

# Can Including Soil Biological and Physical Measurements Improve the Predictability of Corn Response to P Fertilization

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## CORE IDEAS

- Soil test phosphorus was the most influential predictor of corn yield response to P fertilization.
- Including additional soil fertility, soil texture, or selected soil health variables had a minimal impact on improving prediction of corn response to P fertilization (<7% improvement in explained variability).
- The use of typical soil fertility measurements without selected soil physical and biological measurements is still the best option for predicting responsiveness of corn to P fertilization in South Dakota.

## INTRODUCTION

Soil testing with extracting solutions for available nutrients has been the standard for determining nutrient availability since the 1950's. The soil testing approach is based on identifying a critical value that separates a soil test response into zones that are deficient and sufficient. Recent studies in South Dakota have shown good relationships between relative yield, the percentage of responsive sites, and delta yield with Olsen STP. Using the critical STP value of 16 ppm resulted in the accuracy of correctly categorizing a site as responsive or unresponsive to be 70%. However, there was high variability in determining the critical STP value (Confidence interval range of 7-21 ppm) and 40% of sites with Olsen STP >16 ppm still showed a response to P fertilization while 22% of sites < 16 ppm did not respond to P fertilization. Therefore, further evaluations on what additional soil fertility, soil physical, and soil

biological measurements can be included with STP is needed to improve the predictability of corn response to P fertilization. The objective of this research was to determine if the predictability of yield response to P fertilization would be improved by considering additional selected measurements of the soil biology, physical, and chemical properties.

## MATERIALS AND METHODS

### Research Sites and Experimental Design

Research trials were conducted at 35 locations across central and eastern South Dakota from 2019 to 2022 (Figure 1). Locations varied in management practices, landforms, and soil types. At each field between 3 and 5 fertilizer response experiments were conducted in different topographic areas that would likely vary in soil test P (STP) for a total of 117 fertilizer response monitoring sites. The P fertilizer treatments consisted of a control without P fertilizer and a treatment with 100 lbs P<sub>2</sub>O<sub>5</sub>/ac applied as triple super-phosphate (0-46-0). This rate applied was considered substantial enough to maximize the likelihood of seeing a yield response to P fertilization and the current South Dakota P recommendations for an expected yield of 200 bu/ ac. Nitrogen was applied to all treatments based on the farmer's usual rate of N and placement practices. The cooperating farmer selected the corn hybrid for planting and completed all other agronomic practices according to their standard practices.

Soil samples were taken at each monitoring site in the spring before planting or fertilization at the 0-6 in. depth.

The samples were then analyzed for Olsen P, typical soil fertility variables (pH, soil organic matter, apparent cation exchange capacity), soil texture (percent sand, silt and clay), and selected soil health variables [total C, total N, permanganate oxidizable C, soil respiration, and enzymes related to nutrient cycling (arylsulfatase, acid phosphatase, and beta glucosidase)]. The center two rows of each plot were harvested, and grain yields were adjusted to 15.5% moisture.

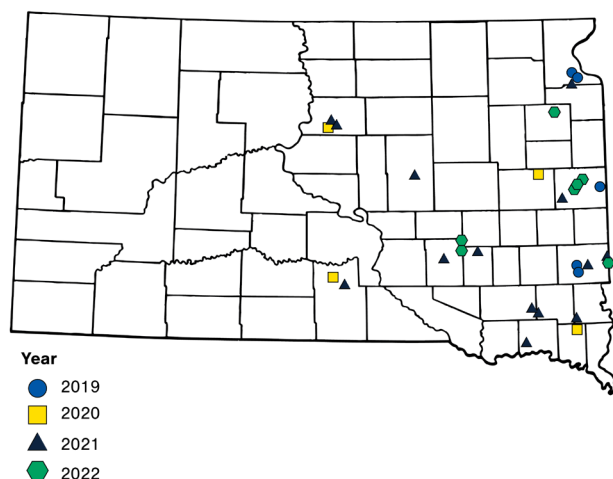


Figure 1. Map of South Dakota showing locations of field experiments.

## RESULTS AND DISCUSSION

### Combining soil fertility, physical, and biological properties

The random forest machine learning technique can be used to identify the relative importance of variables in a dataset in predicting the dependent variable, which in this study is the response of corn yield to P fertilization. Variables from the model were ranked by importance using the increase in node purity and increase in MSE parameters (Archer & Kimes, 2008). Both increase in node purity and mean square error indicated that Olsen STP was the most influential predictor of relative yield (Figure 2). The only other consistent variable that had a strong influence on relative yield was apparent cation exchange capacity (CECa) that was listed second for increase in node purity and fourth in increase in MSE. This variable is likely important for predicting P response because soils with high CECa and clay content have a greater ability to fix P into plant-unusable forms (Penn & Camberato, 2019). Thus, soils with a higher CECa, would likely need a different P fertilizer rate than soils with a lower CECa. Current South Dakota P recommendations do not include CECa. Therefore, these results indicate that CECa has the potential to improve P fertilizer recommendations. All other soil fertility and texture

variables evaluated varied in their level of importance measured by the two variable importance methods used in this study.

