Combining Soil fertility and Soil Health to improve Corn Potassium, Phosphorus, and Sulfur Fertilizer Recommendations

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Co-PIs: Anthony Bly, David Karki, and David Clay SDSU AHPS Department

Summary
Much of the data used to create the soil fertility recommendations for South Dakota in the South Dakota Fertilizer Recommendations Guide and Corn Best Management Practices manual is decades old. Over the past decade, more acres have been planted to corn and soybean creating a shift in crop rotations and yields have increased due to better genetics and improved agronomic practices, removing more nutrients from the soil. Further, soil health practices such as no-till, cover crops, and more diverse rotations are being promoted to improve soil structure, organic matter, nutrient cycling, and the overall health of the soils. There is also a growing interest in measuring these improvements by completing soil health tests. However, a strong connection between soil health measurements and crop yield and nutrient recommendations has not been made to aid producers in making management decisions. This project will address these issues by making the connections between traditional soil fertility tests, soil health tests, and nutrient recommendations. The information from this project will be used to help update current nutrient management recommendations based on measured soil properties and specific management practices.

Goals and Objectives
The goal of this project is to update P, K, and S recommendations in South Dakota under different management practices. The specific objectives of this project are 1) Determine corn yield and nutrient uptake response to added P, K, and S fertilizers under various soil fertility and soil health conditions, and 2) Identify soil health measurements that can alone or in combination with traditional soil fertility measurements be used to improve P, K, and S fertilizer recommendations.

Results:
- Studies have been established at 7 field sites with 4 stamps in each field for a total of 28 stamps.
- Over 200 stamps have been established in Missouri.
- Soil characterization, soil fertility, and soil health samples have been collected at each of these field sites. Soils have been processed and sent to commercial and USDA labs for analysis.
- Graduate student has been selected and started on project.

The experiment is being conducted at 7 sites (Fig. 1) all of which have been in no-till for at least 6 years. Each location had four treatments replicated four times: 1, a control (no P, K, or S); 2, 100 lbs. P_2O_5/ac; 3, 100 lbs. K_2O/ac; and 4, 25 lbs. S/ac. All treatments received N fertilizer at the rate the farmer applied to the remaining field area.

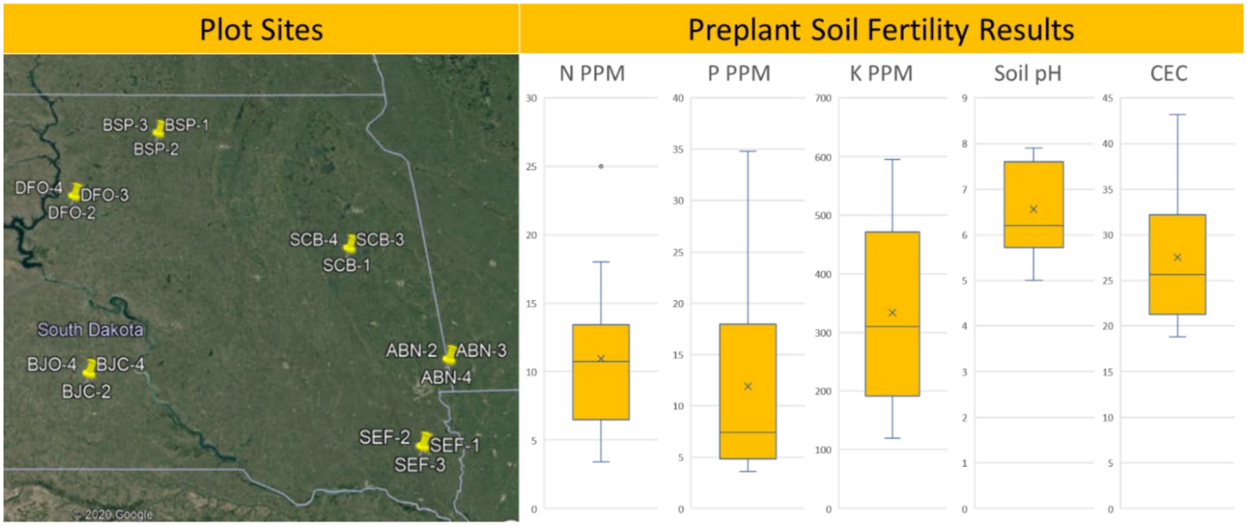

Figure 1. Experimental sites for 2020 and their range in soil fertility values of nitrogen (N), phosphorus (P), potassium (K), soil pH, and cation exchange capacity (CEC).

