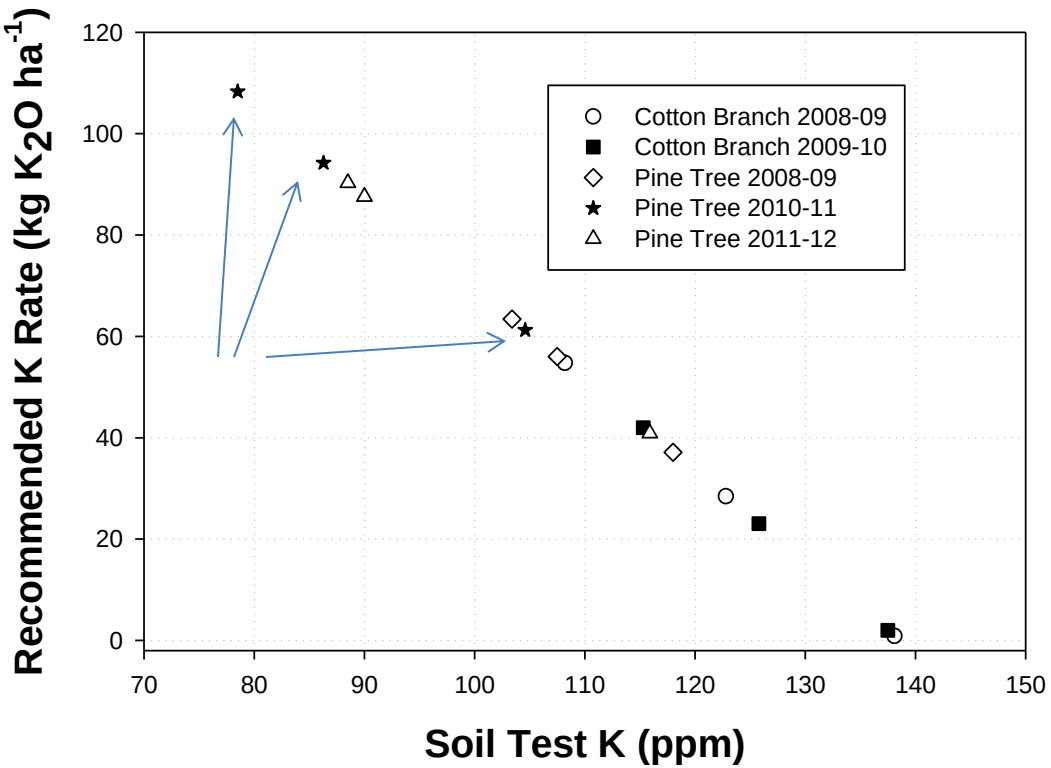
How does soil sample time influence soybean fertilizer recommendations?

- Using the VRT equation for K fertilization of **soybean** within each of the five site-years the recommended K_2O rates varied by 54, 40, 26, 58 & 49 kg K_2O ha^{-1}



Each point represents the mean of 12-24 composite samples (4-5 cores/sample) collected from a ~0.25 ha research area.

Benefits of foliar-applied biostimulents (Arkansas 2012)?

Product	No Fertilizer	0-60-80	Average
	kg ha^{-1}		
None (B only)	4234	4771	4502
Perc Plus	4032	4435	4234
Foliar Blend	4301	4502	4368
SoyAstim-27	4032	4637	4368
BioForge	4234	4704	4435
Average	**4166 b**	**4637 a**	--
LSD0.10	Interaction NS (0.6095) **Fertilizer Rate Main effect (<0.0001)**		Product effect NS (0.3678)

Armor 53-R15; Fertilizer applied as MES10 (12-40-0-10S) and Muriate of Potash
Products applied at V4 fb R1-2 stages; Perc Plus (530 mL fb 530 mL ha^{-1}); Foliar Blend (1060 mL fb 1060 mL ha^{-1}); BioForge 265 mL fb Sugar Mover 1060 mL ha^{-1}); & Pro Team SoyAstim-27 1060 mL fb 1060 mL ha^{-1})

Chloride management
(chloride from irrigation water)

Summary/Conclusions

- **Can upland crop fertilizer recommendations be used for irrigated crop production?**
  - **Decisions should always be guided by good research**
  - Soil pH dependent
    - Alkaline and acid soils present different challenges for different crops & **must be addressed by research.**
    - Micronutrient issues:
      - Toxicity or deficiency??
    - If soil pH and mineralogy are similar, then good chance that recommendations are transferable.

Summary/Conclusions

- **Can upland crop fertilizer recommendations be used for irrigated crop production?**
  - Potassium
    - Many published 'critical soil test K values' are comparable despite different crops, rotation, weather, soil and irrigation practices
    - Must address the problems of temporal variability and accuracy of soil test recommendations

Summary/Conclusions

- **Can upland crop fertilizer recommendations be used for irrigated crop production?**
  - Phosphorus
    - No or maybe, prolonged flooding changes soil P chemistry and influences the availability of P to the subsequent crop.
    - Several studies have shown P availability is different following flooded rice production

Summary/Conclusions

- What information do you need to make sound fertilization decisions? Knowledge of
  - Soil test method
  - Fertilization philosophy
  - Yield response curve (correlation & calibration curves)
  - Frequency of response within each soil test level
  - Magnitude of response
  - Keep good records of soil test results

Thank You

- Special thanks to:
  - Luis Prochnow & IPNI staff
  - Nelson Horowitz
  - Leandro Souza da Silva

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