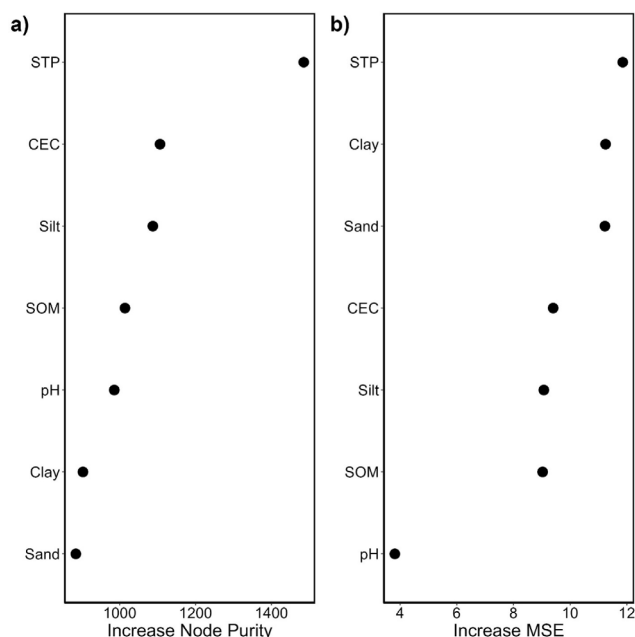


Figure 2. Random forest variable importance plots (VIP) for predicting corn yield response to P fertilization. The two methods of VIP shown include a) the increase in node purity that shows the reduction in the residual sum of squares at each random forest node split and summed over all splits and trees and b) the percent increase in mean square error (MSE) as each variable is randomly selected and permuted over the dataset while all other explanatory variables are held constant. A higher mean increase in node purity and MSE means a variable was more important to the model.

Including additional soil fertility, soil texture or selected soil health variables had a minimal impact on improving prediction of corn response to P fertilization (<7% improvement in  $R^2$ ) (Table 1). Specifically, including pH, SOM, and apparent cation exchange capacity (CECa) with STP increased the  $R^2$  value by 6% and including soil texture and/or soil health variables in the model only improved the  $R^2$  value by  $\leq 3\%$  with the RMSE only changing by 1%. These results indicate that including additional soil fertility variables of pH, SOM, and CECa that are commonly included in soil testing can improve the prediction of corn yield increase from P fertilization. However, including soil texture or selected soil health variables had a minimal impact on improving prediction of yield response to P fertilization. Additionally, the economic cost of testing for these additional soil texture and soil health variables would not likely be worth the small increase in  $R^2$  from including them in the P response prediction models. Therefore, the use of typical soil fertility measurements without soil physical and biological measurements is currently the best option for predicting the responsiveness of corn to P fertilization in South Dakota.

Table 1. Model statistics for random forest algorithms predicting corn yield response to P fertilization using soil test P alone and soil fertility, soil texture, and soil health variables.

| Model Input Categories                 | Calibration    |      | Validation     |      |
|----------------------------------------|----------------|------|----------------|------|
|                                        | R <sup>2</sup> | RMSE | R <sup>2</sup> | RMSE |
| Soil test P only                       | 0.18           | 7%   | 0.02           | 11%  |
| Soil fertility                         | 0.24           | 8%   | 0.18           | 10%  |
| Soil fertility + texture               | 0.27           | 8%   | 0.31           | 9%   |
| Soil fertility + soil health           | 0.27           | 8%   | 0.28           | 9%   |
| Soil fertility + texture + soil health | 0.26           | 8%   | 0.41           | 9%   |

## CONCLUSIONS

To improve the accuracy of predicting corn responsiveness to P fertilization beyond the 70% found in this study, additional soil fertility, soil physical, and soil biological measurements were included in prediction models. However, inclusion of additional soil biological and physical measurements into random forest models did not substantially improve predictions of yield response to P fertilization (<7% improvement). Random forest variable importance methods affirmed Olsen STP as the most important factor with CECa as a second factor that highly influenced the prediction of yield response to P fertilization. Therefore, the use of typical soil fertility measurements without selected soil physical and biological measurements is still the best option for predicting responsiveness of corn to P fertilization in South Dakota. Continued research will be needed to determine additional soil testing methods that can improve P recommendations across varying management practices and climate areas.

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