LOWER SOIL TEST P VALUES DO NOT AFFECT CROP YIELD VALUES WHEN UNDER CONSERVATION PRACTICES

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ABSTRACT

Sustainable P management in cropping systems is a challenge in modern agriculture. Phosphorus moving from agricultural fields to aquatic ecosystems resulting in eutrophication and other water quality problems continues to be a challenging issue for the agricultural community to solve. Despite the large amount of P in agricultural soils, most P is held within insoluble complexes, making this pool of P unavailable to plants. The implementation of conservation practices of no-till, retaining high levels of residue in the field, and diverse crop rotations have shown the potential of being able to lower the amount of soil test P required without reducing yield. At the Dakota Lakes Research Farm in Pierre, South Dakota soil test levels were drawn down to 5 ppm Olsen P in 2014. To create field areas with low, medium, or high soil test P levels within the field, P fertilizer rates of 0, 52, and 104 lbs P_2O_5 were applied in randomized strips across the field in 2014. These rates were again applied to the same treatment areas in 2017, 2019, and 2021 to maintain three distinct soil test levels. In 2022, the mean soil test P value of low, medium, and high areas at 0-6 inches were 12, 19, and 24 ppm, respectively. A five-year crop rotation was also started in this field in 2014 (soybean-wheat/cover crop-soybean-corn-corn). Each year approximately 26lbs P2O5 was applied to all treatments prior to planting in the soil three inches from the seed and at seed depth. After five years, regardless of the soil test P level there was no significant difference in yield response from P fertilization. This result indicates that soil test P levels and P application can be intentionally left at low levels, without a decrease in crop yield in long-term no-till plus high residue rotations. The relationship between arbuscular mycorrhizal fungi and soil test P levels were studied to determine if there was an increase in fungi activity in areas with lower soil test P values. Thus far, we have seen an increase in fungi numbers at the lower soil test P levels, indicating that these fungi populations may be assisting the plant in providing P during the growing season. Establishment of fungi and microbial communities in agricultural soils may be a key component in reducing the need of P fertilizers to optimize crop yield and the subsequent reduction of P fertilizers moving into aquatic ecosystems.

INTRODUCTION

Crop fertility is one of the most critical objectives of producers during the growing season. The fertility amendments that are most commonly applied are nitrogen, P, and potassium, all of which have important physiological benefits to plants. However, unlike nitrogen and potassium fertilizers that are synthesized in labs, P fertilizers are mined from the ground as phosphate rock (PR). This ultimately means this resource is nonrenewable, creating a sustainability problem. In fact, on a global scale, peak phosphate rock production is estimated to be reached as early as 2050 (Beardsley, 2011). The limited availability of this element in the future, and the rising prices of agricultural inputs in general have the potential to create significant problems in food scarcity and agricultural production. However, there are pools of phosphorus available in most agricultural soils, held as insoluble complexes. Using management systems like no-till, diverse cropping rotation, and high residue rotations, soil test P levels may be able to be left intentionally at low levels without reducing yield as has been noted at the Dakota Lakes Research farm in Pierre, SD. However, the mechanisms that allow lower soil test P levels to occur without yield reduction are unknown. Therefore, the objectives of this project are to compare the soil chemical, biological, and physical properties of a long-term P project where a low, medium, and high soil test P level has been established and evaluate crop nutrient content and crop yield responses to P fertilization.

MATERIALS AND METHODS

This study has been continuously conducted at Dakota Lakes Research Farm in Pierre, South Dakota since 2014. At the start of the experiment, soluble P concentrations were drained down to five ppm Olsen P. The study was arranged as randomized strips across the field with five replications. Since the initial depletion of soluble P, three distinct rates were applied in the field to create areas of low, medium, and high concentrations of soluble P measurements. Phosphorus fertilizer was applied at rates of 0, 52, and 104 lbs P_2O_5 ac^{-1} in 2014 as monoammonium phosphate (11-52-0), and again applied to the same treatment areas in 2017, 2019, and 2021 to maintain the low, medium, and high soil test P levels. A five-year crop rotation was initiated in 2014 as well, planted in succession as soybean-wheat/cover crop-soybean-corn-corn. The rotation was developed to maximize the amount of residue left in the field.