Among the seven sites, we were able to obtain a good range in soil N (4-25 ppm), P (4-35 ppm), K (110-600 ppm), pH (5.0-7.9), and CEC (18-44 $cmol_c$) of the top six inches of soil. This will aid in creating correlation curves needed for determining at what soil amount of each nutrient do we not see a corn yield response to added fertilizers.

<u>P 100 lbs.</u>

The plots fertilized with P had yields that ranged from 112-266 bu/ac with an average of 186 bu/ac. The yield response ratio averaged at 1.07 while the V6 tissue response averaged at 1.3 (**Figure 2**). Of the sites with low soil test P levels, more than half showed an increase in yield while 5 of the 21 showed a decrease in yield. Of the sites with medium, high, or very high soil test P, none of them showed a decrease in yield while more than half still increased yield (**Table 1**).

<u>K 100 lbs.</u>

The plots fertilized with K had yields ranging from 78 to 273 bu/ac with an average of 170 bu/ac (Figure 2). The yield response ratio averaged at 0.99 and the V6 tissue response averaged at 1.16. For a medium soil test K level, 3 of the 8 sites raised yield while 2 lowered yield. For a high soil test K level, 3 of the 11 sites raised yield while 5 sites lowered it. Lastly, with a very high soil test K level, 10 of the 28 sites raised yield while 7 sites lowered it.

<u>S 25 lbs.</u>

The plots fertilized with S had yields ranging from 81 to 248 bu/ac with an average of 174 bu/ac (Figure 2). The yield response ratio averaged at 1.0. and the V6 response ratio averaged 1.27. All soil test S levels were grouped together as our sampling method and lab data does not match the South Dakota standards of 0-6 and 6-24 in. sampling. Of the 41 sites, 17 showed a positive yield response while 10 showed a negative repsonse.

Since we are still awaiting soil health results from the lab, we have not been able to make comparisons between soil health indicators, soil fertility, and yield for this year's data. Looking at our yield data from both years, an application of phosphorus had a positive effect on yield at all soil test P levels, especially low. The P treatment plots averaged 186 bu/ac compared to the 170 bu/ac of the control plots. An increase in yield across all soil test P levels shows the possibility of adjusting the P recommendations in the future.

Impacts:

- Knowledge of the relationship between phosphorus, potassium, and sulfur response to soil fertility and soil health measurements will be obtained for South Dakota.
- Knowledge will be increased of the relationship between soil health measurements and agricultural management practices
- Training of a graduate and several undergraduate students in soil fertility.
- Extension research report published with the Southeast Research Farm's annual research report.

Project Budget (As of Jan. 1, 2020):

Budget Category	Budget	Total Expenses	Available Balance
Salaries	16,350.00	12,192.42	4,157.58
Benefits	4,256.00	2,448.47	1,807.53
Travel	7,000.00	-	7,000.00
Contractual	20,000.00	8,019.22	11,980.78
Supplies	6,000.00	4,940.66	509.35
Tuition remission			-
Total	**$53,606.00**	**$28,150.76**	**$25,455.24**

