EVALUATION OF SOIL TEST PHOSPHORUS EXTRACTANTS AND TISSUE ANALYSIS FOR CORN IN KANSAS

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ABSTRACT

Phosphorus (P) is a critical nutrient for corn (*Zea mays* L.) productivity. Determining an appropriate concentration of soil test phosphorus (STP) and P tissue concentrations is a fundamental step needed to make accurate phosphorus management decisions. The main objective of this study was to evaluate the relationship of four different STP methods (Mehlich 3, Bray 1, Bray 2, and H3A) for corn production and determine critical P tissue concentration at different growing stages. The study was conducted in 12 locations across Kansas during 2021. Fertilizer treatment consisted of five phosphorus fertilizer rates and was applied one time by broadcast pre-plant. Soil samples were collected at the 0-6-inch; samples were recollected before treatment application by block. Tissue samples were collected at the V6, and R1 grow stages. The relationship between different STP, model R^2 varies between (0.24-0.93), Mehlich 3 and Bray 1 have the higher correlation, and Bray 1 and Bray 2 have the lower correlation. Linear Plateau determined the critical P levels for V6 at 0.42 %, and for R1 stage was 0.22 %. The relationship between the concentration at V6 and R1 was moderately correlated with R^2 = 0.62, having a higher P concentration in the early stage.

INTRODUCTION

Phosphorus (P) is a macronutrient that plays several essential roles in plants and is required in relatively large quantities. The available fraction of the total soil phosphorus is typically low, and P fertilizer needs to meet crop P needs. Understanding the adequate P rate in corn production is necessary to sustain high yield potentials. Phosphorus fertilizer may not be enough to replace what the crop is removing in the long term if rates are too low. Therefore, soil testing should be performed to determine the correct fertilizer rate for an economic yield response (Mallarino & Blackmer, 1992); Critical concentrations of STP and critical tissue concentrations can be used to identify the response to phosphorus fertilization should be expected.

Critical levels could depend on many factors, including specific crops as well as soil characteristics, environmental, and other factors. Determining an appropriate concentration of STP and their relationships is a fundamental step required in making fertilizer recommendations. Error in determining critical concentration results in an incorrect decision relating to fertilizer application (Mallarino & Blackmer, 1992). New STP methods for corn have not been evaluated recently in Kansas.

MATERIALS AND METHODS

Field experiments were conducted at 12 locations across Kansas in producers' fields and Kansas State University Research and Extension Centers (table 1). The experiment design was a randomized complete block design with four replications; plots were 10 ft width per 40 ft length. Fertilizer treatment were four rates of phosphorus (P) fertilizer (30, 60, 90, and 120 lbs. P_2O_5 acre^{-1}), using mono-ammonium phosphate (MAP) (11-52-0). A total of 5 treatments was established, including one control; all fertilizer was applied one time by broadcast pre-plant. Before treatment application, soil samples were collected, composite by blocks at 0-6-inch depth using a hand probe; soil measurements include pH and different extractants for P (Mehlich 3, Bray 1, Bray 2, and H3A). Corn was harvested, and yield was calculated and corrected to 15.5% moisture.

Soil samples were dried at 40 °C, plant tissue samples were dried at 60 °C, and both were ground to pass a 2 mm sieve. Soil samples were analyzed for pH 1:1 (soil:water) using a pH meter equipped with glass electrodes (Skalar, Inc). Mehlich 3 extraction was performed using solution ratio 1:10 (soil:solution), extraction solution (0.2N CH_3COOH, 0.013N HNO_3, 0.015N NH_4F, 0.25N NH_4NO_3, and 0.001N EDTA) and shaken for five minutes at 200 epm (Mehlich, 1984) For Bray 1 (0.03 M NH4F + 0.025 M HCl) and Bray 2 (0.03 M NH4F + 0.1 M HCl) the extraction solution ratio was 1:10 and was shacked for five minutes at 200 opm (Bray & Kurtz, 1945). H3A extractions were collected using a solution ratio of 1:10 extracting solution (0.35 g L^{-1} citric acid monohydrate, 0.55 g L^{-1} malic acid, and 0.225 g L^{-1} oxalic acid dihydrate) and shaken for 10 minutes at 200 epm. The H3A extracts were centrifuged at 3500 rpm for 5 minutes (Haney et al., 2017). All extracts were filtered through Whatman 2V filter paper. Extractable P was measured at 660 nm using a colorimeter (Lachat QuikChem 8500 Series 2). The plant's tissue samples were digested using Nitric-Perchloric Acid Digestion and analyzed using ICP-OES.

Relationships between different STP were evaluated using linear regression models. Critical levels were performance between relative yield and plant tissue concentrations and relative P uptake at V6 and different STP using linear plateau models. Data analyses were performed in R version 4.1.

