Corn and Soybean Yields as Affected by Soil Test P and Fertilization Philosophy

Jeffrey Vetsch

Researcher 4

Univ. of Minnesota,

Southern Research and Outreach Center

Tenth Annual Nutrient Management Conference

February 20, 2018, Verizon Wireless Center, Mankato

Corn and Soybean Yields as Affected by Soil Test P and Fertilization Philosophy

Daniel Kaiser, Albert Sims, Carl Rosen, Jeff Vetsch, Jeff Strock, and Karina Fabrizzi

University of Minnesota

Funding for this project from Agricultural Fertilizer and Research and Education Council (AFREC) is greatly appreciated by the authors.

Minnesota's Agricultural Fertilizer
Research & Education Council

Background

- Phosphorus (P) is an essential nutrient and the second most commonly applied nutrient in Minnesota agriculture. Phosphorus management is critical to reduce environmental risk while sustaining field productivity.
- Phosphorus fertilization in Minnesota and the Midwest is based on one of two philosophical approaches:
- Build and Maintain ("I" states) or Sufficiency (MN, WI, SD).
  - Recently, many have labeled the sufficiency approach as "to conservative" or "will limit yield or yield potential".
  - They proclaim greater fertilizer rates, used in B&M and crop removal approaches, are necessary to obtain and maintain production levels in today's agricultural systems.

Objectives

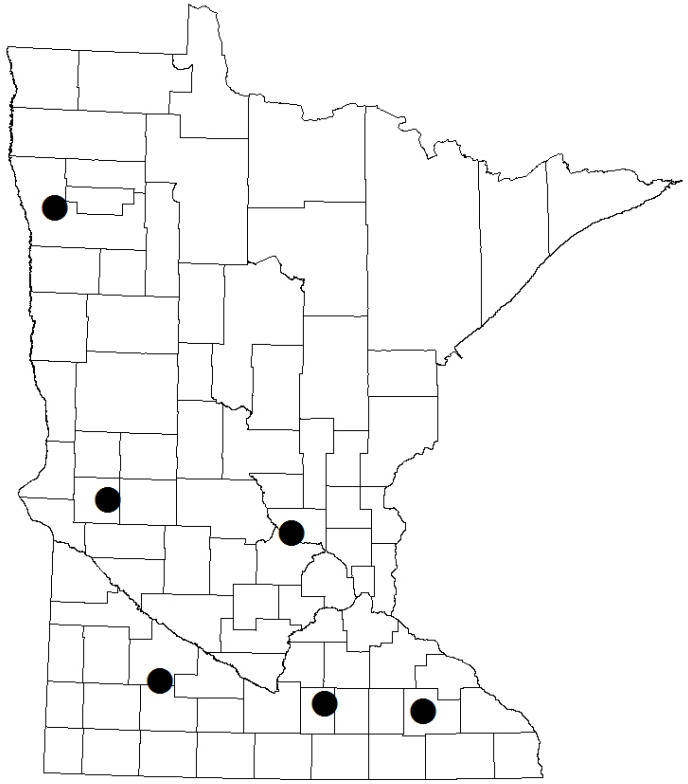
The objective of this study was to establish long-term experiments in primary agronomic regions of Minnesota and to test / compare current and future P management strategies.

PHASE I: Establish at each site replicated soil test P (STP) level treatments ranging from Low, Medium, High, and Very High (V.High), over a period of 4 growing seasons (2011-2014).

PHASE II: Evaluate response to applied P as affected by initial STP levels and evaluate maximum grain yield achieved under various applied P, initial STP level combinations.

Experimental sites

1. Becker
2. Crookston
3. Lamberton
4. Morris
5. Rochester
6. Waseca



Split-plot randomized complete block design with four replications.

- **Whole plot: STP classes (Low, Medium, High, Very High) (80’ x 55’)**
  - **P_2O_5 rates for this period (Low=0, Med.=30, High=60, V. High=90 lb/ac)**

- **Split-plot: were established Fall 2014 for PHASE II (20’ x 55’)**

Measurements and Methods

- Annually at each site
  - Grain yield, P removal, and P inputs
  - Soil samples at 0-6 inch sampling depth (June sampling at all sites except Morris).
- Triple superphosphate (0-46-0) was the only P fertilizer source used at all locations. Broadcast and incorporated.
- All agronomic practices at each location were customary for the region Only P fertilizer rates varied.
- Crop rotation: corn (2011-13), soybean (2014), corn (2015-16), soybean (2017) at all sites except Crookston (wheat in 2013).

Soil Description

		pH	CCE	O.M.
Site	**Soil Series**		**%**	**%**
Becker±	Hubbard ls	5.2	0.1	1.4
Lamberton	Normania l	5.4	0.2	3.4
Rochester*	Port Byron & Mt Carroll silt loam	7.5	0.5	4.3
Waseca	Nicollet & Webster clay loam	6.0	0.1	4.7
Morris	Dolan sl	7.6	1.5	3.9
Crookston§	Gunclub Si cl	8.1	2.5	4.8

± Becker site was limed in 2012 to bring soil pH up to 5.8.
*** Rochester site was limed just prior to the initiation of the experiment.**
§ Crookston and Morris typically use the Olsen STP for P fertilizer recommendations.

Soil test phosphorus (P) Interpretation Classes and associated extracted-P concentrations used in Minnesota.

	Minnesota STP Category				
Extractant	Very Low	Low	Medium	High	Very High
	---------- ppm P extracted ----------				
Bray-P	0-5	6-11	12-15	16-20	21+
Olsen-P	0-3	4-7	8-11	12-15	16+

What is the meaning of low P?

- Think of your soil test as a probability function

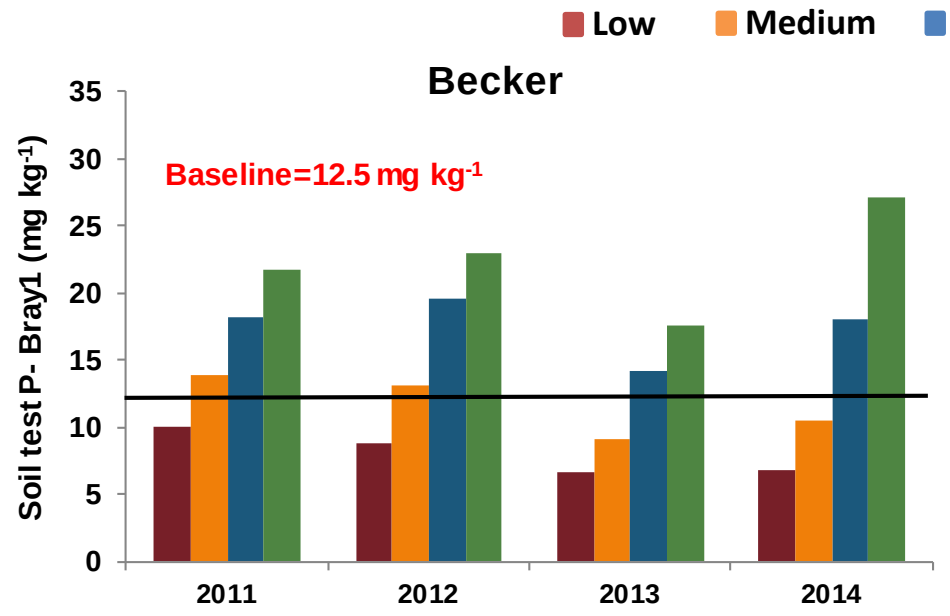
"Low" testing soils should have a low potential to supply required nutrients

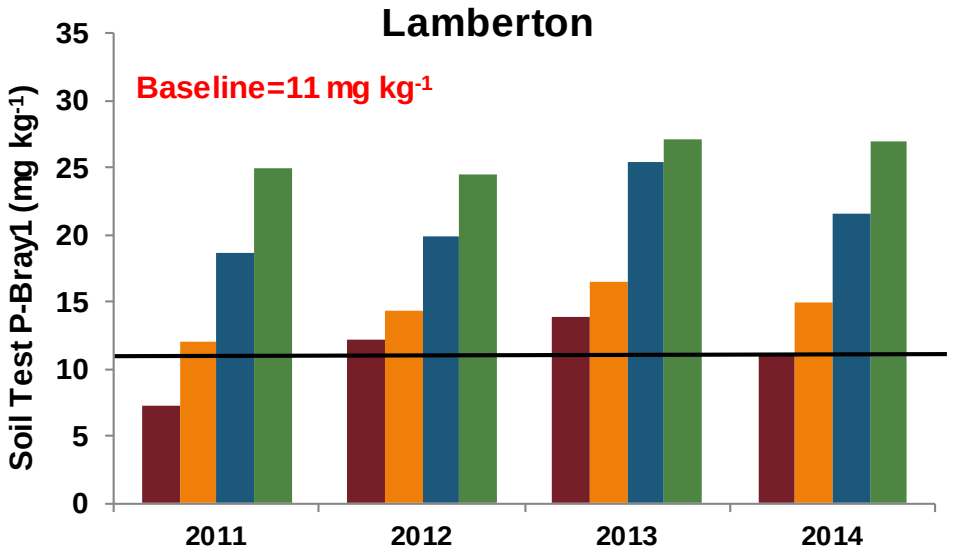
Table 8. Corn grain yield response to applied P fertilizer based on soil test category.

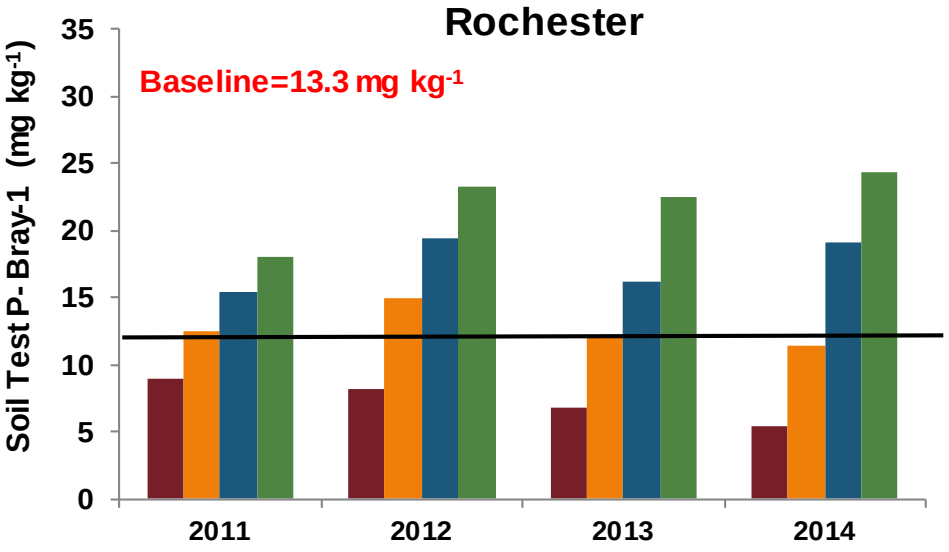
BRAY-P1 OR OLSEN SOIL TEST P CATEGORY	EXPECTED TIME P FERTILIZER WILL INCREASE CORN GRAIN YIELD	EXPECTED YIELD WITHOUT P FERTILIZER
	----------%	
Very Low	87	87
Low	83	90
Medium	27	98
High	13	99
Very High	7	99

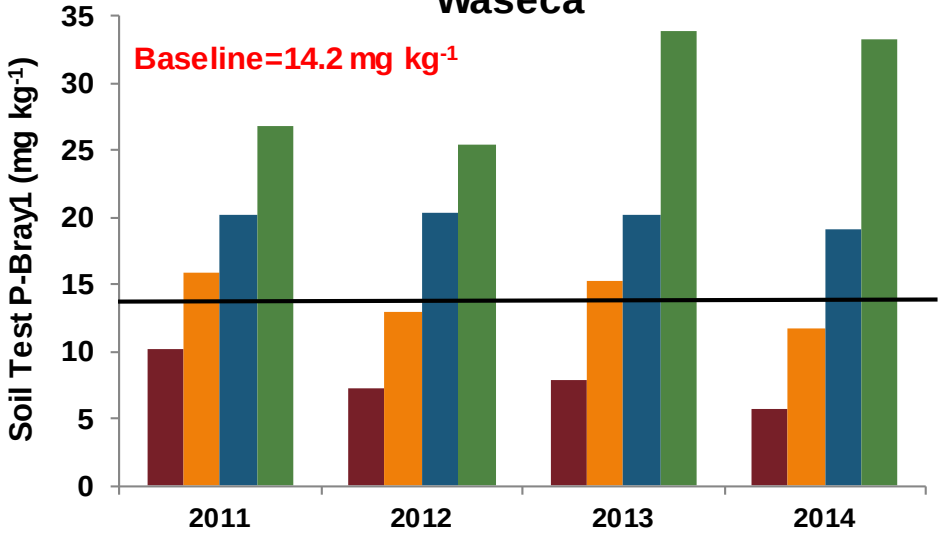
Phase I- Results

Phase I Soil Test P

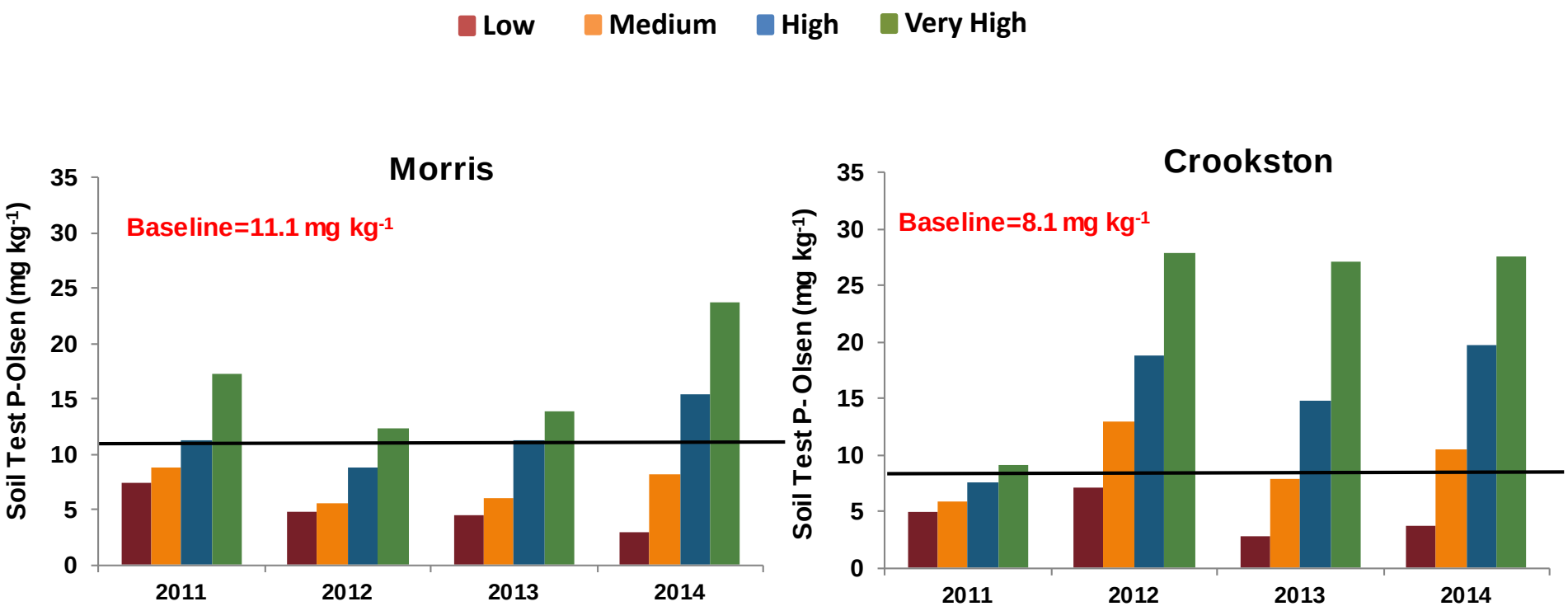








Phase I Soil Test P



Phase I Soil Data-Summary

At the end of Phase I in 2014, all sites had reached the four established interpretation classes: Very High, High, Medium and Low and most of them were within the range established for Minnesota, with some exceeding only by a small margin.