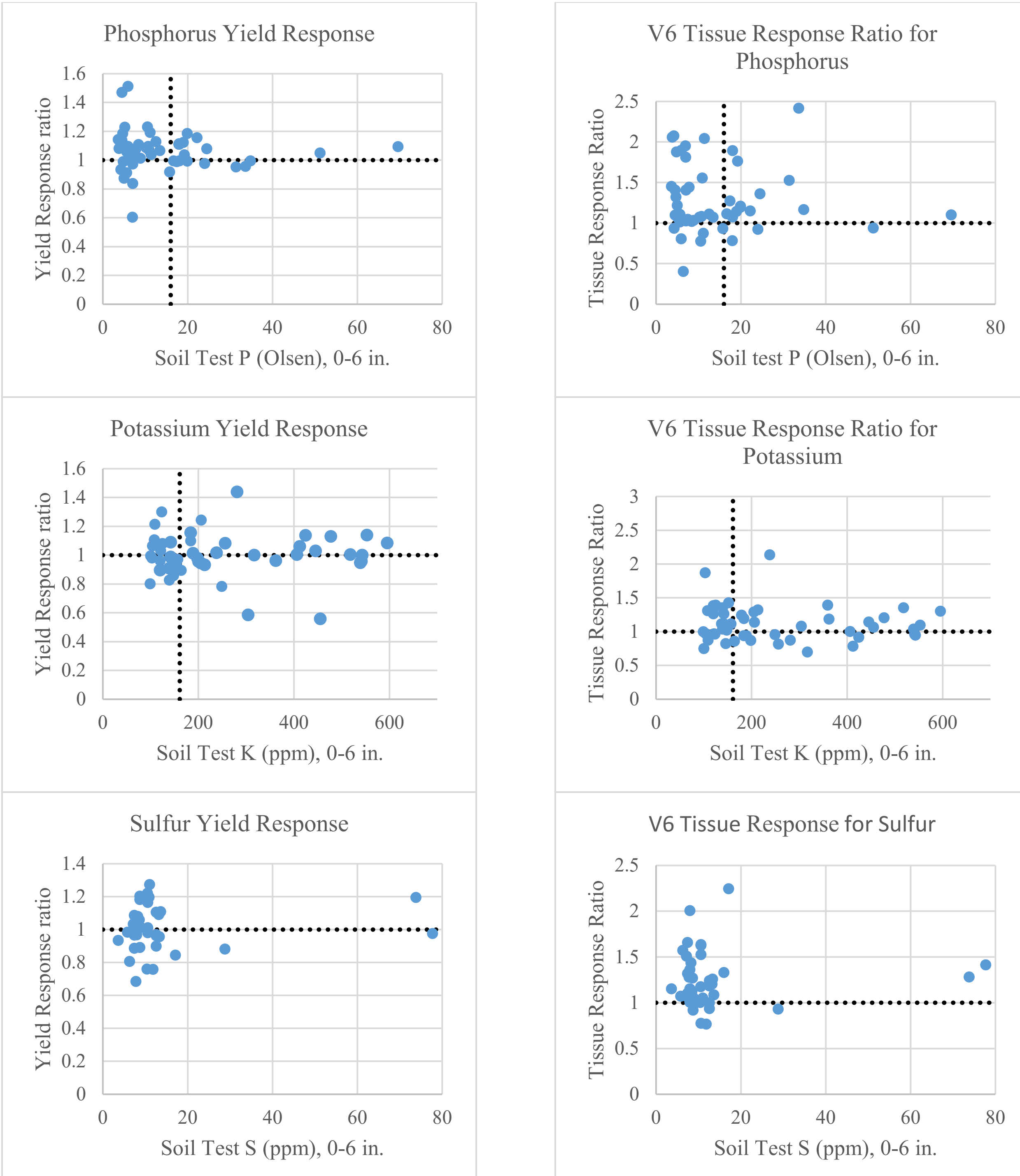

Figure 2. These graphs show both the yield response and the V6 tissue response at all plots from 2019 and 2020. The yield response graphs show the soil test P, K, and S levels compared to the yield response ratios. The vertical dotted lines represent the current cutoff for fertilizer inputs according to the South Dakota Fertilizer Recommendations Guide. Since our soil test S procedure was only 0-6 in. and did not include 6-24 in., the cutoff line was not added for the Sulfur graph. The V6 tissue response graphs show the soil test P, K, and S levels compared to the nutrient uptake of the plant at V6. For example, a P response ratio of 1.5 means that the amount of P in the plant tissue was 1.5 times higher than in the corresponding control plot with no P.

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Changes in climate and land management practices have identified the need to reevaluate the accuracy of current corn (*Zea mays* L.) P fertilizer recommendations in South Dakota (SD). Also, an increase in soil health understanding has created the potential for soil health measurements to be used to improve the accuracy of these recommendations. The objectives for this study were to 1) evaluate the current P and K critical value and 2) determine the effect of including soil health indicators on the accuracy of predicting yield responses to fertilization. This project was conducted throughout central and eastern SD from 2019-2021 at 97 experimental areas that varied in management, landform, and soil type. A fertilizer addition treatment of 100 lbs P_2O_5 ac^{-1} and 100 lbs K_2O ac^{-1} was compared to a control with no P or K fertilizer. Soil health and fertility samples (0-15 cm) were collected before fertilization and analyzed for physical, chemical, and biological characteristics.