Soil samples were collected in the spring and fall periods of the year, once before planting and fertilization and once after harvesting. The samples were collected at depths of 0 to 3 and 3 to 6 inches. The 0 to 3-inch samples were collected using a spade in a cross-section pattern to include the banded and non-banded areas. The 3 to 6-inch samples were collected using a standard 0.75-inch soil sampler. These samples were analyzed for soil test P concentrations (Olsen P, Mehlich P, and Bray P-1) and Total P concentrations. Additionally, biological soil samples were collected using a standard soil core on June 14, 2022, and analyzed soil genetics measurements from, TRACE Genomics (Redwood City, CA) and for Phospholipid Fatty Acid (PLFA), and Autoclave centrifuge extraction (ACE) soil health assessment from Ward Laboratories (Kearney, NE) to determine if these biological indicators are affected by different soil test levels.

Tissue samples were collected at various stages of growth. For corn, samples were collected at the V3, V7, VT, and R6 growth stages. The V3 tissue was collected as whole plant samples, collecting four five-foot sections of corn in each treatment. The V7 tissue was collected by obtaining twenty uppermost collared leaves in each treatment. The VT samples were collected by obtaining twenty leaf samples in each treatment from the collared leaf below and opposite of the ear leaf. The R6 samples were collected as whole plants, collecting 10 plants in a row, and measuring the distance these 10 plants occupied in the row. These R6 samples were divided by transects, using the east and west sections of the field and then, combining the twenty plants collected in each treatment. All plant samples collected were dried and sent to Ward Labs (Kearney, NE) for analysis of elemental concentrations.

RESULTS AND DISCUSSION

Soil Testing:

Soluble P is the portion of P in the soil that is readily available for uptake by plants. The three categories of soluble P that have been studied in this project include Olsen, Bray, and Mehlich P. Preplant soil test results from 2022 show three distinct categories of available soluble P (Table 1). For example, using Olsen P the mean soil test levels in the low, medium, and high soil test level areas were 12, 19, and 24 ppm, respectively. According to the SDSU Fertilizer Recommendations, optimum soil test P values for Olsen is 16 ppm and Bray is 21(Gelderman et al., 2019). The low category of soil test P is below both these critical values, showing that our low level has been maintained since the start of the experiment in 2014. Using Bray P-1, these results show that our low, medium, and high soil testing levels are still in their correct category. However, when using Olsen P, the low testing soil fits in the medium category, the medium in the high category, and the high in the very high category. The differences in the placement of these categories may be due to the higher pH of this site (7.6) as the Bray P-1 soil test is less accurate in soils with pH above 7.2 (Antonio P, n.d.).

Table 1. Preplant soluble P levels and pH in low, medium, and high soil test P soil along with corn grain yield response to P fertilization.

Soil Test Level	Olsen P	Bray P-1	Mehlich P	pH	Yield
		ppm			bu/ac
Low	12	6	21	7.6	184
Medium	19	12	32	7.6	190
High	24	16	37	7.6	191

Water extractable C: N is commonly used to indicate microbial life in the soil that is evaluated. Carbon: N ratios have been shown to indicate mineralizable N content in soils along with microbial life from the C fraction. However, recent studies have shown that the relationship between soil microbial activity and water extractable C: N values are much stronger than that of traditional organic C:N ratios (Haney et al., 2012). In our study, the “Low” soil test P category had the highest average water extractable C:N ratio (Figure 1). This result provides evidence that in low testing P soils that there are more available C sources for the microbial community and that there is more microbial activity in lower soil test P soils.

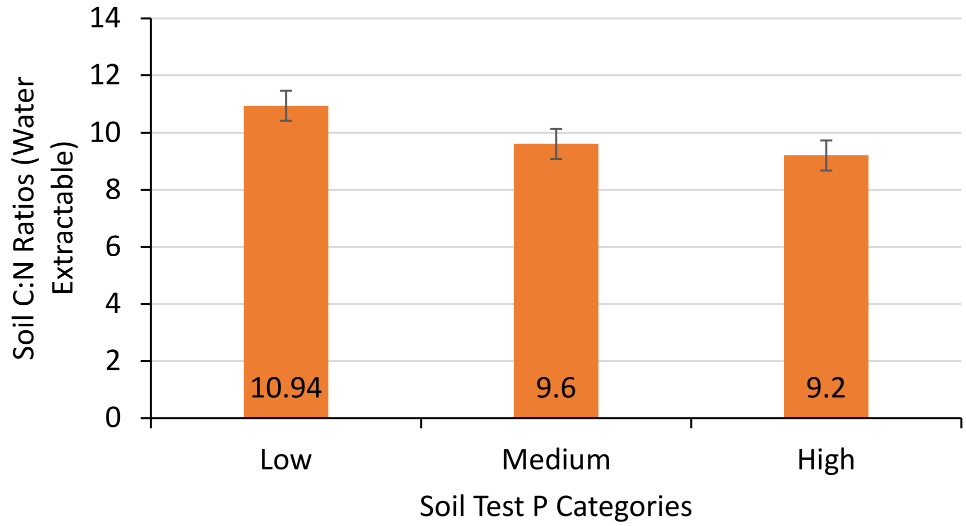

Figure 1. Average preplant water extractable C:N ratios in a low, medium, and high soil test P soil.