METHODS OF PHASE II

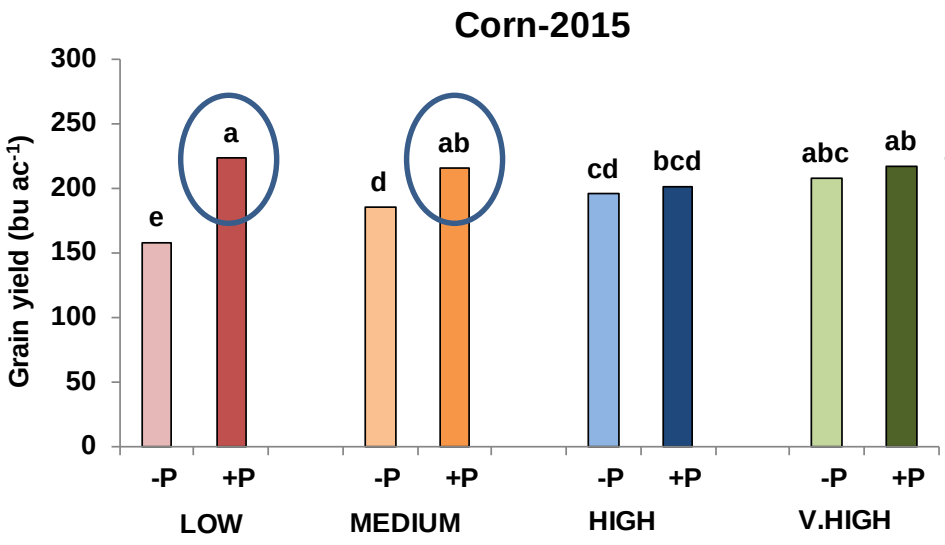
- **Divide each whole plot into 4 split-plots**
  - Group split-plots into adjacent pairs
  - One pair used in 2015 trial
    - One split-plot fertilized
    - One split-plot not fertilized (crop relies on residual P from Phase I)
  - Additional pairs used for 2016 and 2017 trials
    - Fertilized to maintain original Whole plot STP Interpretation Class
- **Fertilizer rates for Phase II (fertilized plot only)**
  - Low: 150 lbs. P_2O_5 ac^{-1}
  - Medium: 90 lbs. P_2O_5 ac^{-1}
  - High: 30 lbs. P_2O_5 ac^{-1}
  - Very High: 30 lbs. P_2O_5 ac^{-1}

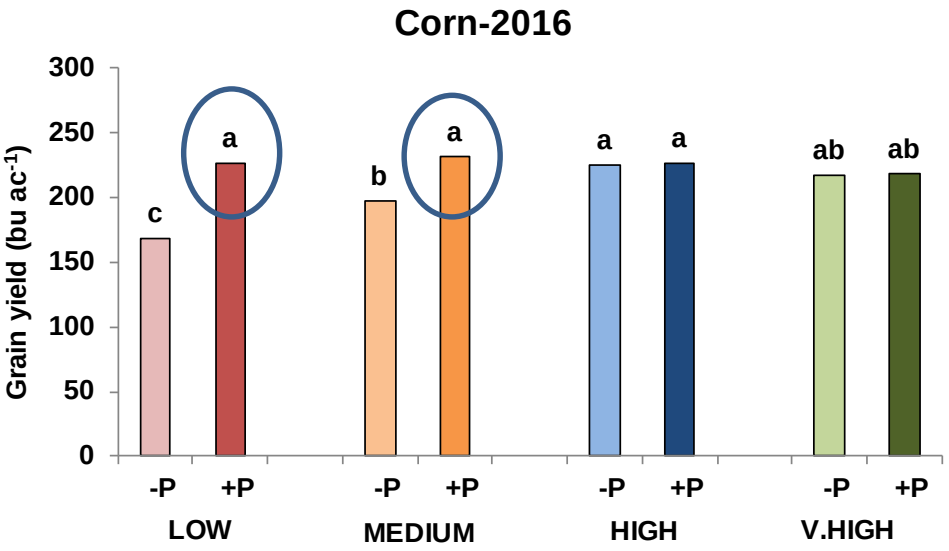
Methods for Phase II

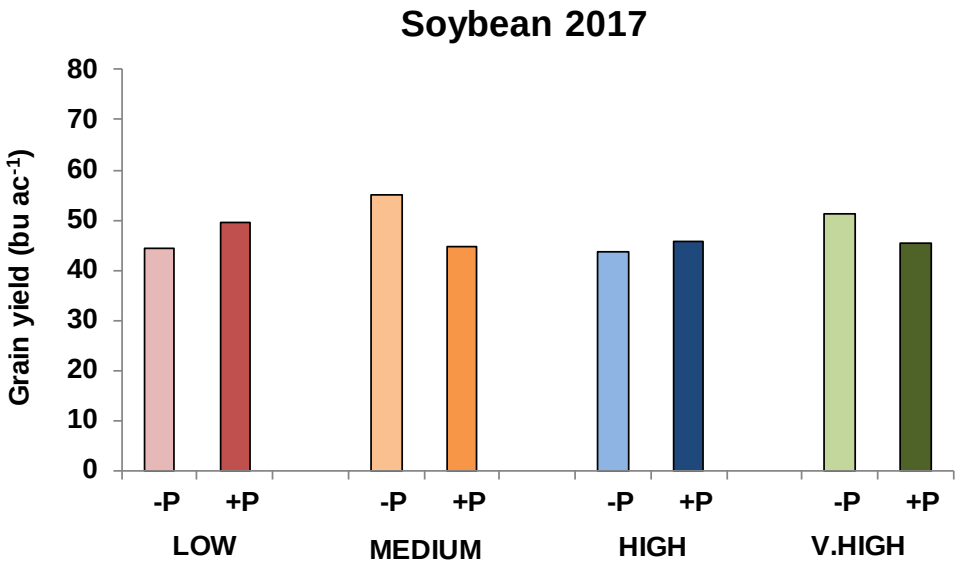
- Fertilizer rates used were University of Minnesota recommendations based on STP levels plus 50%.
- This trial was not to test fertilizer recommendations
- Wanted to ensure minimal chance recommended P rate was inadequate

Phase II- Results

Phase II Becker- Grain Yield

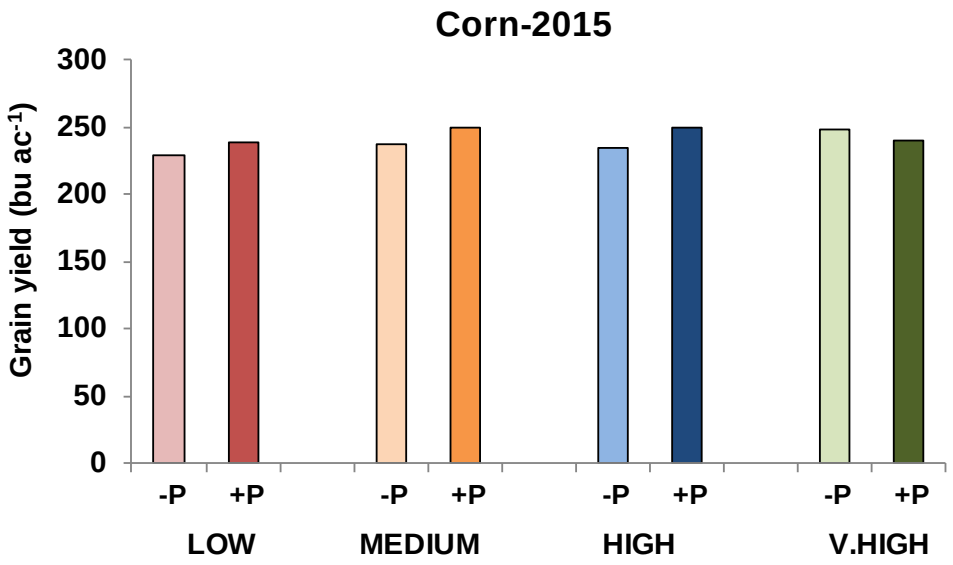


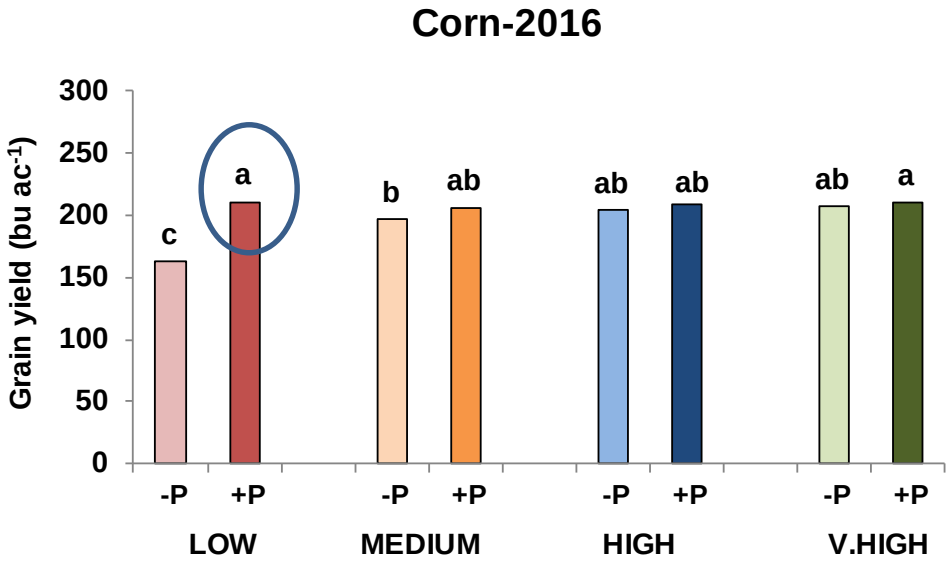


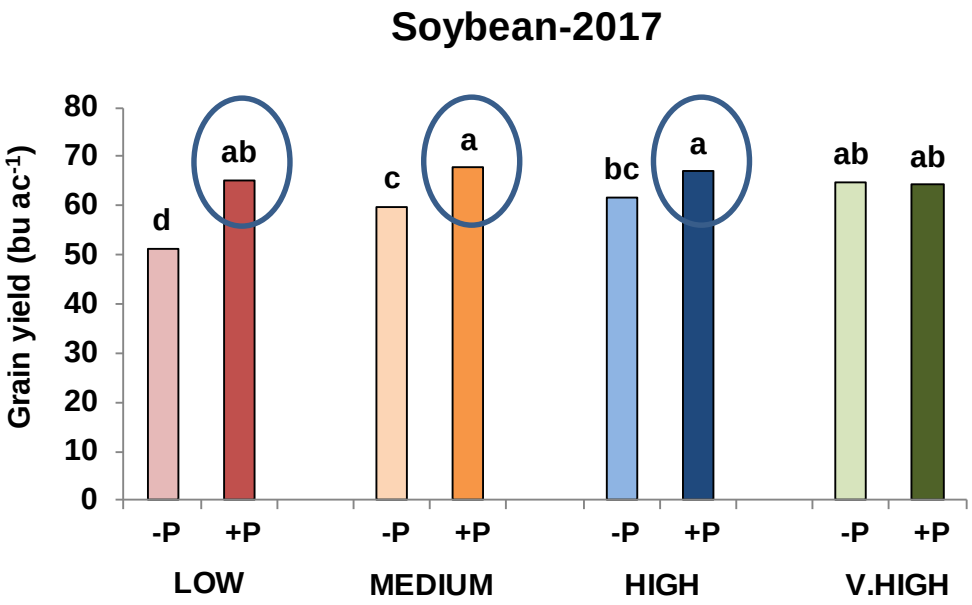


	2015	2016	2017
	.....*P* value.....		
Class (C)	0.11	0.09	0.54
P fert. (P)	<0.01	<0.01	0.34
C x P	<0.01	<0.01	0.11

Phase II Waseca – Grain Yield

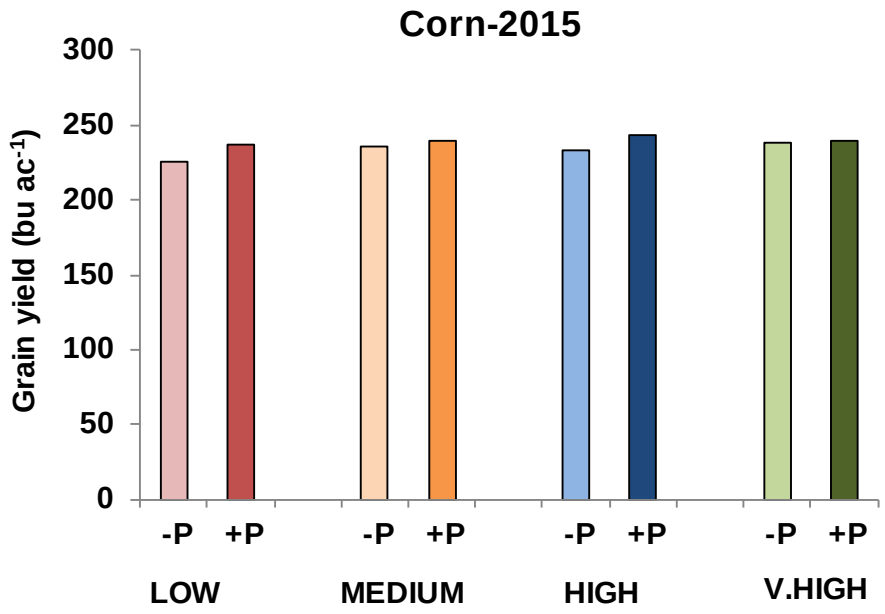


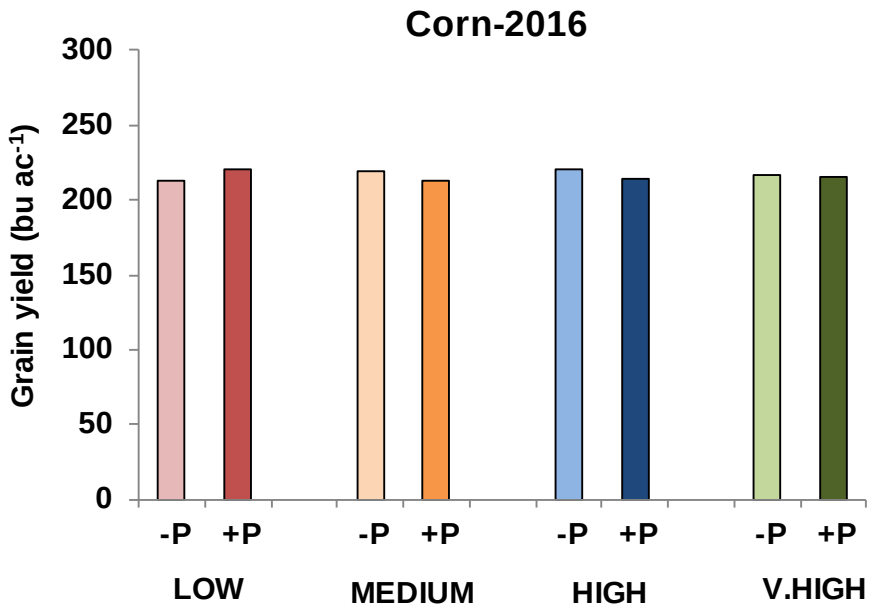


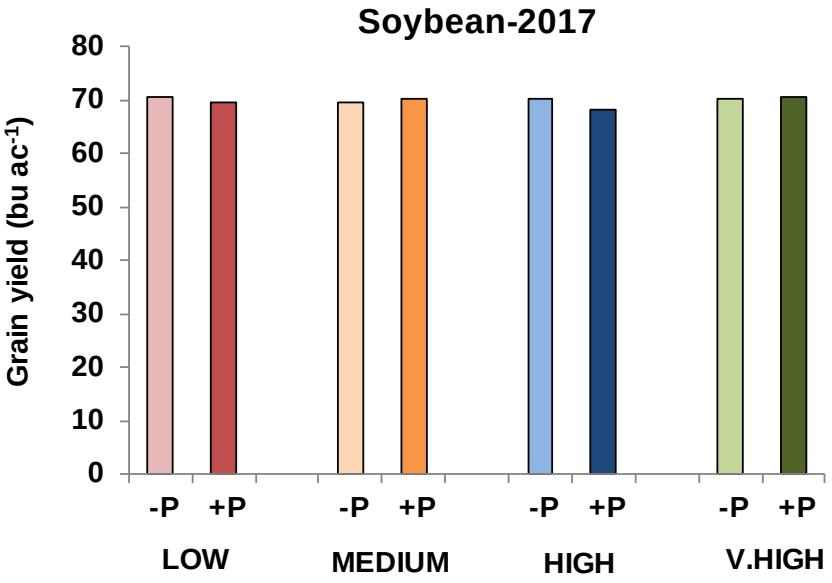


	2015	2016	2017
	.....*P* value.....		
Class (C)	0.21	<0.01	<0.01
P fert. (P)	0.06	<0.01	<0.01
C x P	0.17	<0.01	<0.01