For P, positive yield responses to P fertilization were observed at many soil test P (STP) levels beyond the current critical value of 16 mg kg^{-1}, indicating a critical value of 20 mg kg^{-1} would better fit our dataset. However, there was no change in RSE (0.145) and model accuracy was only improved by 1%, meaning there was not sufficient evidence to merit a critical value change. Random forest variable importance methods found differences among variables, although they were not significant. Decision tree analysis found several variables (Olsen P, CEC, soil respiration, and clay content), that when split using a decision tree, improved prediction accuracy to 74% compared to 63% when using Olsen P alone. These results demonstrate that soil health indicators along with soil fertility testing improves the accuracy of our yield response predictions to P fertilizer.

For K, positive yield responses were only observed at 27% of sites, likely because only 33% of sites had soil test K values below the current critical value of 160 ppm. Modeling showed the critical value could be lowered (140 ppm), but the model significance was never below 0.05, meaning more data points or different modeling approaches are needed before any change in the current critical value should be made. Random forest variable importance methods found differences among variables, but these differences were not significant. Decision tree analysis found several variables (soil test K, tillage practice, and pH), that when used to split a decision tree, improved prediction accuracy to 77% compared to 63% when using soil K alone. These results demonstrate that soil health indicators along with soil fertility testing improves the accuracy of our yield response predictions to K fertilizer.

Goals and Objectives

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Results:

- Studies have been established at 7 field sites with 4 stamps in each field for a total of 28 stamps in 2020 and 15 field sites with 4 stamps in each and 1 with 3 stamps for a total of 59 stamps in 2021.
- Over 200 stamps have been established in Missouri.
- Soil characterization, soil fertility, and soil health samples have been collected at each of these field sites. Soils have been processed and sent to commercial and USDA labs for analysis. V6 Tissue samples and grain samples have also been collected and sent to commercial labs for nutrient analysis.
- Grain yields obtained from 2022 growing season and are currently being compared to soil health and fertility measurements.

Phosphorus

Our current P recommendations were compared to yield responses (**Figure 1**). The data points ranged from less than Olsen P of 5 ppm to approximately 70 ppm. Yield responses ranged from 50% losses to 50% gains.

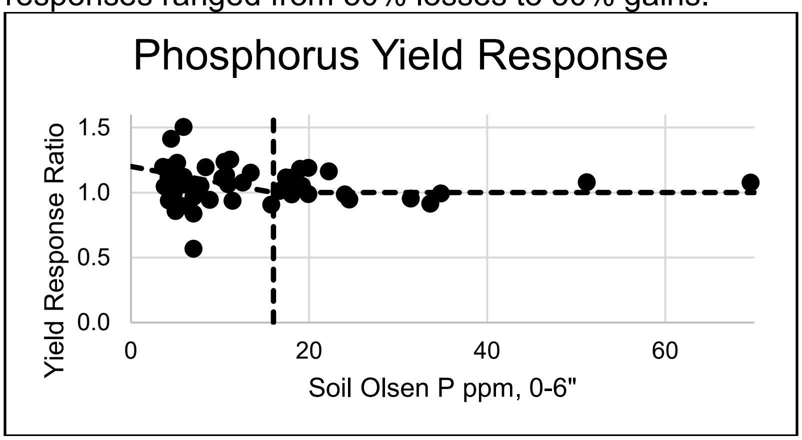

Figure 1. Corn yield response with added P fertilizer as a function of soil test P levels (Olsen-P). A yield response of 1 means the treatment plot yielded the same as the control plot. A vertical line represents the current critical value (Olsen P 16 ppm). The horizontal line represents the theoretical ideal regression line where yield responses should no longer be seen past the critical value. The yield response is considered a “response” in the tables when it is at least 5% higher than the control plot (a yield response ratio of ≥1.05).

The current recommendations are considered “correct” when Olsen P is below the critical value and yield was raised with a P application or if yield did not increase when Olsen P was above the critical value. The current critical value of 16 ppm was right 54% of the time. By increasing the critical value to Olsen P 24 ppm, the current recommendation increased to being right 64% of the time.

