

Evaluating the Soil Test Phosphorus Level Where No Further Corn Yield is Expected from Phosphorus Fertilization

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Core Ideas

- Corn relative yield increased as soil test P increased until it plateaued at an average of 18 ppm, which is close to the current P critical value of 16 ppm.
- Yield response frequency decreased from 100% when soil test P was <4 to 33% when soil test P was > 30 ppm.
- The average delta yield between corn fertilized with P and without generally decreased as soil test P increased and reached zero at a soil test P of approximately 27 ppm.
- On average, using the current soil test P categories one could expect an increase in yield from P fertilization of 16, 21, 16, 10, and <6 bu/ac for the very low, low, medium, high, and very high STP categories (very high only including STP from 16-19 ppm), respectively.
- Overall, mean yield response frequency and delta yield plateaued around the 16-19 ppm range in soil test P, providing further evidence that when soil test P reaches between 16 and 19 that minimal yield response of corn to P fertilization is expected.

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. Since creating the South Dakota P recommendations (over 20 years ago) the adoption of no-tillage has increased, soil organic matter content has increased, and corn yields have steadily climbed.

These shifts in genetic, climatic conditions, and management practices likely changed soil processes that impact the dynamics of plant-available P in the soil. For example, using no-till compared to conventional tillage can increase total P in soils (Essington & Howard, 2000). Including cover crops causes changes in the soil organic matter (SOM) fraction of the soil, which has a large pool of soil P (Torbert et al., 1996). Cover crops can immobilize P while they are growing that is later released as the cover crop decomposes (Bünemann, 2015). Further, cover cropping has been associated with increases in mycorrhizal fungi that aid with plant uptake of P (Hallama et al., 2019). Including the above field management practices has improved the health and function of soils that likely impact the abundance of plant-available P (Alagele et al., 2019; Karlen et al., 2017; Nunes et al., 2020; Veum et al., 2015). Thus, the objective of this research was to evaluate the accuracy of current South Dakota corn P recommendations in predicting yield increases.

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 P₂O₅/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.

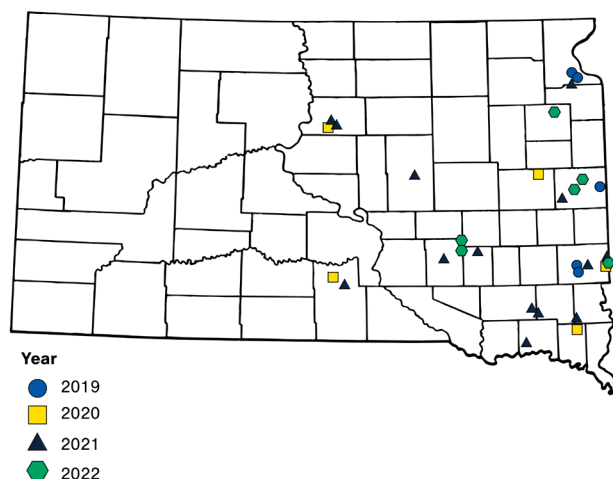


Figure 1. Map of South Dakota showing locations of field experiments.

Sampling and Laboratory Analyses

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, pH, soil organic matter, and cation exchange capacity. The center two rows of each plot were harvested, and grain yields were adjusted to 15.5% moisture. Relative yield was calculated for each monitoring site by dividing the control plot by the P fertilized treatment plot and multiplied by 100.

Data Management and Statistical Analyses

Current South Dakota P fertilizer recommendations group STP into classifications of very low, low, medium, high, and very high. The beginning of the very high classification is the critical value where P fertilization is no longer recommended. This value for Olsen STP is 16 ppm. Other relationships explored were for delta yield (P fertilized yield – control yield) and percentage of responsive monitoring sites as a function of STP. For these evaluations the monitoring sites were grouped in 4 or 8 ppm intervals (0-3, 4-7, 8-11, 12-15, 16-19, 20-23, 24-27, 28-35, and ≥ 36 ppm). Increments of 4 were used until we reached greater STP levels where there

were fewer sites. To increase the number of sites within each interval, the intervals were increased to 8 ppm. Monitoring sites were considered responsive when the P fertilized plot increased grain yield $>5\%$ compared to the control plot. This number was then compared to the total number of monitoring sites within each interval to calculate the percentage of responsive sites within each STP interval.