Phase II Rochester

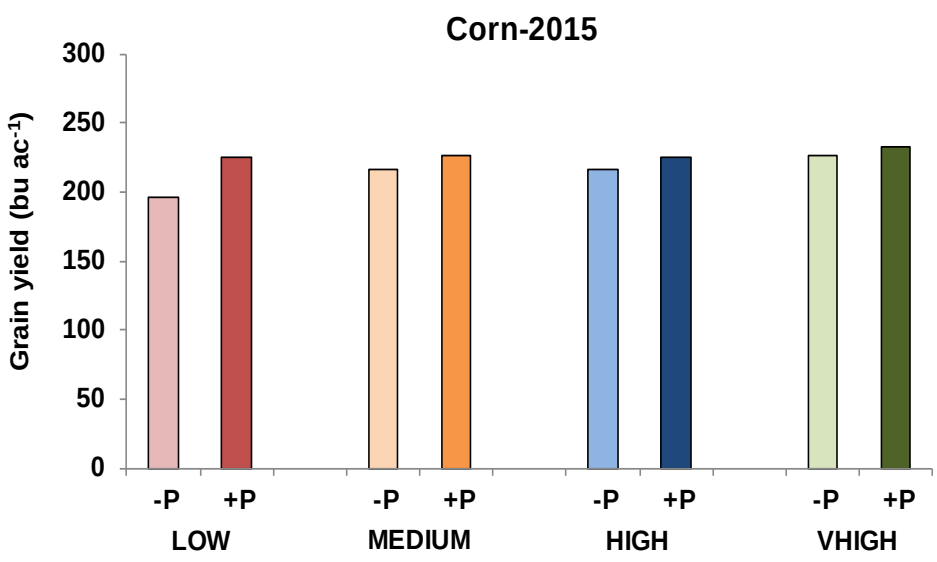


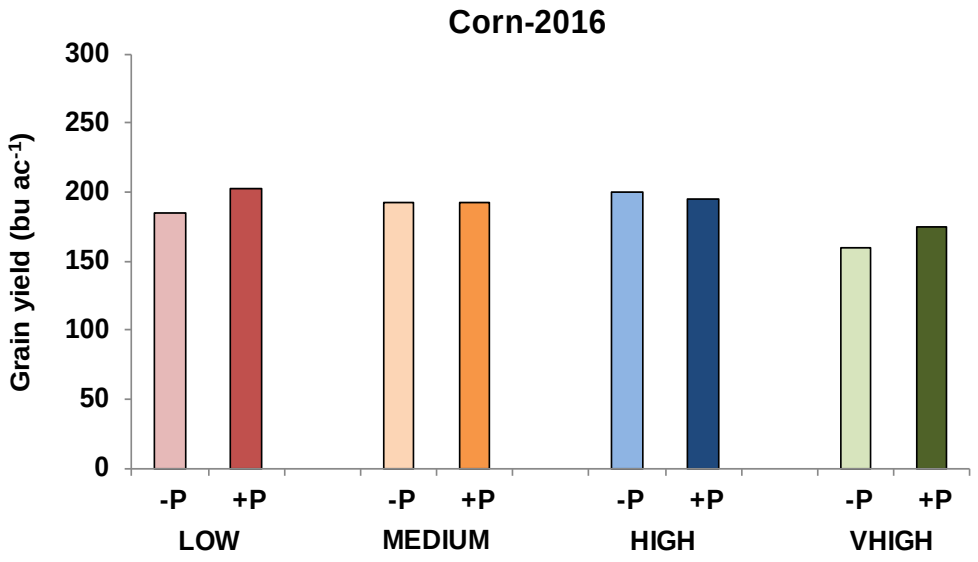


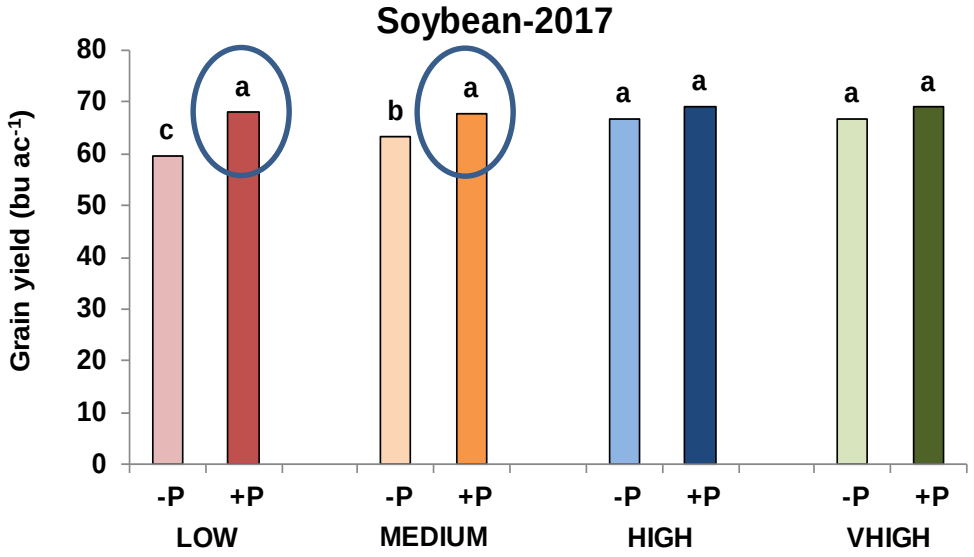


	2015	2016	2017
	.....*P* value.....		
Class (C)	0.04	0.99	0.69
P fert. (P)	<0.01	0.62	0.53
C x P	0.30	0.27	0.53

Phase II Lamberton

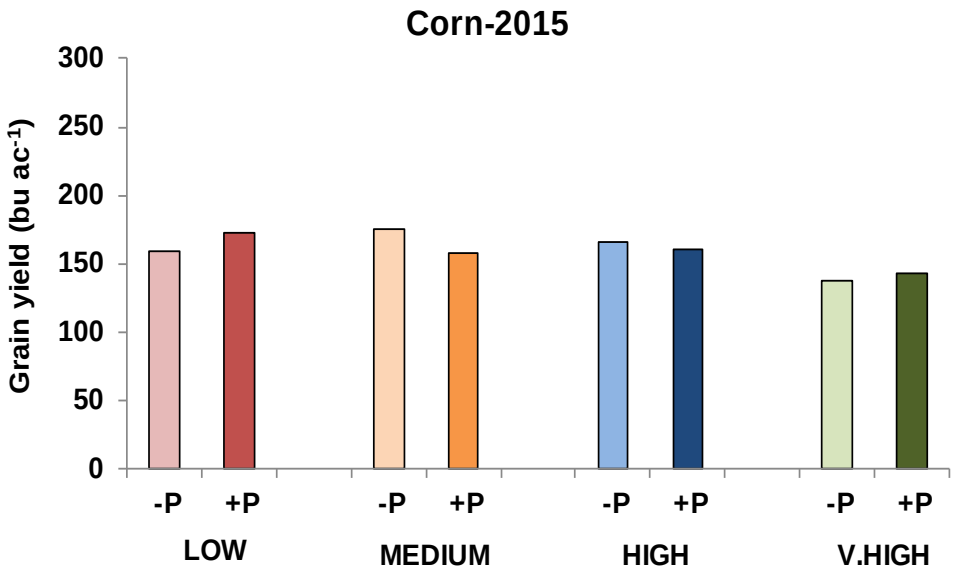


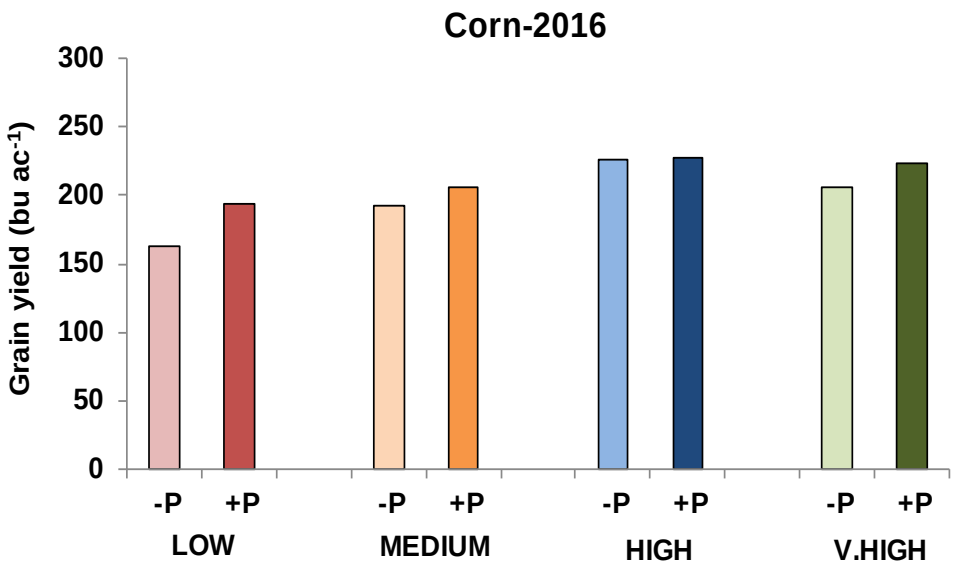


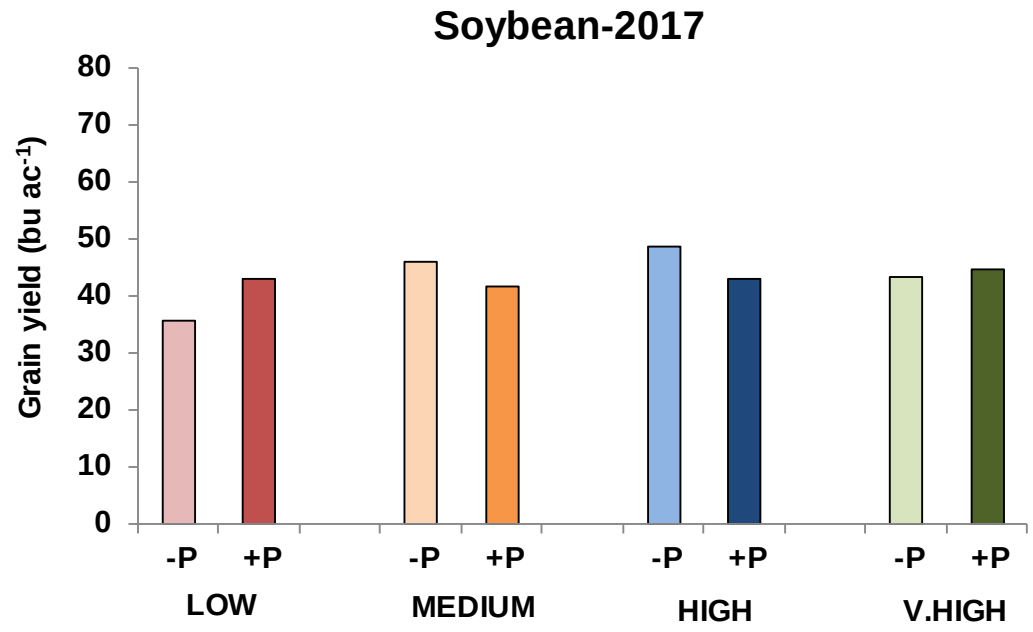


	2015	2016	2017
	.....*P* value.....		
Class (C)	0.03	0.05	<0.01
P fert. (P)	<0.01	0.09	<0.01
C x P	0.16	0.14	0.05

Phase II Morris

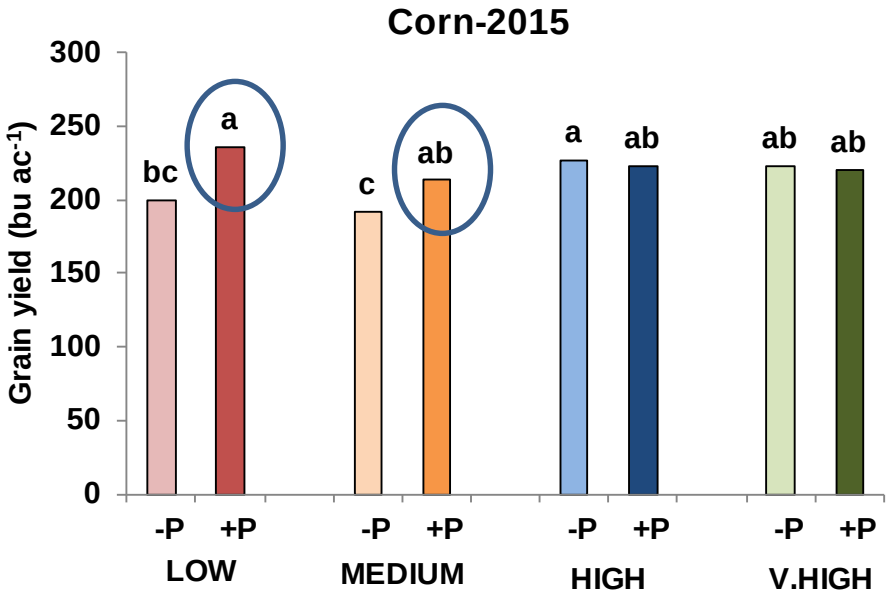


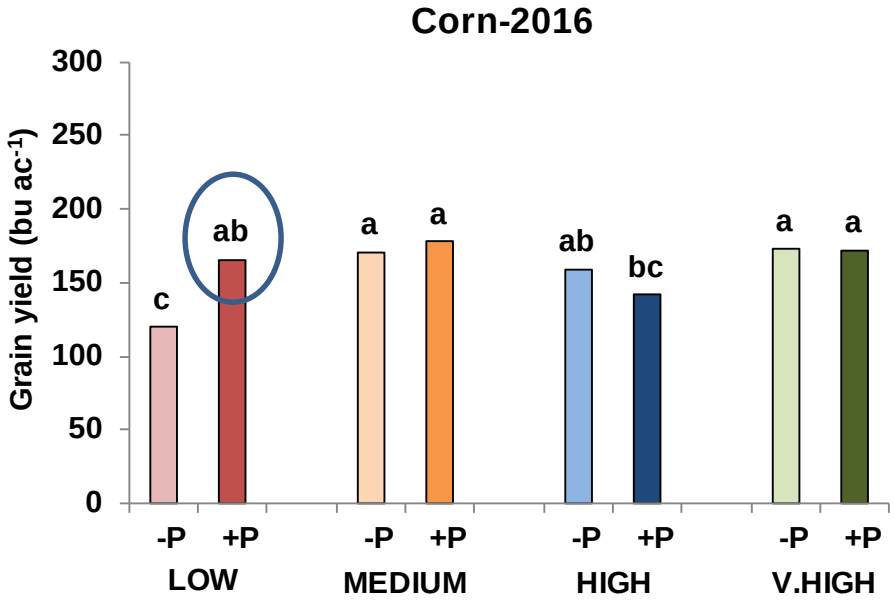


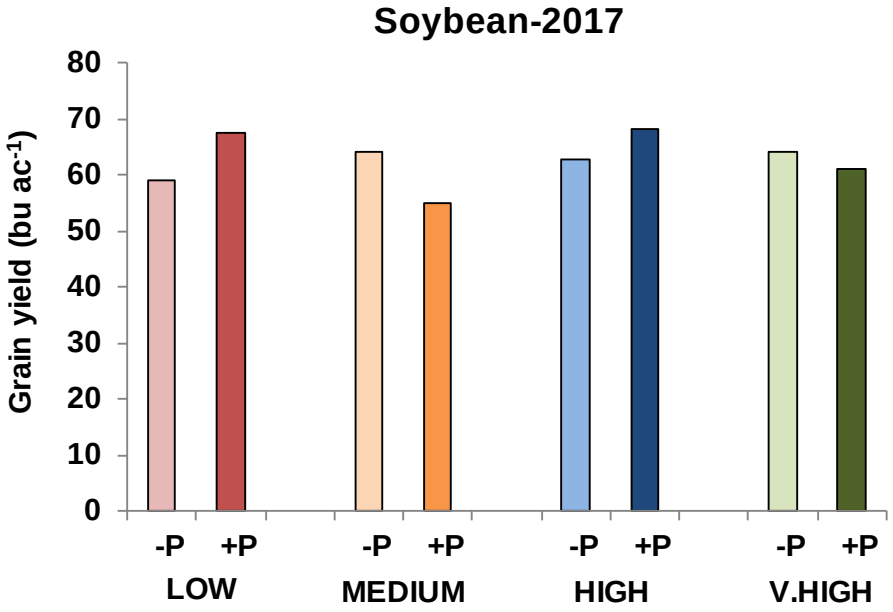


	2015	2016	2017
	.....*P* value.....		
Class (C)	0.28	0.07	0.41
P fert. (P)	0.88	0.11	0.87
C x P	0.40	0.73	0.15

Phase II Crookston







	2015	2016	2017
	.....*P* value.....		
Class (C)	0.24	0.02	0.77
P fert. (P)	0.01	0.20	0.89
C x P	0.01	0.02	0.30

Yield Data Summary

- Corn yields responded to P fertilizer application at Becker, Waseca, and Crookston.
- Morris, Lamberton, and Rochester had minimal response to P fertilizer.
- In 18 of 23 site-years from Phase I (individual year data not shown), yields were optimized with STP in the Medium soil test level (12-15 ppm Bray-P1 and 8-11 ppm Olsen-P).
- The Medium STP level or class received 30-lb P_2O_5 ac^{-1} annually during Phase I.