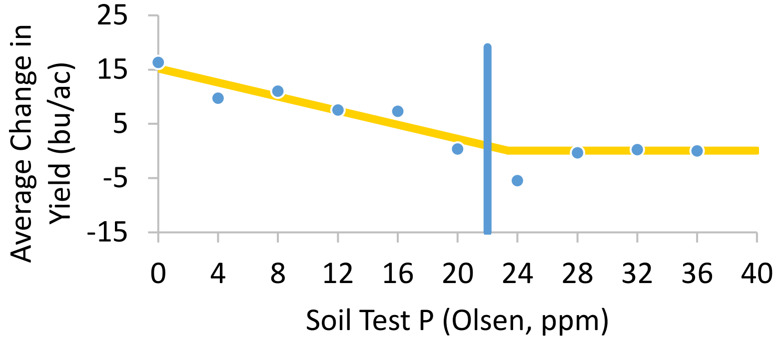

Figure 2. Average change in corn yield as a function of soil test P.

In evaluating change in yield as a function of soil test P, we see a decrease in yield change as soil test P increases until we hit 22 ppm Olsen P (Figure 2). This value is close to the 24 ppm shown in the relative yield graph above (Figure 1). We can use the average change in yield graph to determine what yield increase we want to see before we fertilizer. For example, if we want a minimum of a 5 bu ac^{-1} yield increase then 16 ppm Olsen P would be our critical value, which is the current critical value used for South Dakota.

Potassium

In the K fertilized plots, V6 dry mass decreased by 3% from the control plot but K uptake increased by 15%. Both P and S uptake also slightly increased by 5% and 8%, respectively. Grain K content averaged 5% higher while P and S remained roughly the same as the control. Across all sites, yield was lowered 3% with a K application, possibly due to 60% of sites already being sufficient in K.

For soil types, the only texture that significantly raised yield was sandy clay loam, but this soil type was only present at one site. Silt loam soils also showed a slight increase in yield when they were deficient in K. The V6 K content generally increased with K application on coarser textured soils with insufficient K in the soil. Grain K content was not significantly different among soil types.

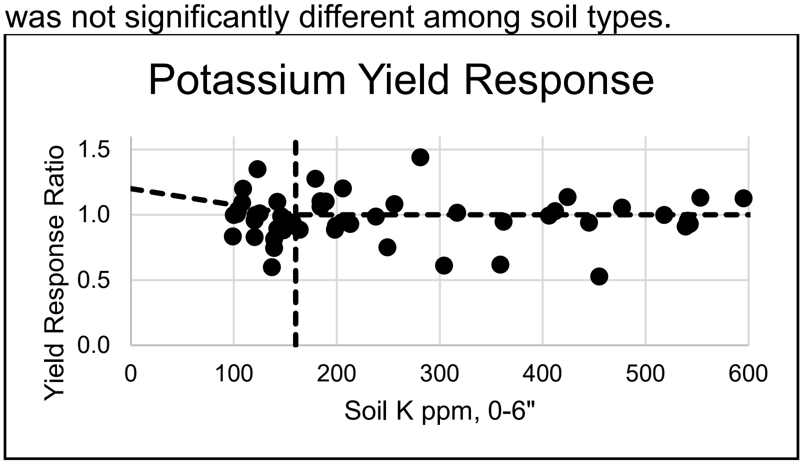

Figure 2. Corn yield response with added K fertilizer as a function of soil test K levels. The vertical line represents the current critical value (K 160 ppm), and the horizontal line is the theoretical ideal regression line.

Lowering the current K critical value from 160 ppm to 120 ppm would increase the accuracy of the recommendations from 46% to 66% (**Figure 2**). Since only 12% of sites would be considered insufficient at a critical value of 120 ppm, more testing needs to be done on K-deficient sites to see how they react to K applications.

Products and Impacts:

- Knowledge that the use of additional soil tests besides soil test P and K can be used to improve the predictability of crop response to fertilizer P and K applications.
- Training of a graduate and several undergraduate students in soil fertility.
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- Abstract and poster presentations of study results at the ASA/CSSA/SSSA annual International Conference (1 oral and 2 poster presentations)
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- Interactive social media posts relating preliminary results
- Two Research reports published in the annual Southeast Research Farm's annual research report.
- 7 extension presentations to South Dakota farmer and agronomists related to improving P and K fertilizer response predictions.