Results and Discussion

Evaluating accuracy of fertilizer recommendations

Olsen STP ranged from 3.6 to 106.7 ppm with a mean of 17.6 ppm. In all, 57% of the monitoring sites were below the current South Dakota critical STP value of Olsen P 16 ppm (Figure 2; Table 1). When sites were divided into current STP categories only two sites were in the very low category with a similar number of sites in the low (29 sites), medium (22 sites), and high categories (14 sites) (Figure 2; Table 1). The very high category had the greatest number of sites (50 sites) and had a mean Olsen STP of 36 ppm. Corn relative yield increased as Olsen STP increased until it plateaued at an average of 18 ppm. These results indicate that the P fertilization critical value could be increased from 16 to 18 ppm. However, this increase is very small, and the current value of 16 ppm is within the 68% confidence interval for the linear (12 to 19 ppm) and quadratic plateau (16 to 26 ppm) models, indicating it is still accurate. Therefore, we elected to leave the critical value at 16 ppm.

The increasing of relative yield as STP increased until it plateaued where a yield increase was no longer expected indicates that as STP increases there is a reduced likelihood of a yield increase from P fertilization. Our critical STP value of 16 ppm Olsen-P is the same as the Olsen P or Bray-1 equivalent values of the surrounding states of ND, MN, NE, IA and KS which are all approximately 16 ppm. Additionally, in a national survey, our CSTV value is well within the range of critical values of those states using the Olsen-P test (7-30 ppm) and slightly lower than the mean (22 ppm) (Lyons et al., 2023). Using the critical STP value of 16 ppm resulted in the accuracy of correctly categorizing a site as responsive or unresponsive to be 70% (Figure 2; Table 1). This accuracy of 70% was substantially higher than the 40-48% accuracy found in studies in Arkansas, Ohio, and the US Northeast (Culman et al., 2023; Fryer et al., 2019; Heckman et al., 2006).