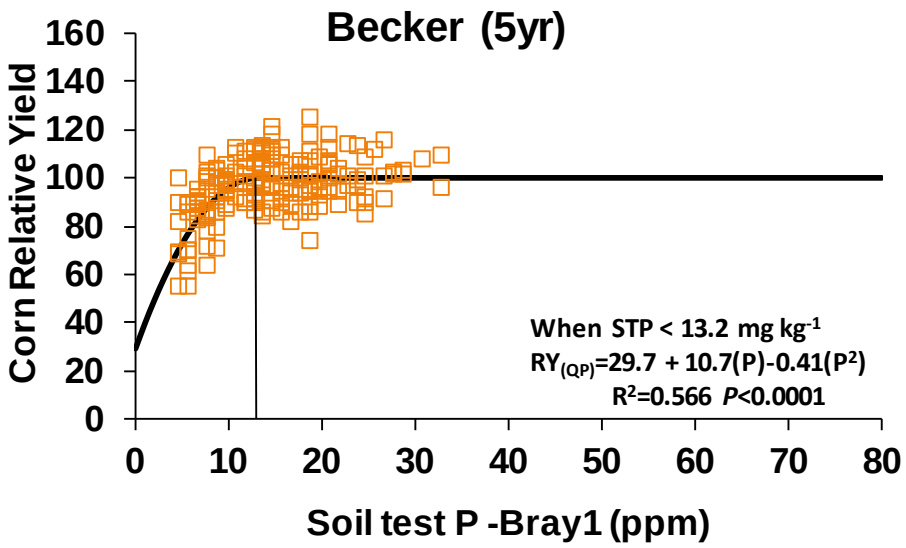
CONCLUSIONS

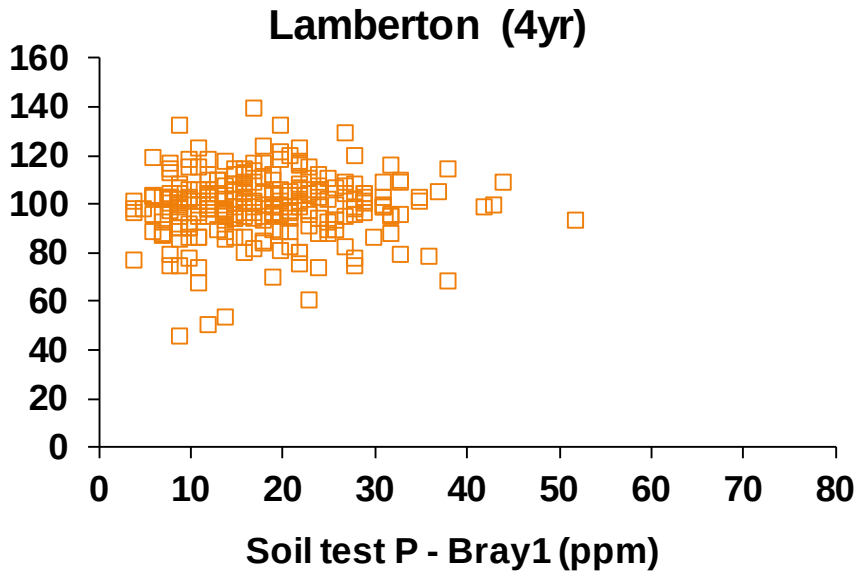
- **Greater response to P application was observed in the Low and Medium STP classes, with little to no response in the High and Very High STP classes.**

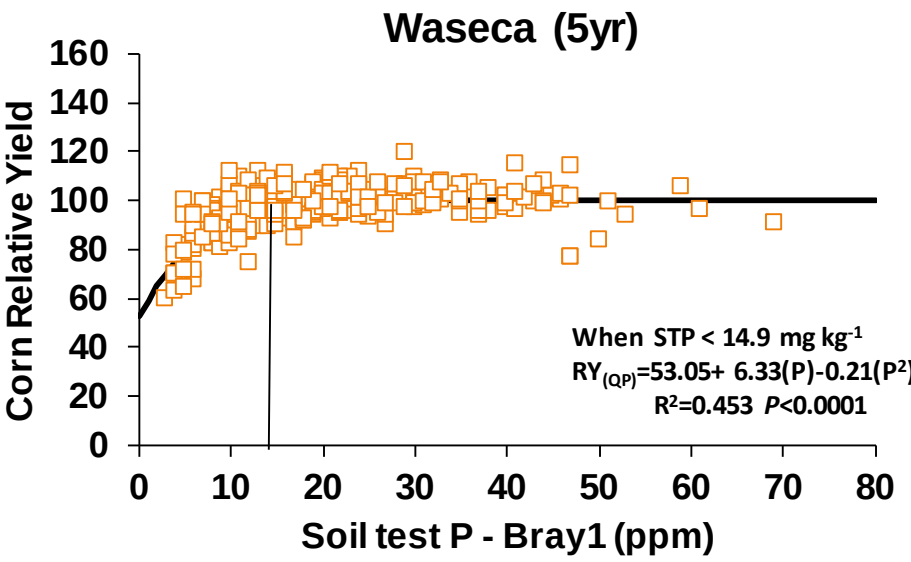
- **Applying P fertilizer annually based on STP level resulted in similar grain yield potential than building and maintaining high STP regardless of P level and soil type.**