Tissue testing:

Leaf P content at V7 decreased marginally from the high (0.49%) to low (0.42%) in soil test P areas (Figure 2). These results indicate that there might be a slight decline in P percentage at the V7 growth stage in the low soil test category, suggesting there might be a decline in P translocation in these treatments. Nitrogen and K percentages show no significant difference between treatments.

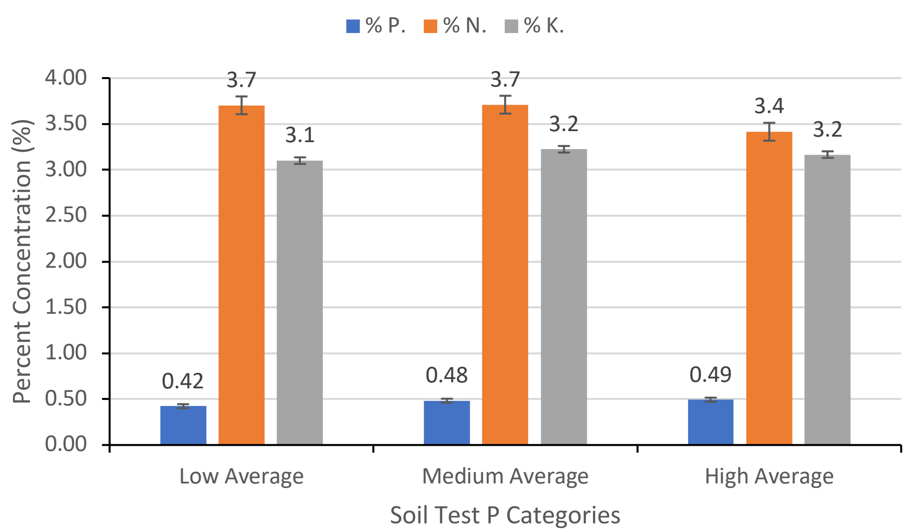

Figure 2. Average percent P, N, and K concentrations in V7 corn top-most collared leaf samples in low, medium, and high soil P testing soil treatments.

Leaf P content at VT decreased marginally from the high (0.52%) to low (0.40%) in soil test P areas (Figure 3). These results indicate that there might be a slight decline in P percentage at the VT growth stage in the low soil test category, suggesting there might be a decline in P transolcation in these treatments. Nitrogen and K perecentages show no significant difference between treatments.

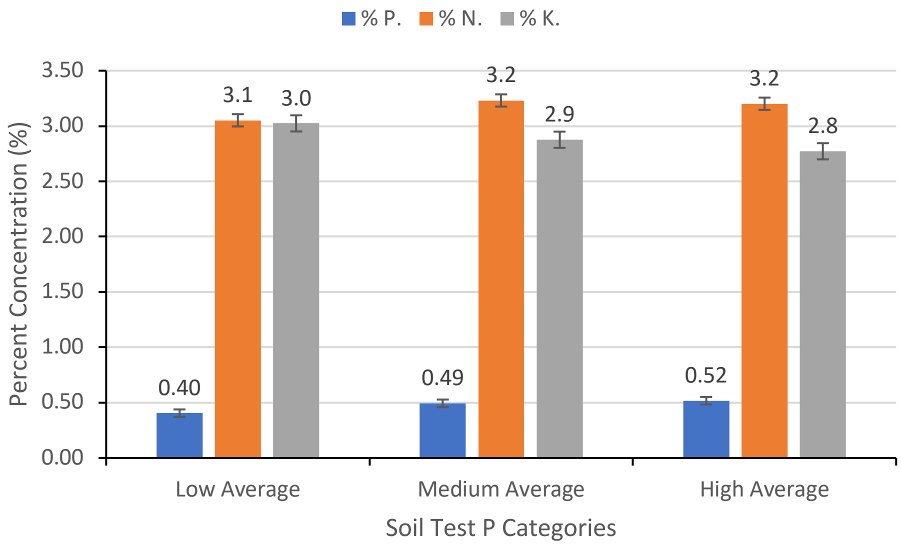

Figure 3. Average percent P, N, and K concentrations in VT corn ear leaf samples in low, medium, and high soil P testing soil treatments.

References

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