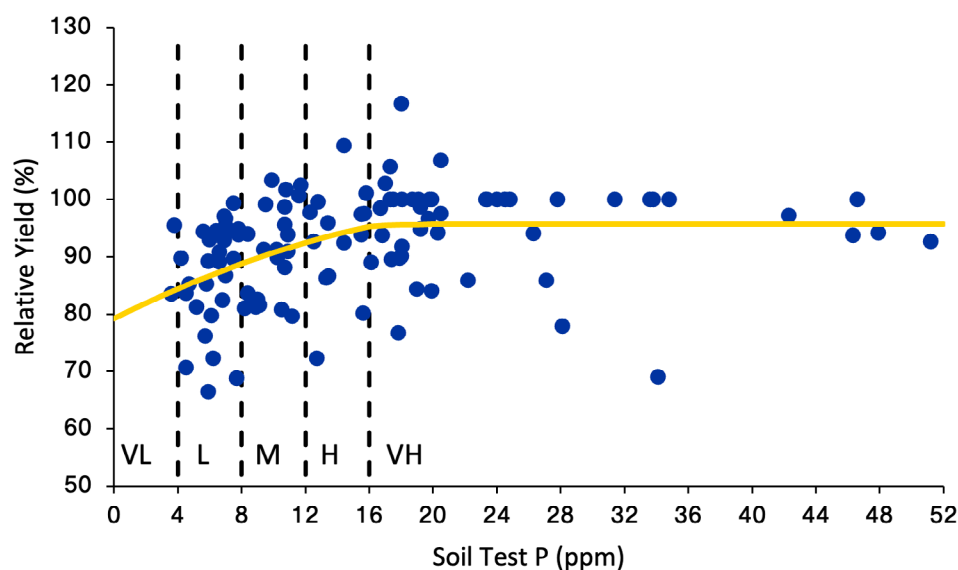


Figure 2. Corn relative yield (RY) as affected by soil test P (STP). Vertical dashed lines represent South Dakota State University soil categories of very low (VL), low (L), medium (M), high (H), and very high (VH). The beginning of the VH category is where P fertilization is no longer recommended.

Table 1. Olsen soil test P (STP) categories and their associated intervals, number of sites within each interval, mean Olsen STP, mean yield of control with no P, mean max yield with P, mean relative yield (RY) of control treatment, mean yield responsiveness with P fertilization (%), and mean delta yield with P fertilization.

Category	STP Range	No. of Sites	Mean Olsen STP (ppm)	Mean Yield no P (bu ac ⁻¹)	Mean Max Yield (bu ac ⁻¹)	Mean RY (%)	Mean Yield Response Frequency (%)	Mean Delta Yield (bu ac ⁻¹)
Very low	<4	2	3	153	170	89	100	16
Low	4-7	29	6	149	170	87	90	21
Medium	8-11	22	10	181	184	91	73	16
High	12-15	14	14	158	161	93	57	10
Very high	16-19	23	18	176	181	96	43	6
-	20-23	6	22	182	187	97	33	-1
-	24-27	6	26	139	132	97	33	-2
-	28-35	6	33	138	138	91	33	0
-	≥36	9	62	148	145	97	44	-3

The frequency of yield responses (>5% yield change) to P fertilization decreased in a nonlinear fashion as Olsen STP increased (Figure 3 and Table 1). Yield response frequency decreased from 100% when Olsen STP was <4 to 33% when STP was > 30 ppm. The model's declining trend is expected because the higher the STP, the lower the probability that additional P fertilizer is needed to achieve maximum yield. The result that the frequency of responsiveness plateaued around 35 ppm Olsen STP instead of continuing to decrease may be due to the low number of sites (15 sites) evaluated with STP >28 ppm (Figure 3; Table 1). The fact that 40% of sites greater than Olsen STP of 16 ppm increased in yield indicates that more than Olsen STP is likely influencing the responsiveness of corn to P fertilization and needs further investigation into the potential relationships with physical or biological soil properties.

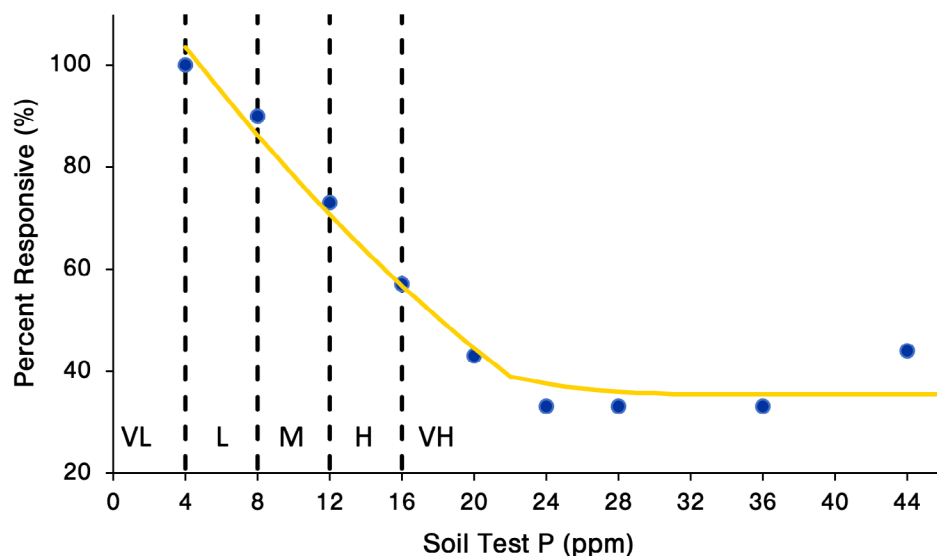


Figure 3. Percent of responsive sites as affected by soil test P (STP). Vertical dashed lines represent South Dakota State University soil categories of very low (VL), low (L), medium (M), high (H), and very high (VH).