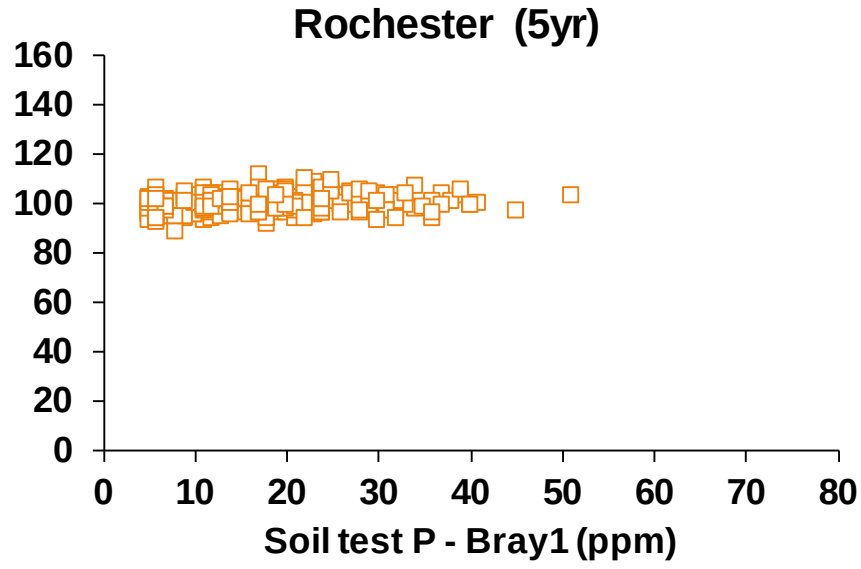
STP Critical Levels

Relative Corn Yield × STP

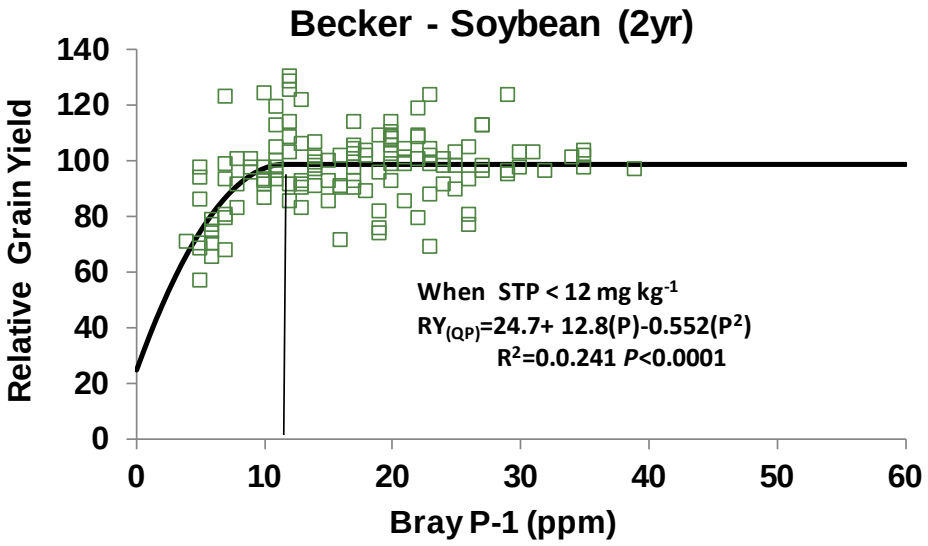


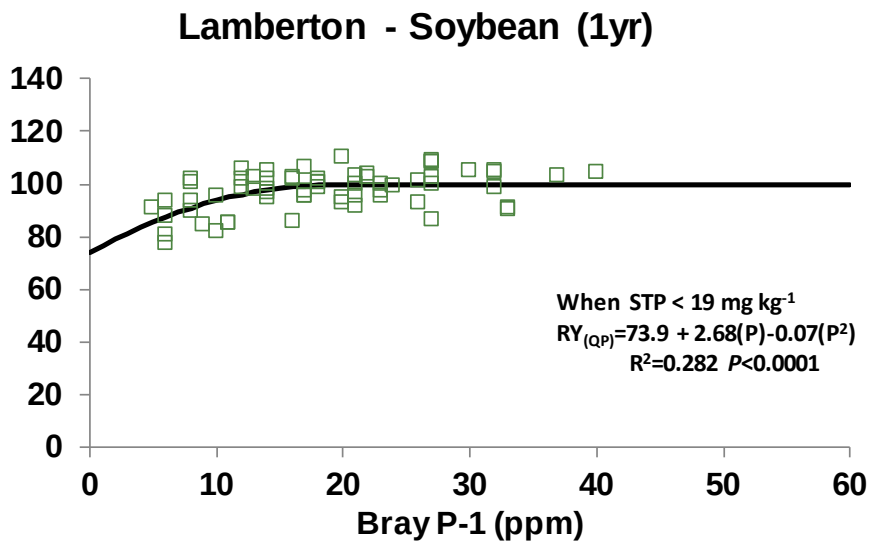


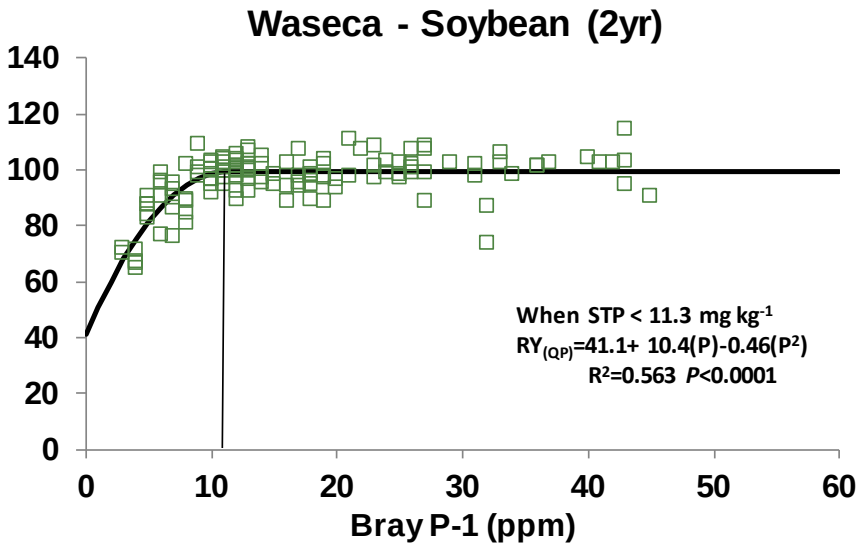


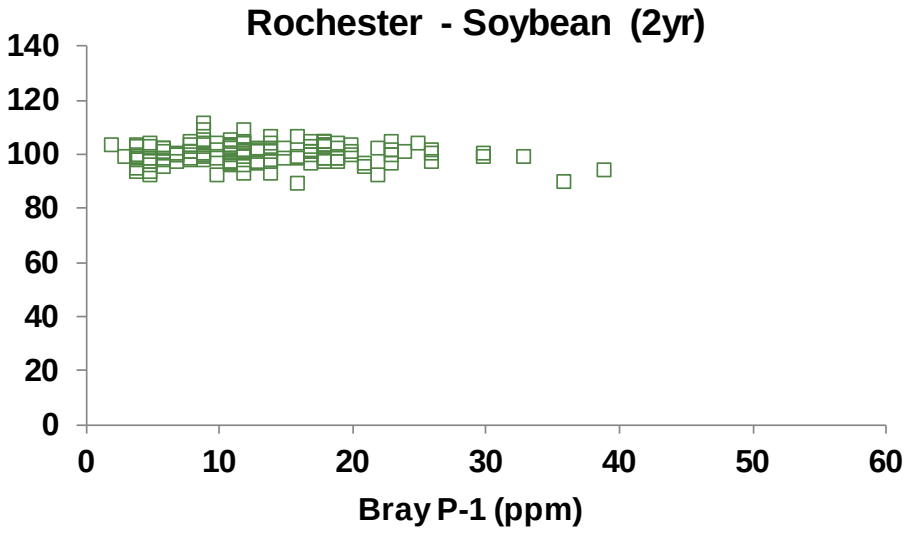


Relative Soybean Yield × STP

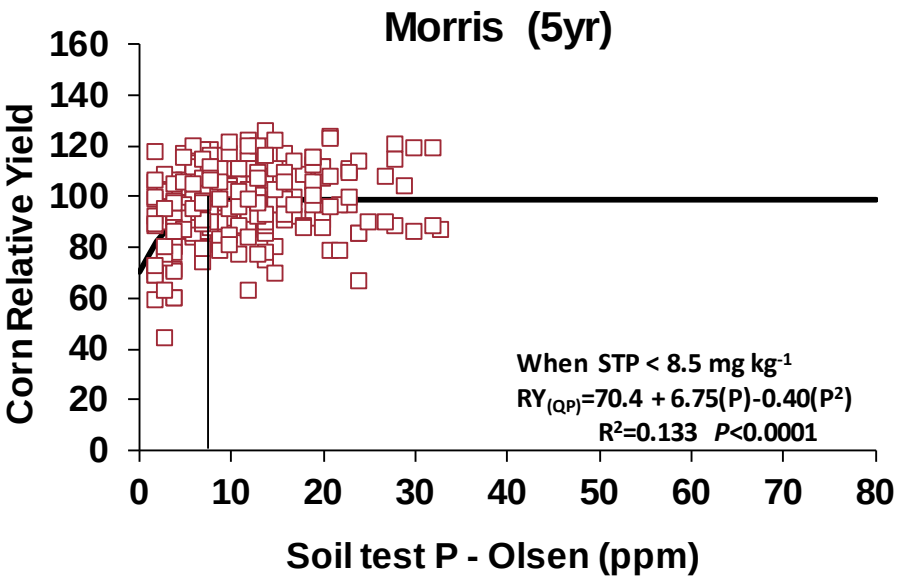


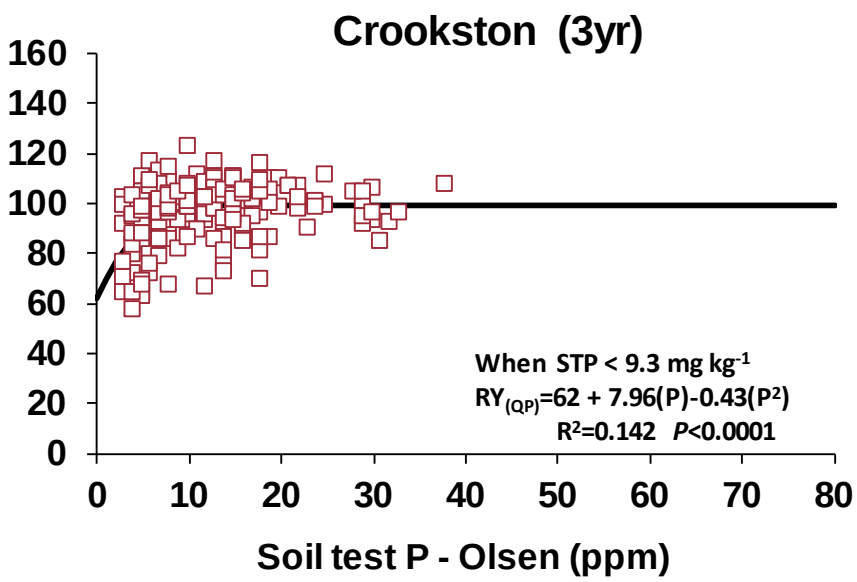




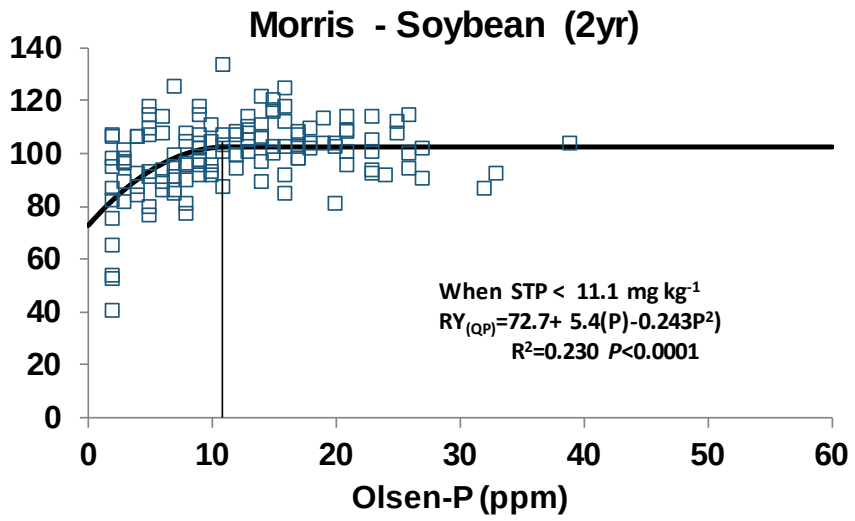


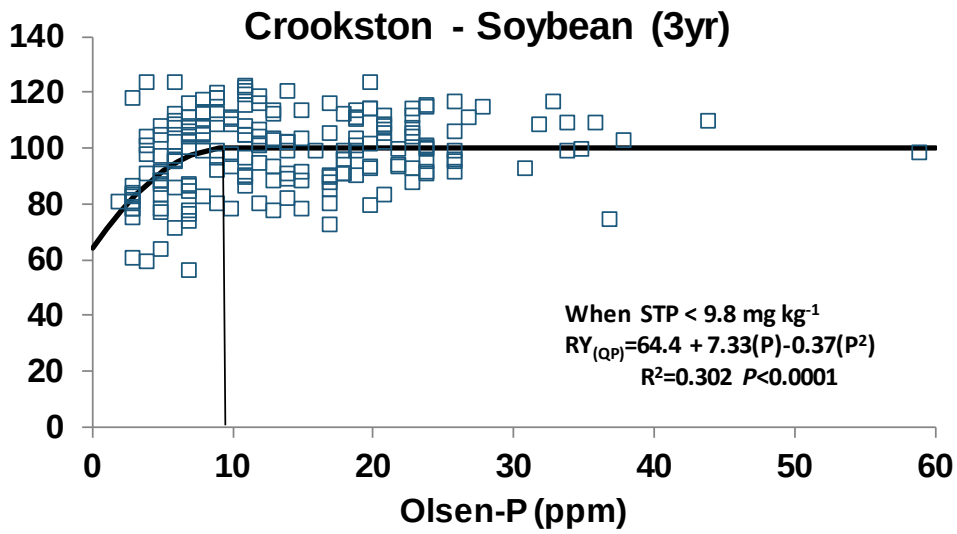
Relative Corn Yield × STP



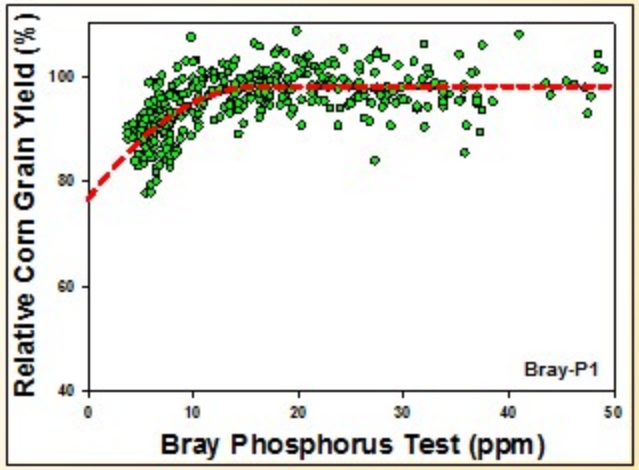


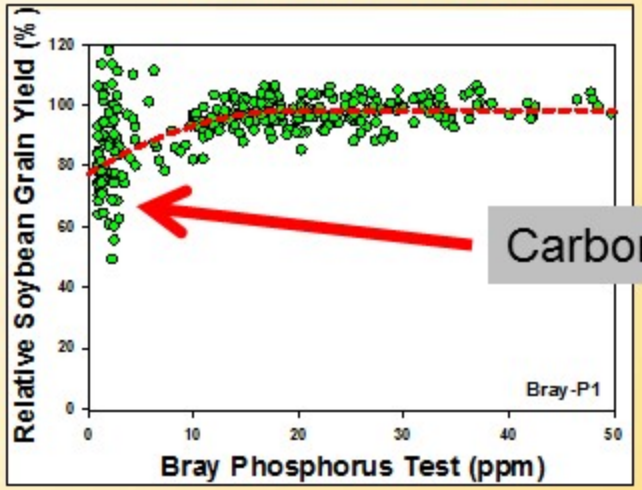
Relative Soybean Yield × STP





Critical Soil Test P Levels





AFREC
Agricultural Fertilizer Research & Education Council

Critical soil test P level at selected relative corn grain yield levels			
Soil Test	95%	98%	100%
	----------ppm----------		
Bray-P1	10	15	16
Olsen	9	12	13
Mehlich-3	14	19	19

Critical soil test P level at selected relative soybean grain yield levels			
Soil Test	95%	98%	100%
	----------ppm----------		
Bray-P1	12	17	18
Olsen	8	10	11

Critical level is typically defined as the soil test at 95% relative yield

RESIDUAL EFFECTS OF PHASE II

- **What are residual effects on 2015 plots in 2016?**

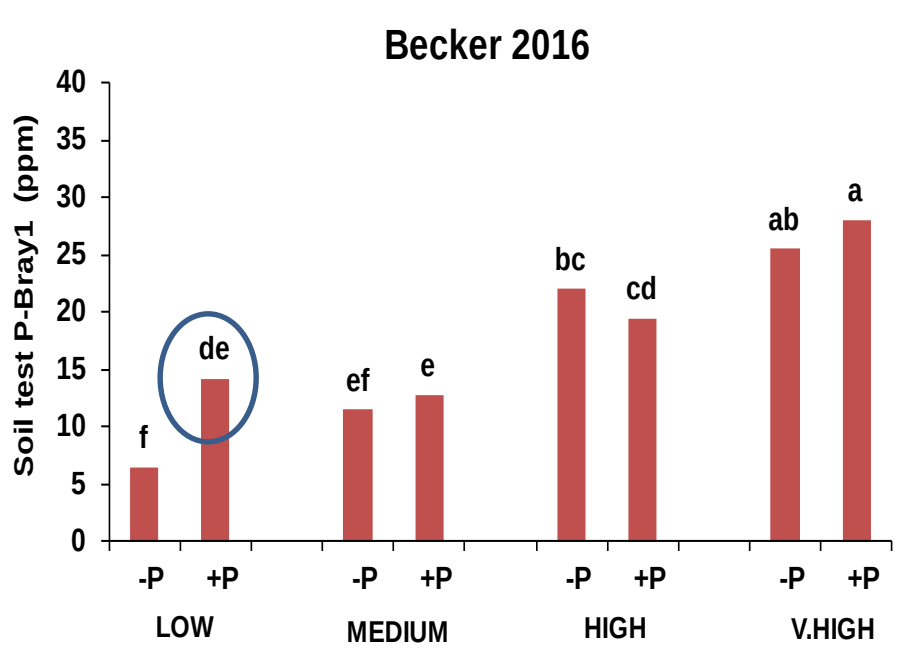
- **Do corn yields and/or STP crash in P fertilized plots in the Low STP class?**

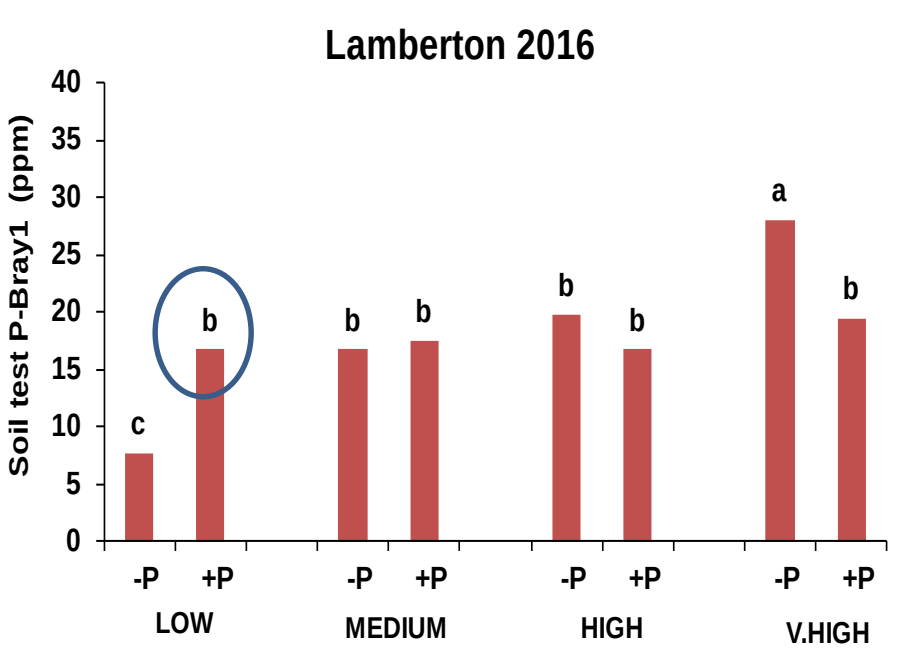
  Pair of plots used for the 2015 comparison

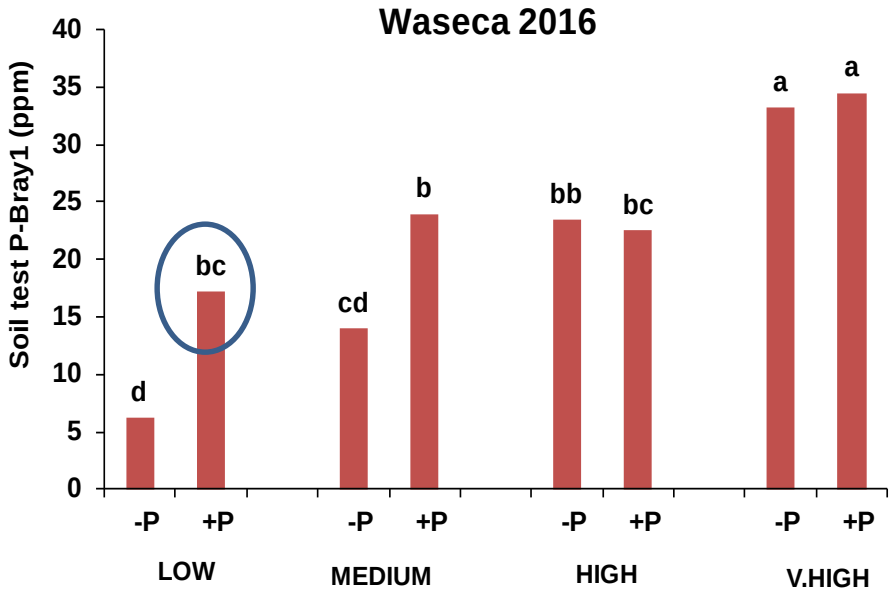
  - **One split-plot fertilized**
  - **One split-plot not fertilized**

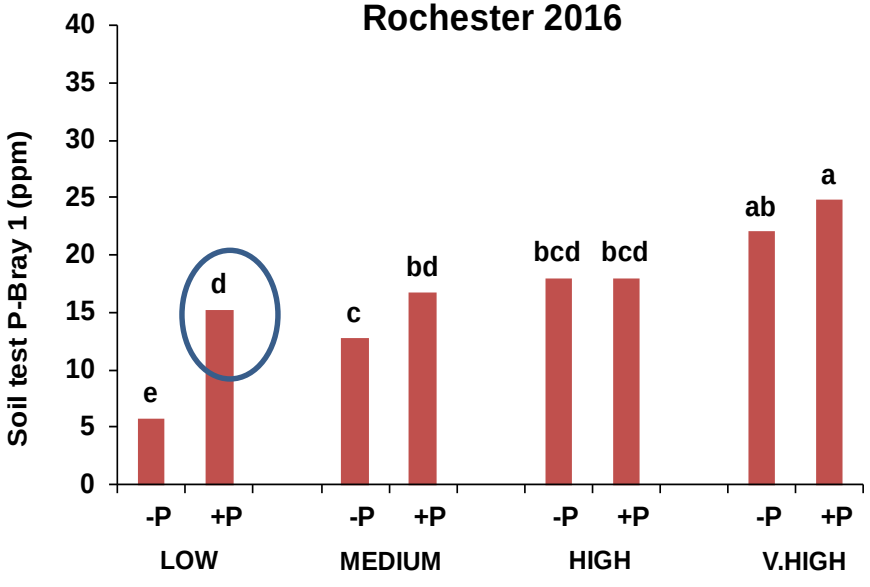
- **Treatments applied to 2015 pair in 2016**
  - **Low: 0 & 150 lb P_2O_5 ac^{-1} for 2015 and 0 & 0 for 2016**
  - **Med.: 0 & 90 for 2015 and 30 & 0 for 2016**
  - **High: 0 & 30 for 2015 and 30 & 0 for 2016**
  - **V. High: 0 & 30 for 2015 and 30 & 0 for 2016**