Budget:

Project Budget (As of Dec. 1, 2022):

Budget Category	Budget	Total Expenses	Available
Salaries	$13,900.00	$4,760.03	$9,139.97
Benefits	$4,241.00	$2,044.24	$2,196.76
Travel	$6,000.00	$2,922.56	$1,208.29
Contractual	$39,500.00	$8,125.46	$0.55
Supplies	$5,000.00	$3,847.54	-$2,029.08
Tuition remission	$0.00	$0.00	$0.00
Capital Equipment	$0.00	$0.00	$0.00
Non-Capital Equipment	$0.00	$0.00	$0.00
F&A (Indirect) Charges	$0.00	$0.00	$0.00
Total	**$68,641.00**	**$21,699.83**	**$10,516.49**

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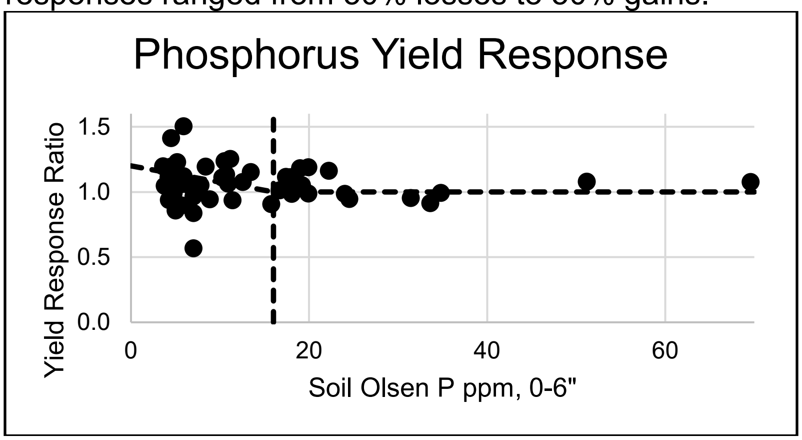

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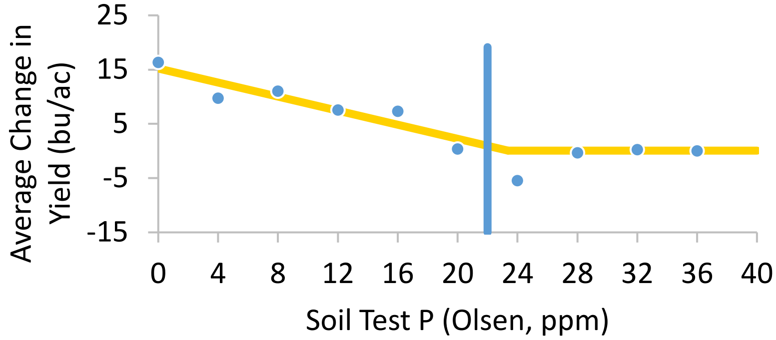

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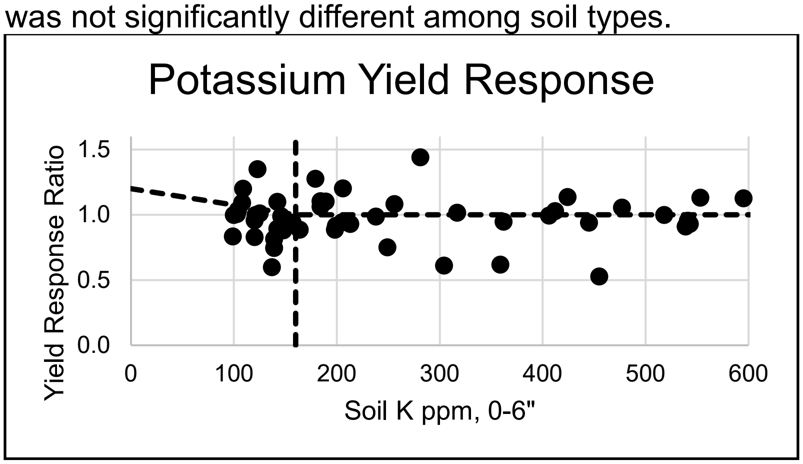

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Budget:

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Salaries	$13,790.00	$3,210.29	$10,579.71
Benefits	$3,907.00	$692.98	$3,214.02
Travel	$6,000.00	$840.92	$5,159.08
Contractual	$32,500.00	$21,645.34	$10,854.66
Supplies	$5,000.00	$2,072.30	$2,927.70
Capital Equipment	$8,796.00	$7,500.00	$1,296.00
Non-Capital Equipment	$0.00	$113.00	-$113.00
Total	**$69,993.00**	**$36,074.83**	**$33,918.17**