The average delta yield between corn fertilized with P and without generally decreased as Olsen STP increased and reached zero at an Olsen STP of approximately 27 ppm (Figure 4; Table 1). Similar to frequency of yield response, the decrease in yield increase as STP increases is expected since as more STP is in the soil the likelihood of needing additional P from fertilization to increase yield should be less. On average, using the current Olsen STP categories one could expect an increase in yield from P fertilization of 16, 21, 16, 10, and <6 bu/ac for the very low, low, medium, high, and very high STP categories (very high only including STP from 16-19 ppm), respectively (Table 1). Using this delta yield model, a farmer could base their P fertilization decision on when they would expect a certain yield increase. For example, if a farmer did not want to apply fertilizer until they were likely to see a 5 bu/ac increase in yield, they would apply P fertilizer once Olsen STP was <20 ppm (Figure 2; Table 1). These results differ slightly from our relative yield results that indicated no expected yield increase from P fertilization when Olsen STP was >16 ppm (Figure 2). However, it is understandable that on average some yield increase above the CSTV may occur when considering the mean confidence interval of the calculated critical STP value from using relative yield data ranged between 14 and 23 ppm.

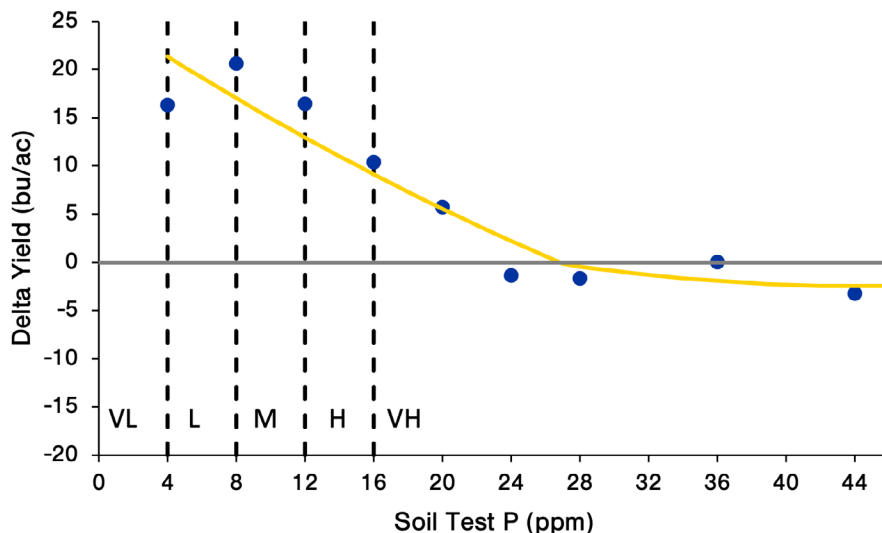


Figure 4. Delta yield from P fertilization as affected by soil test P (STP). Vertical dashed lines represent South Dakota State University soil categories of very low (VL), low (L), medium (M), high (H), and very high (VH).

Conclusions

This study assessed the current South Dakota P fertilizer recommendations by evaluating the accuracy of the current Olsen STP critical value. Relative yield vs. Olsen STP modeling indicated that the critical Olsen STP value could be increased from 16 to 18 ppm. However, this increase was very small, and the current value of 16 ppm was still within the 68% confidence interval for the linear (12 to 19 ppm) and quadratic plateau (16 to 26 ppm) models, indicating it is still accurate. Therefore, we elected to leave the critical value at 16 ppm. Mean yield response frequency and delta yield also plateau out around the 16-19 ppm range in STP, providing further evidence that when Olsen STP reaches between 16 and 19 that minimal yield response of corn to P fertilization is expected.