Phase II Soil test P (Bray-P) Residual Effects

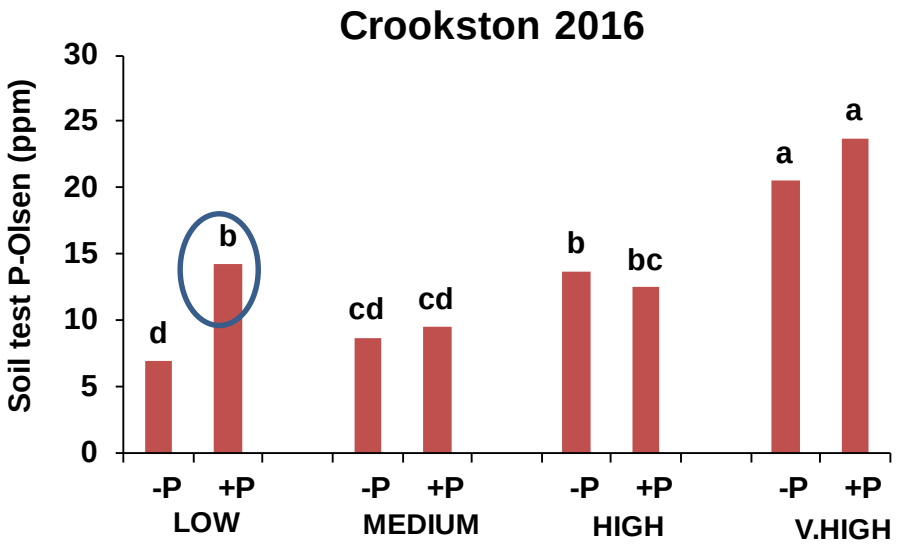


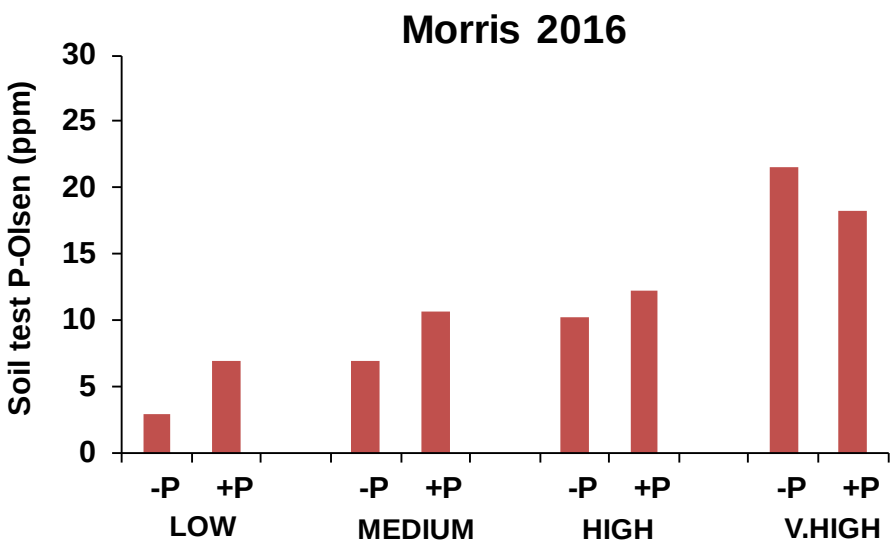




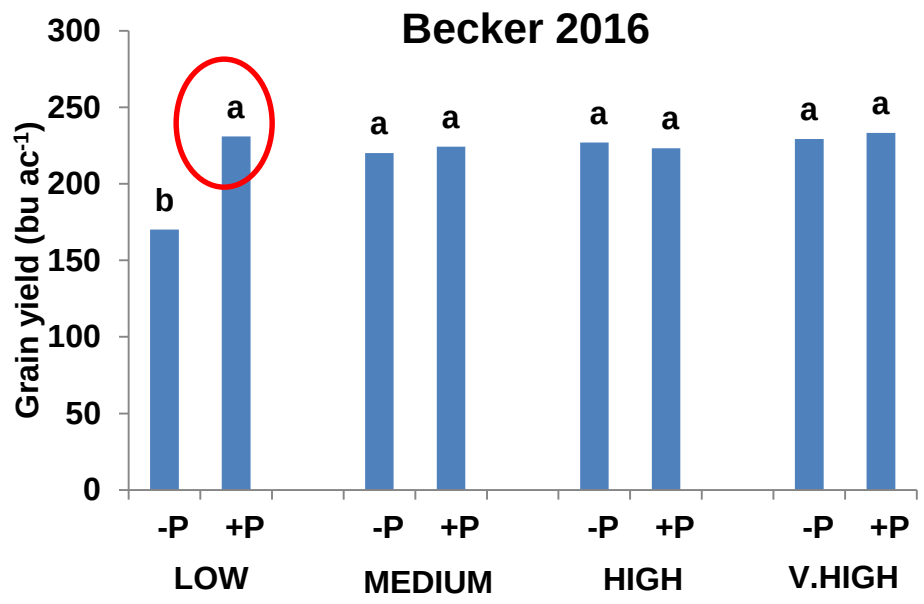


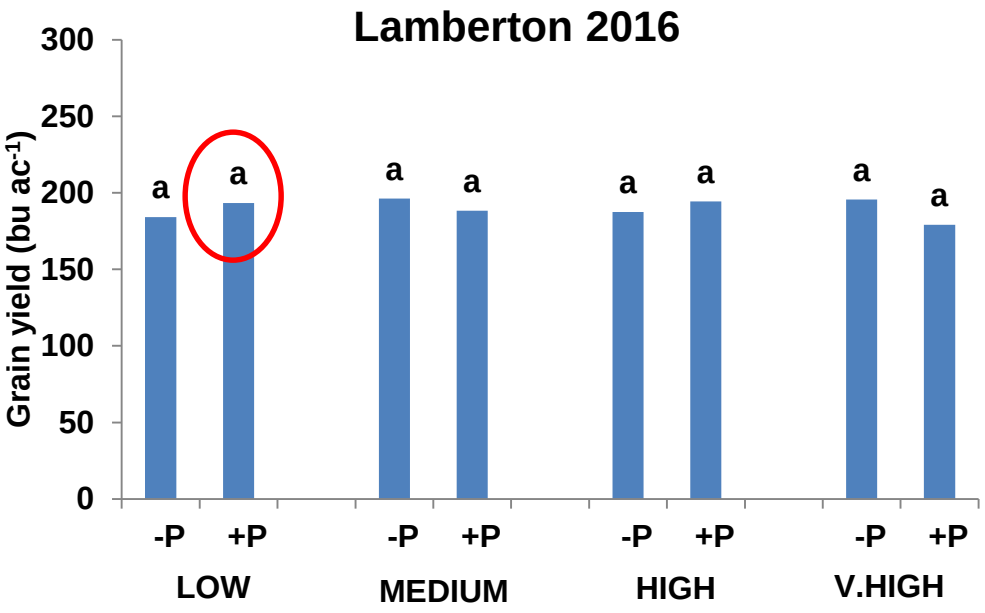
Phase II Soil test P (Olsen-P) Residual Effects

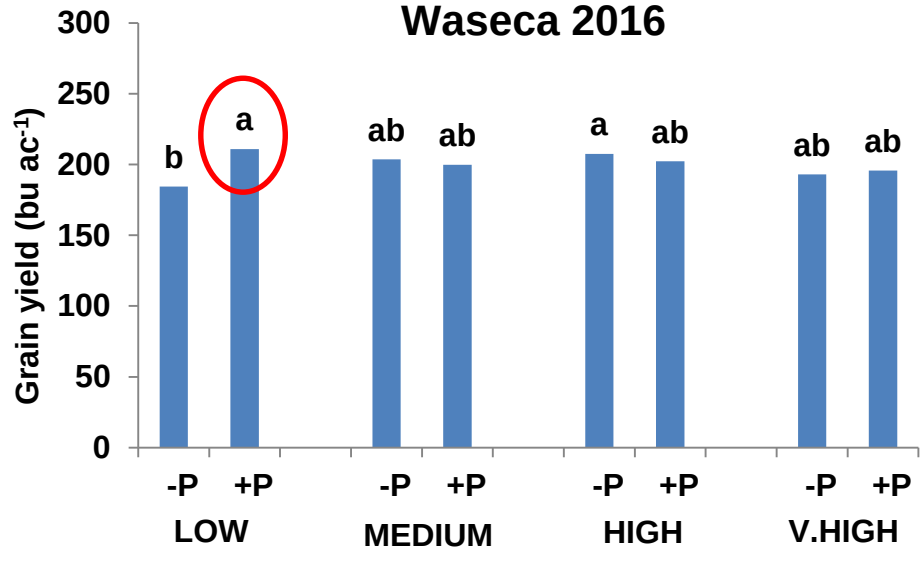


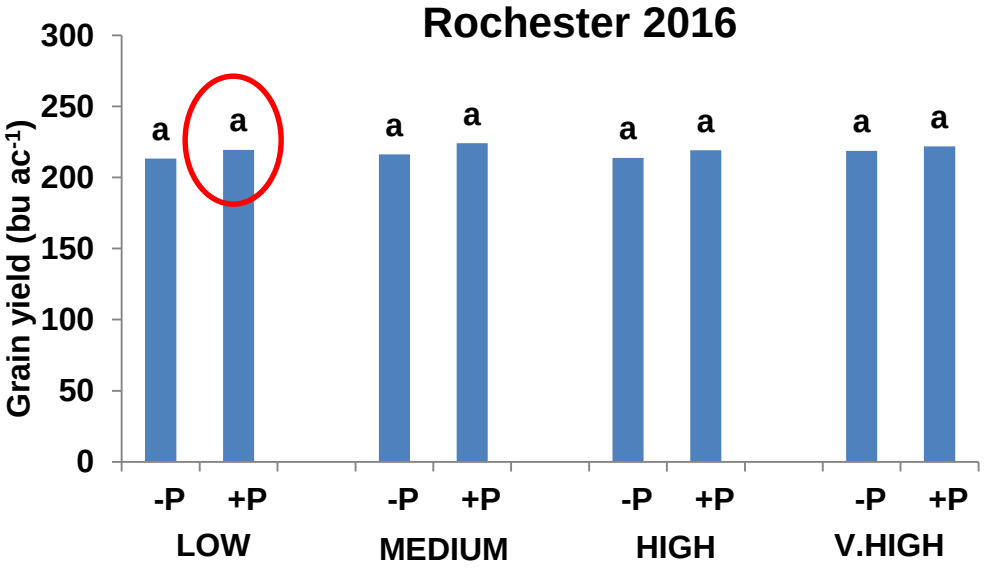


Phase II Corn Yield Residual Effects

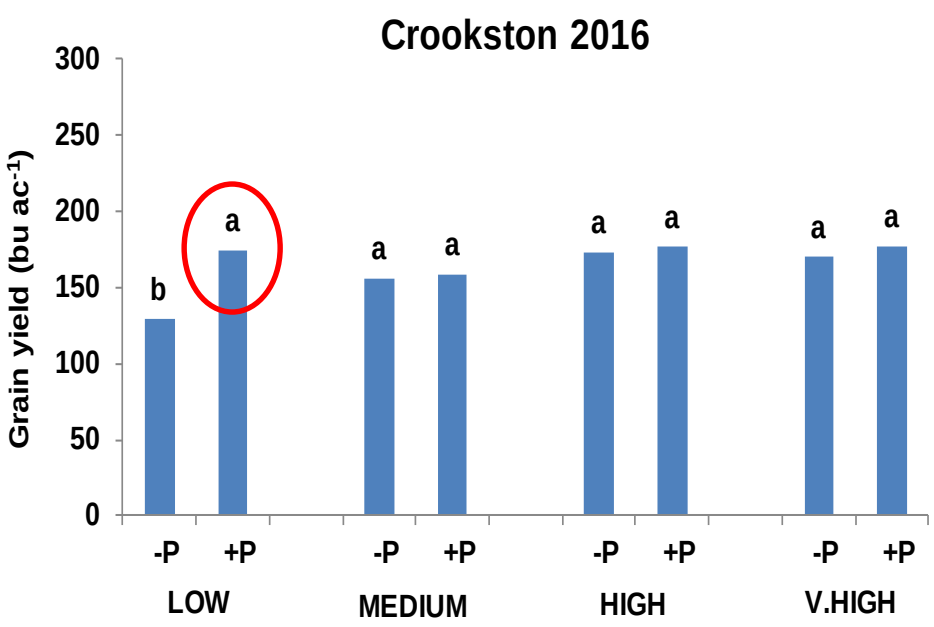


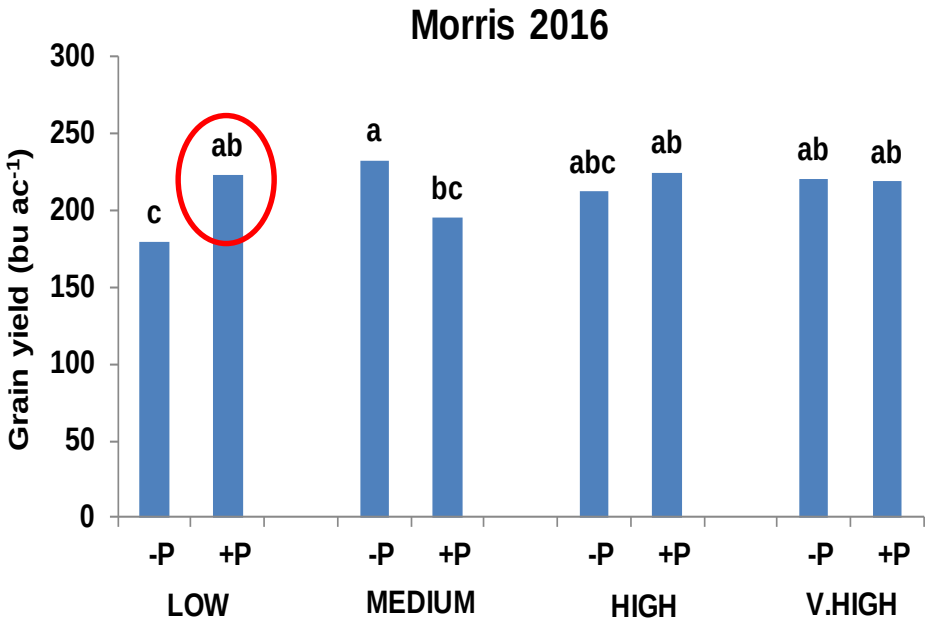






Phase II Corn Yield Residual Effects





Phase II Residual Effect Observations

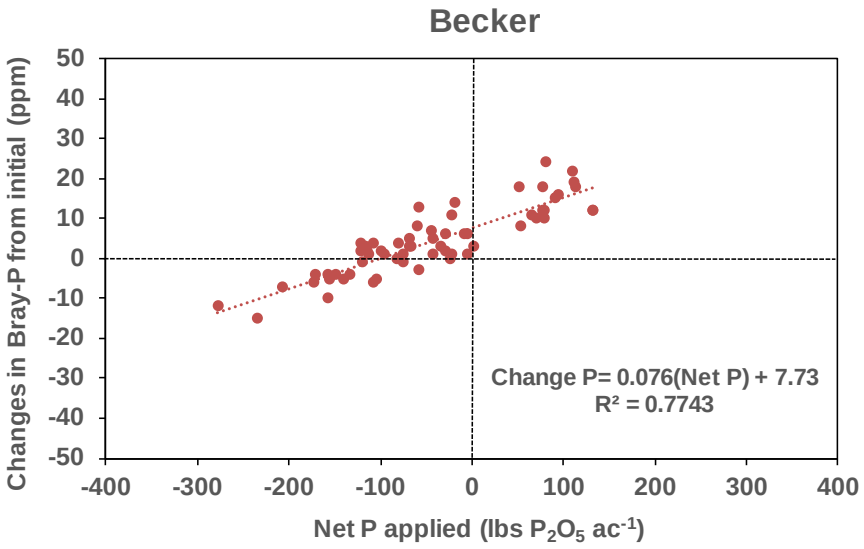
- **STP in P fertilized plot of Low Class did decline somewhat; however, STP still Medium to High and adequate for crop production.**

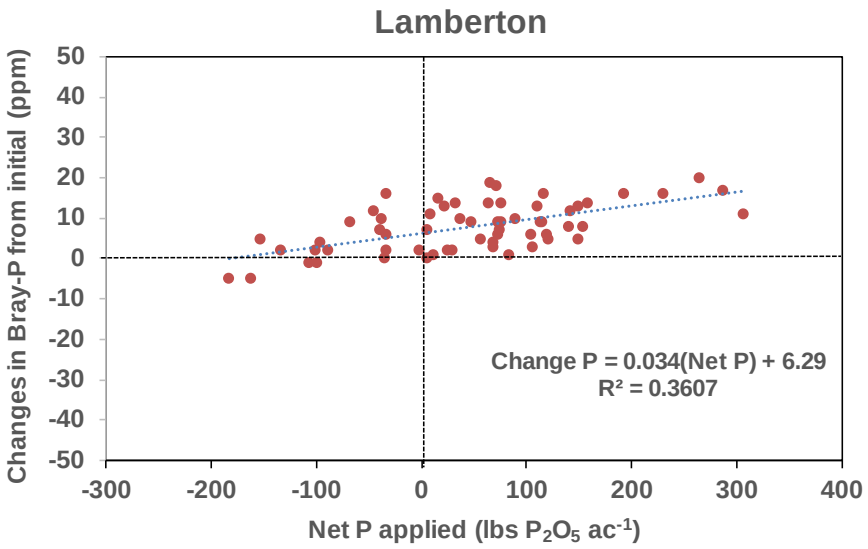
- **Corn yields in 2016 from the P fertilized plot (2015) in Low Class were similar to other fertilized plots; therefore, no additional P fertilizer was needed in year two.**

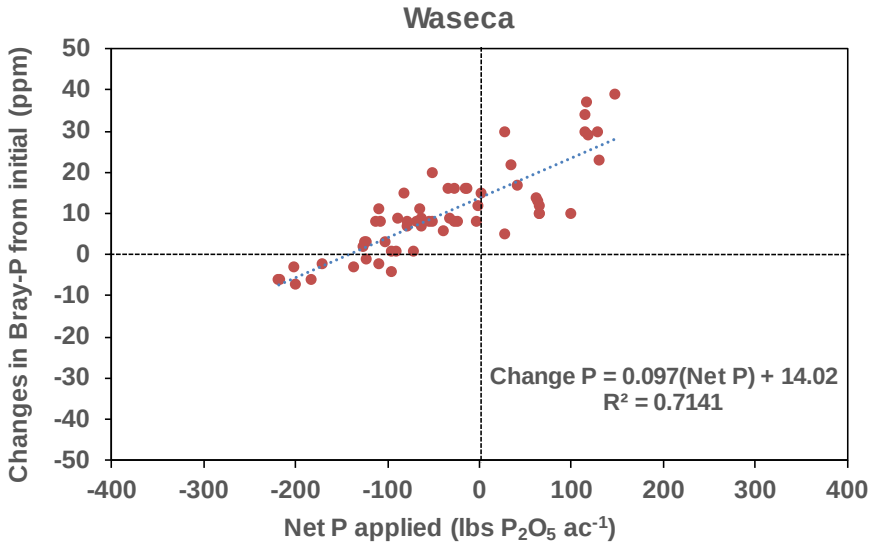
CONCLUSIONS

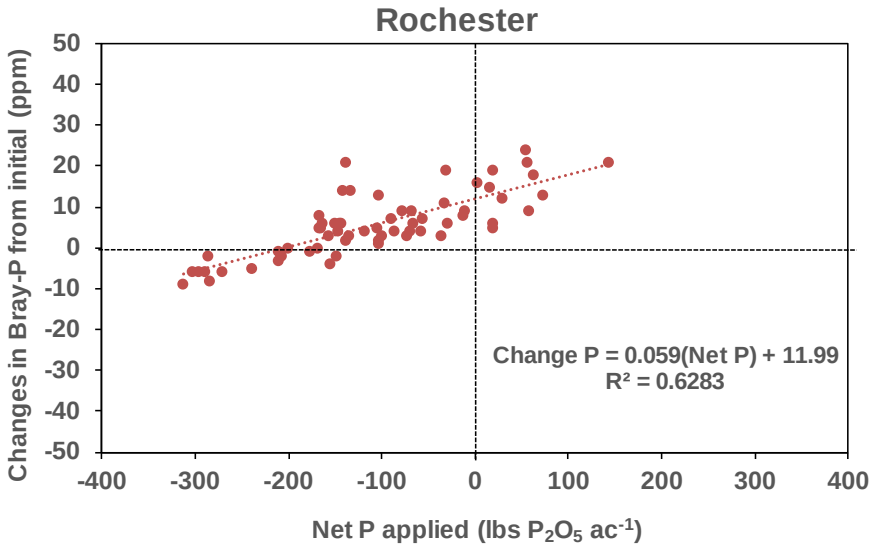
- **Applying P fertilizer to Low and Medium STP classes (Sufficiency Approach) produced the same yields as High and Very High STP classes with or without P fertilizer.**
- **Therefore, applying P fertilizer using a build and maintain approach or at crop removal rates did NOT increase corn and soybean yield potential compared with sufficiency approach.**
- **Following a build and maintain approach would result in greater input (fertilizer) costs and lower economic returns.**

Changes in STP vs Net P_2O_5 applied

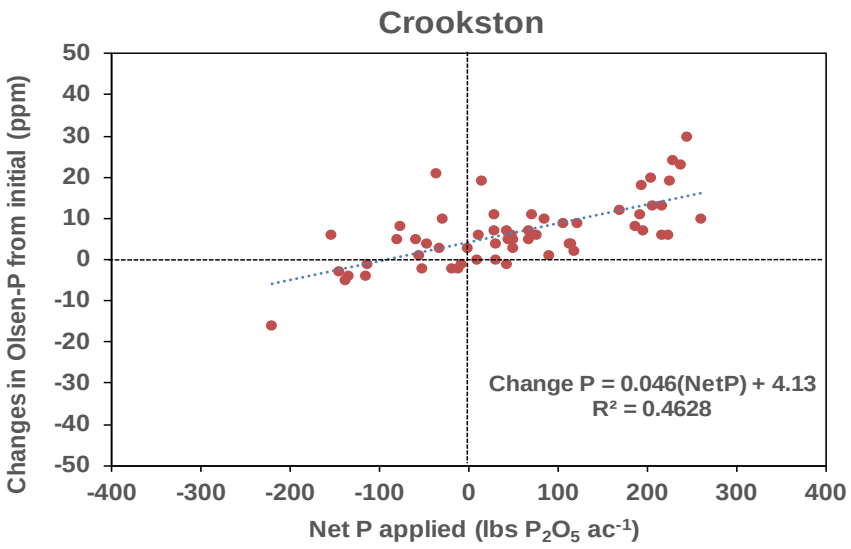


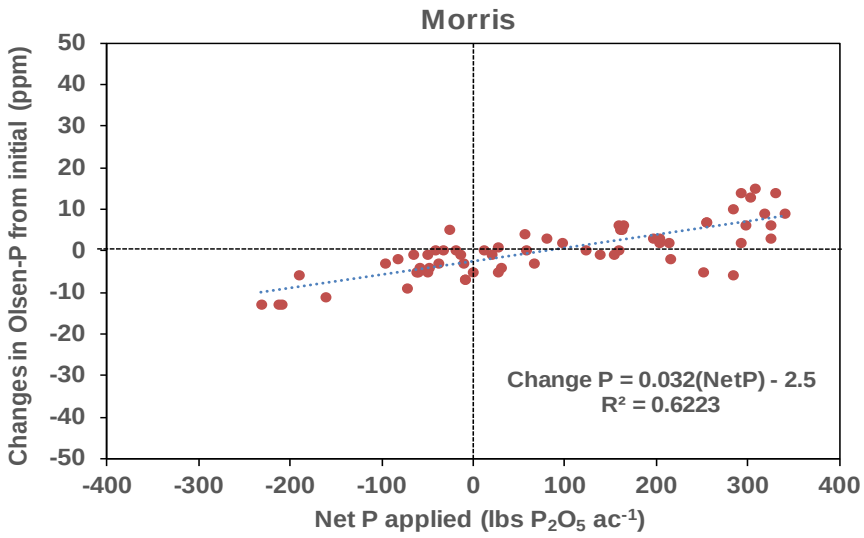




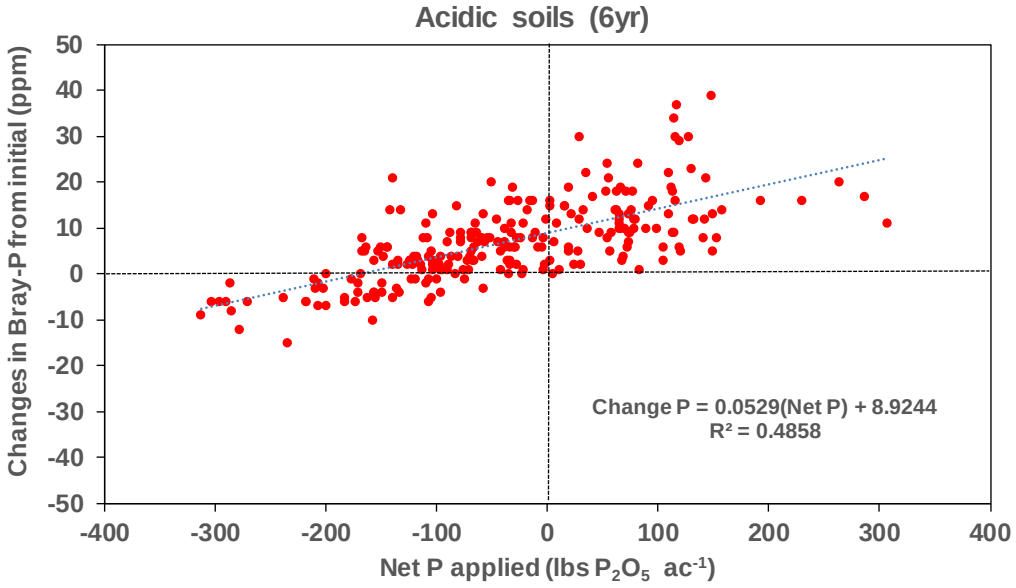


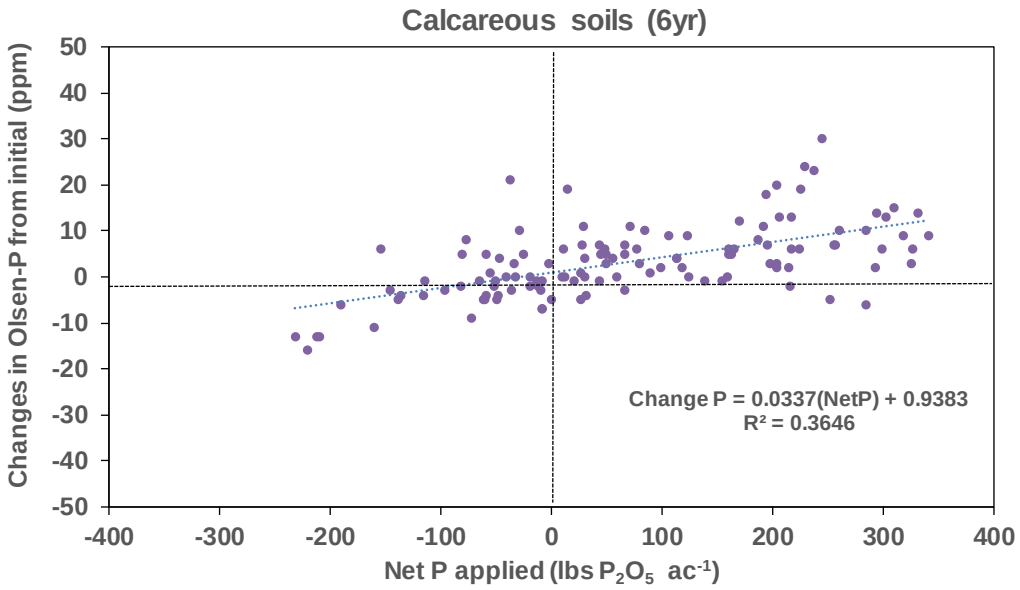
Changes in STP vs Net P_2O_5 applied





Changes in STP vs Net P_2O_5 applied Acidic and Calcareous soils





After 6 years, when net P addition was 0 (P removed=P applied) a positive net change of 1.5 ppm yr^{-1} and 0.2 ppm yr^{-1} was observed for acidic and calcareous soils, respectively (Fig. 4).

Summary of annual soil test change based on crop removal of P following six years for fertilizer application and removal

Location	Soil Test Change when applying P based on crop removal	Annual P application required to Maintain Soil Test
	------ppm yr^{-1}-----	----lb P_2O_5 ac^{-1} yr^{-1}---
Becker	1.3	-16.9
Lamberton	1.0	-31.1
Waseca	2.3	-24.1
Rochester	2.0	-34.0
Crookston	0.69	-15.0
Morris	-0.42	+13.1
Acidic Soils	1.5	-28.1
Calcareous Soils	0.16	-4.64

CONCLUSIONS

- Crop removal rates increased STP, especially on acid soils (Bray P1).
- Build and maintain or crop removal:
  - Will result in greater input (fertilizer) costs.
  - Makes no sense on rented acres.
  - May be difficult B&M some calcareous soils
  - Can provide some flexibility when fertilizer P prices increase unexpectedly (owned acres).
  - May allow you to soil sample less frequently.

When can you reduce fertilizer P inputs?

- If soil test P (STP) is Low or Very Low (<12 ppm Bray or <8 Olsen), **APPLY FERTILIZER P**.
- STP is Medium (12-15 ppm Bray or 8-11 Olsen), a yield response to broadcast P is possible (27%), but may not give an economic return.
- STP is High (16-20 ppm Bray or 12-15 Olsen) a response is unlikely. **A low rate of starter P is fine.**
- STP is Very High (>21 ppm Bray or >16 Olsen). **No fertilizer P is needed. A low rate of starter P is acceptable, IF no broadcast P is applied.**