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References

- Groebner, B., J.D. Clark, J. Svedin, C. Ransom, and D.E. Clay 2024. Soil biological and physical measurements did not improve the predictability of corn response to P fertilization. *Agron. J.* 116: 2048-2059. doi: 10.1002/agj2.21612
- Bünemann, E. K. (2015). Assessment of gross and net mineralization rates of soil organic phosphorus - A review. *Soil Biology and Biochemistry*, 89, 82–98. <https://doi.org/10.1016/j.soilbio.2015.06.026>
- Culman, S., Fulford, A., LaBarge, G., Watters, H., Lindsey, L. E., Dorrance, A., & Deiss, L. (2023). Probability of crop response to phosphorus and potassium fertilizer: Lessons from 45 years of Ohio trials. *Soil Science Society of America Journal*, April, 1–14. <https://doi.org/10.1002/saj2.20564>
- Essington, M. E., & Howard, D. D. (2000). Phosphorus availability and speciation in long-term no-till and disk-till soil. *Soil Science*, 165, 144–152. <https://doi.org/10.1097/00010694-200002000-00005>
- Fryer, M. S., Slaton, N. A., Roberts, T. L., & Ross, W. J. (2019). Validation of soil-test-based phosphorus and potassium fertilizer recommendations for irrigated soybean. *Soil Science Society of America Journal*, 83, 825–837. <https://doi.org/10.2136/sssaj2019.02.0032>
- Heckman, J. R., Jokela, W., Morris, T., Beegle, D. B., Sims, J. T., Coale, F. J., Herbert, S., Griffin, T., Hoskins, B., Jemison, J., Sullivan, W. M., Bhumbra, D., Estes, G., & Reid, W. S. (2006). Soil test calibration for predicting corn response to phosphorus in the northeast USA. *Agronomy Journal*, 98(2), 280–288. <https://doi.org/10.2134/agronj2005-0122>
- Karlen, D. L., Goesser, N. J., Veum, K. S., & Yost, M. A. (2017). On-farm soil health evaluations: Challenges and opportunities. *Journal of Soil and Water Conservation*, 72(2), 26A-31A. <https://doi.org/10.2489/jswc.72.2.26A>
- Lyons, S. E., Clark, J. D., Osmond, D. L., Parvej, M. R., Pearce, A. W., Slaton, N. A., & Spargo, J. T. (2023). Current status of US soil test phosphorus and potassium recommendations and analytical methods. *Soil Science Society of America Journal*, April, 985–998. <https://doi.org/10.1002/saj2.20536>
- Nunes, M. R., Karlen, D. L., Veum, K. S., Moorman, T. B., & Cambardella, C. A. (2020). Biological soil health indicators respond to tillage intensity: A US meta-analysis. *Geoderma*, 369(March), 114335. <https://doi.org/10.1016/j.geoderma.2020.114335>
- Torbert, H. A., Reeves, D. W., & Mulvaney, R. L. (1996). Winter legume cover crop benefits to corn: Rotation vs. fixed-nitrogen effects. *Agronomy Journal*, 88, 527–535. <https://doi.org/10.2134/agronj1996.00021962008800040005x>
- Veum, K. S., Kremer, R. J., Sudduth, K. A., Kitchen, N. R., Lerch, R. N., Baffaut, C., Stott, D. E., Karlen, D. L., & Sadler, E. J. (2015). Conservation effects on soil quality indicators in the Missouri Salt River Basin. *Journal of Soil and Water Conservation*, 70(4), 232–246. <https://doi.org/10.2489/jswc.70.4.232>



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