Questions

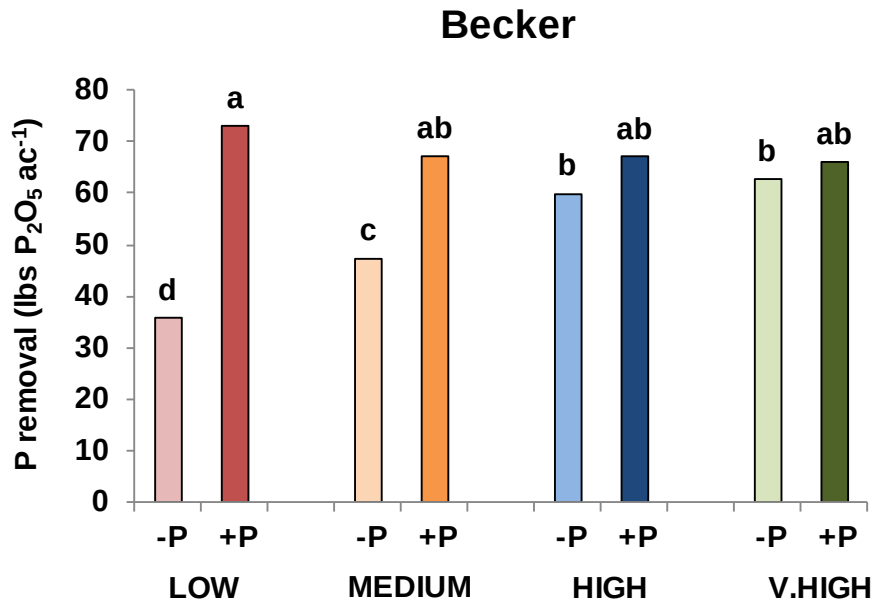
Jeff Vetsch

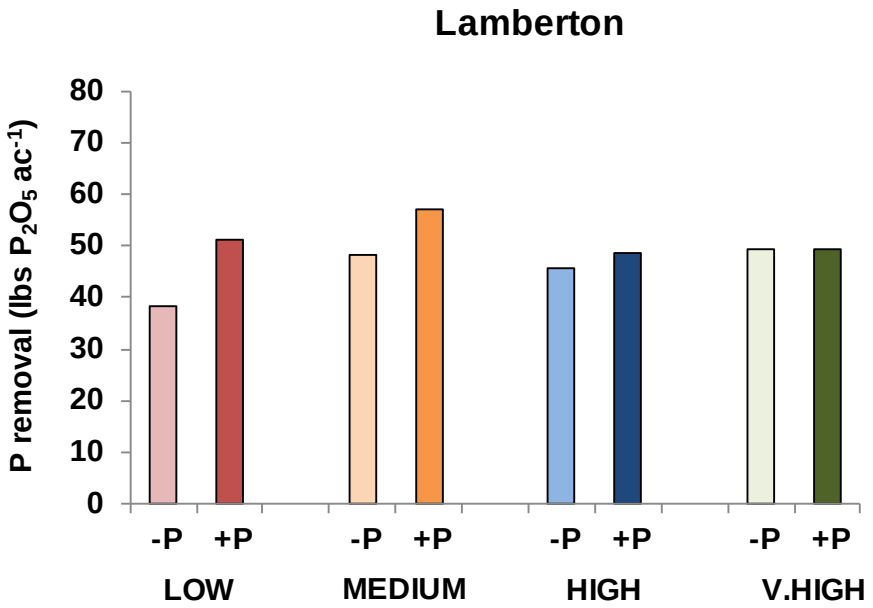
jvetsch@umn.edu

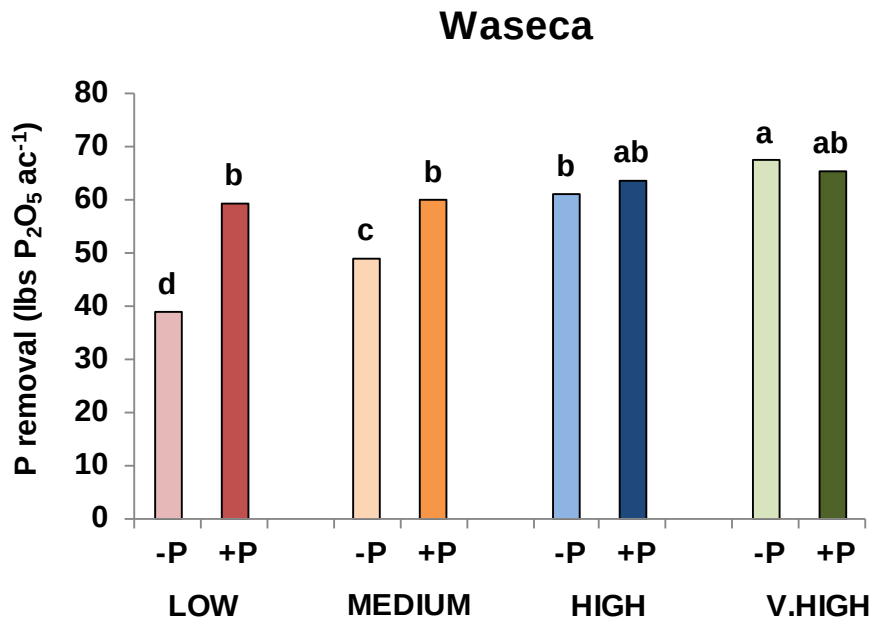
507-837-5654

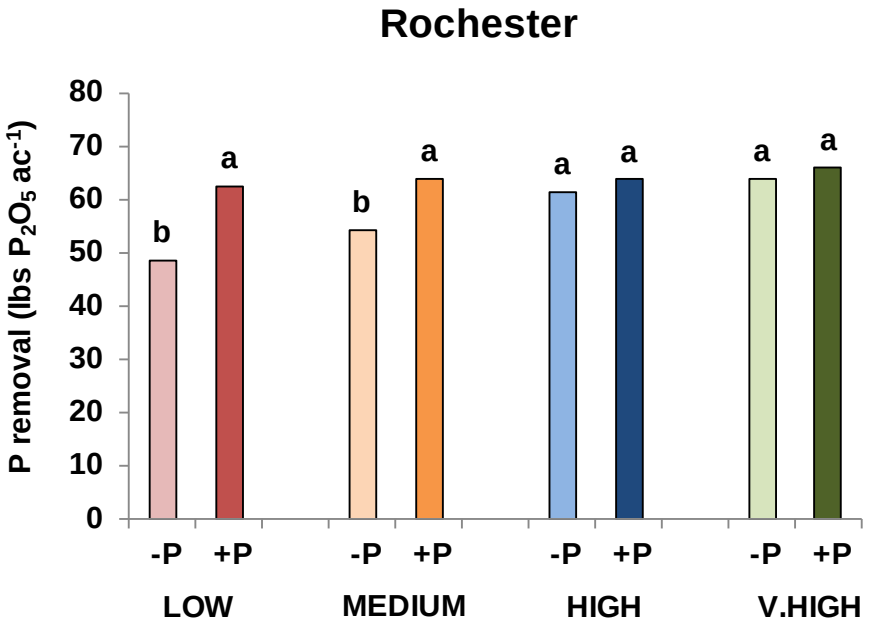
Follow on Twitter
@jvetsch2
@SROCcrops
@UMNNutrientMgmt

Phase II – Grain P removal (2015-2016)

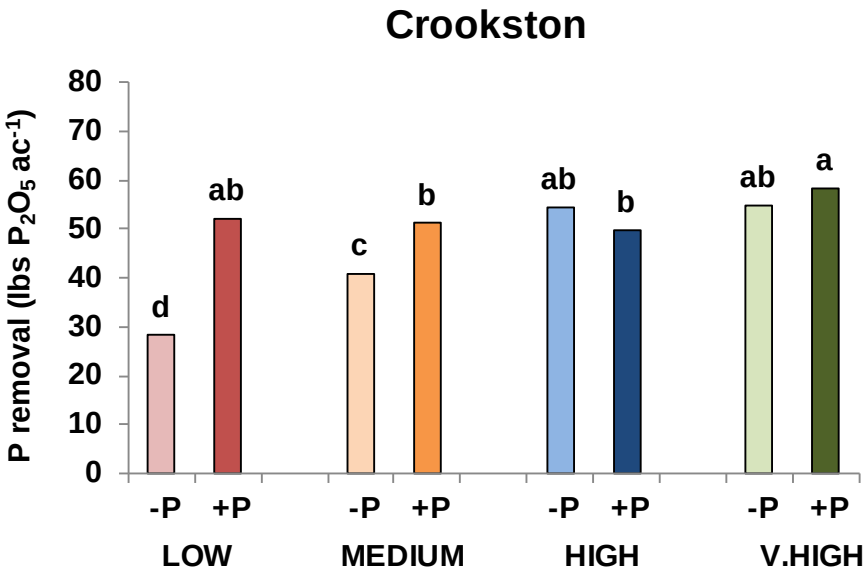


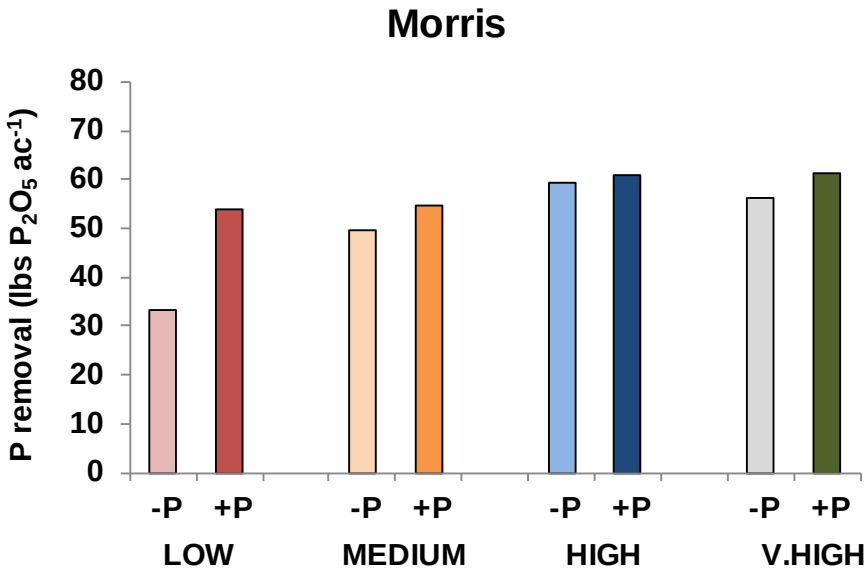






Phase II – Grain P removal (2015-2016)

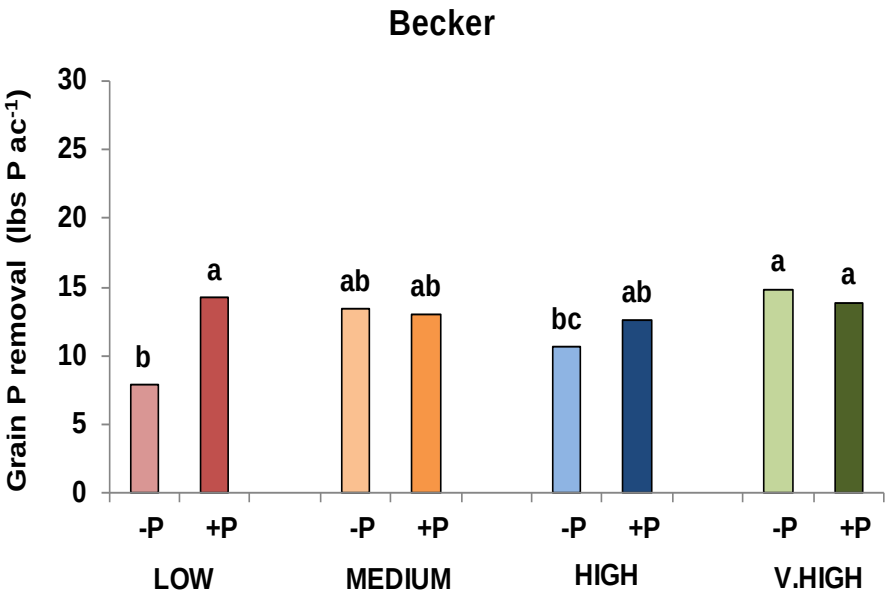


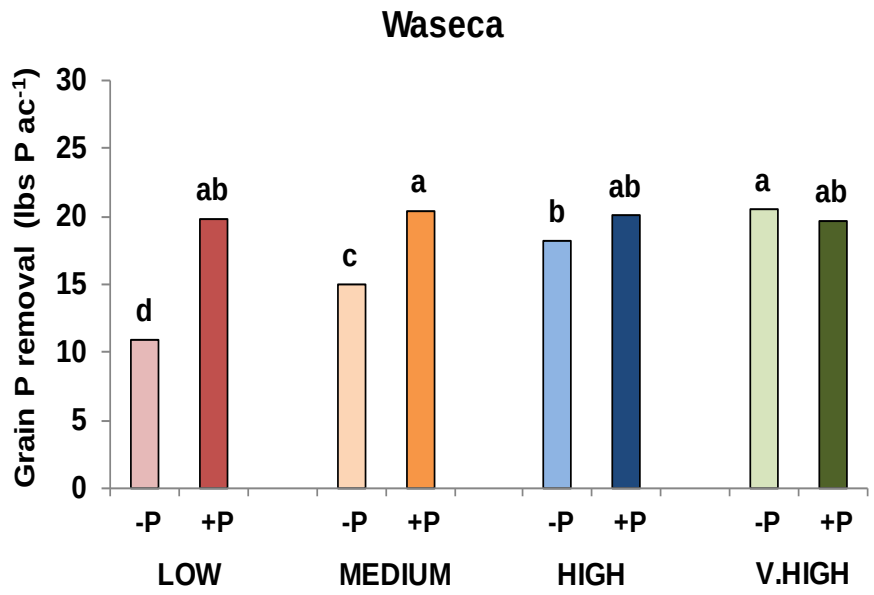


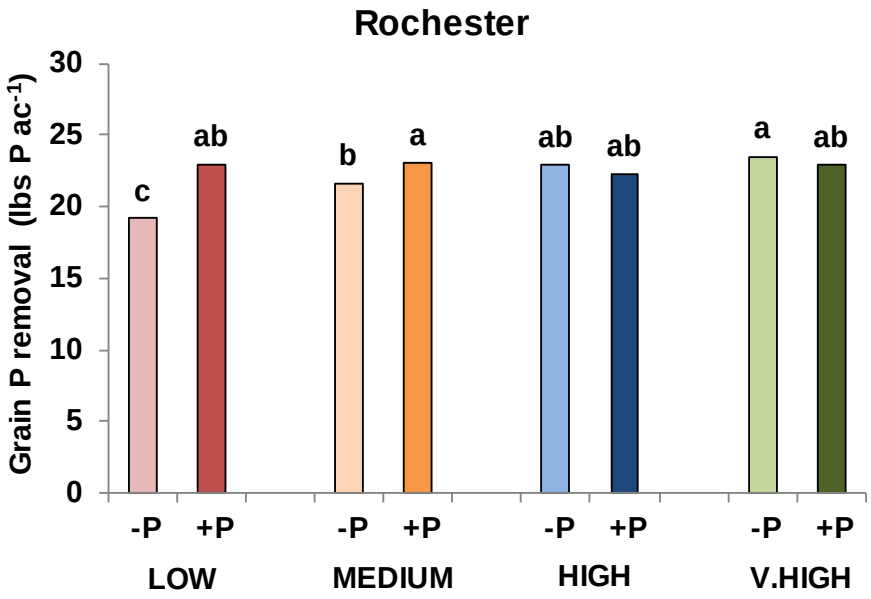
- **Grain P removal was more responsive to P application in 4 of 6 sites.**

- **Fertilizer P (+P) increased P removal in Low or/and Medium classes but not in High and Very High classes.**

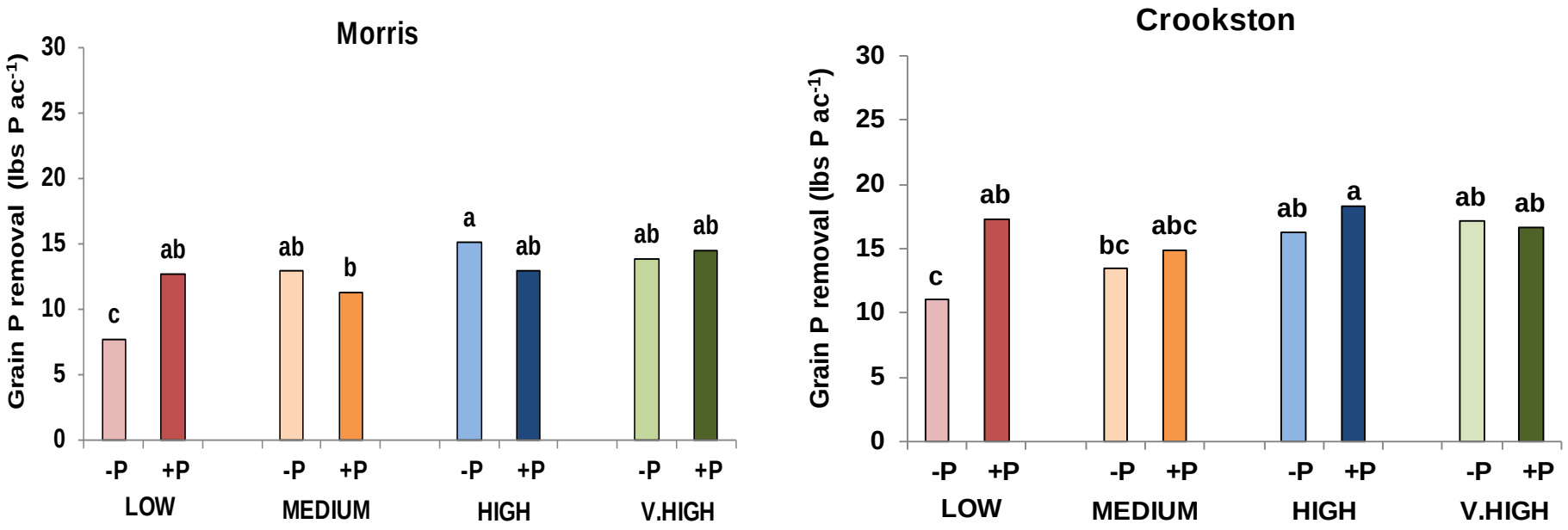
Phase II Soybean Grain P Removal (2017)







Phase II Soybean Grain P Removal (2017)



- **Grain P removal in soybean was more responsive to P application in 5 of 5 sites.**

- **Fertilizer P (+P) increased P removal in Low or/and Medium classes but not in High and Very High classes.**

Nutrient Removal Values Updated through 2015

Corn

- P: n=7806
- K: n=4958
- Removal in lbs/bu
  - P_2O_5 – 0.28
  - K_2O – 0.19

Soybean

- P: n=5071
- K: n=4427
- Removal in lbs/bu
  - P_2O_5 – 0.69
  - K_2O – 1.09

- Values are generated from sites where responses to P or K may or may not have occurred
- Values are median values for removal
  - Actual values may be +/- 10%
  - Mean and median for the dataset are similar