RESULTS AND DISCUSSION

Correlations between different STP

Preliminary results showed that Mehlich 3 vs. Bray 1 and Mehlich 3 vs. H3A were highly and well correlated (R^2 = 0.93 and 0.80, respectively) and exhibit a linear relationship (Figure 1a, and Figure 1b). A similar correlation between Mehlich 3 and Bray 1 was reported several times with a range of R^2 values between (0.85-0.99) (Culman et al., 2020). Rutter & Ruiz Diaz (2020) reported a correlation of Mehlich 3 and H3A with an R^2 of 0.83. The Bray 1 and H3A relationship was moderately correlated with R^2 = 0.60 (Figure 1c); this is similar to what has been reported by Dari et al., (2018), a correlation with an R^2 of 0.54. All method correlated with Bray 2 (Mehlich 3 vs. Bray 2, Bray 1 vs. Bray 2 and H3A vs. Bray 2) was poorly correlated with R^2 = 0.31, 0.24 and 0.47, respectively (figure 1d, 1e, 1f). Soil with a pH above 7.0 was shown in red.

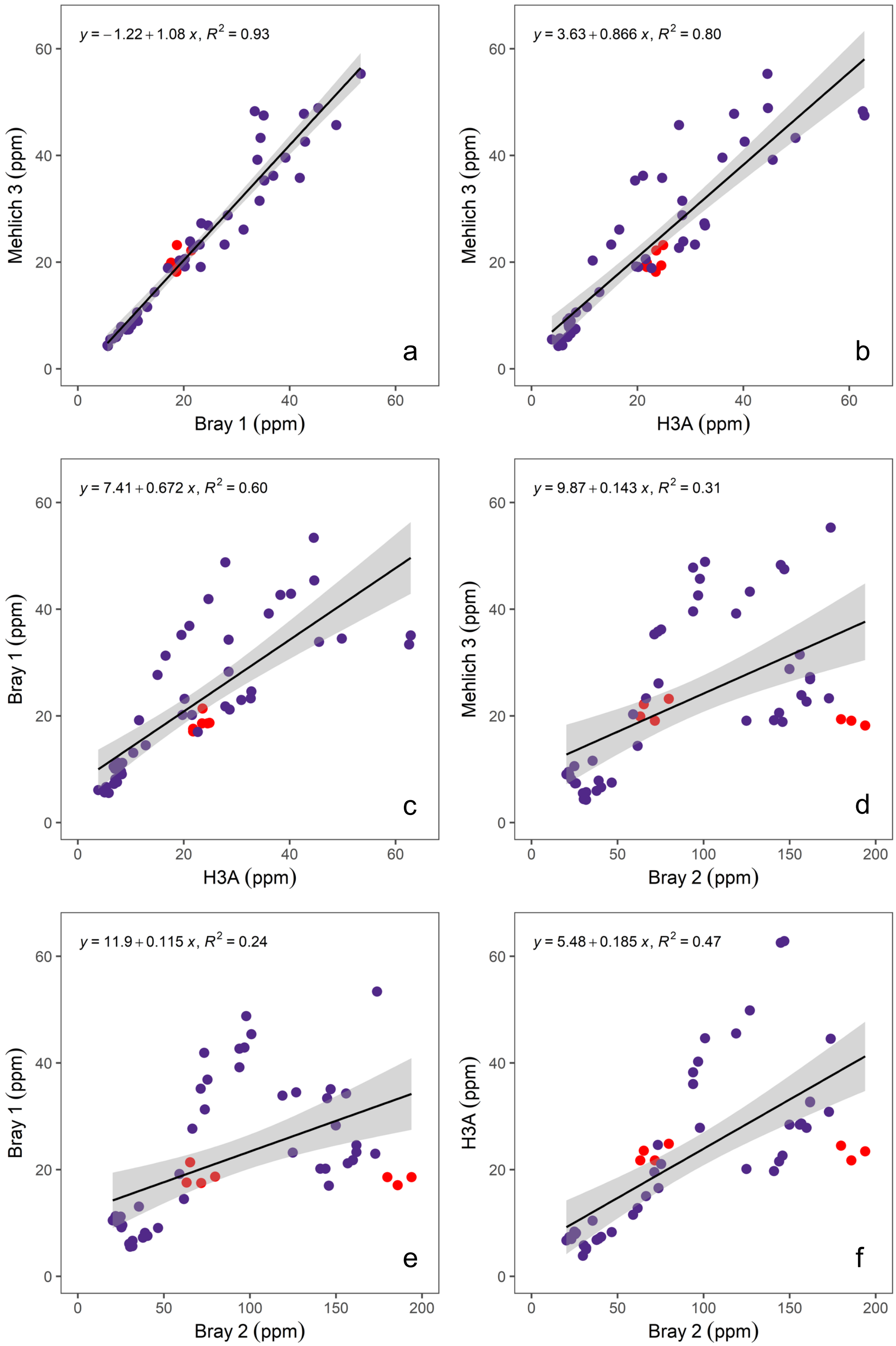

Figure 1. Relationship between different soil test phosphorus methods (a) Mehlich 3 vs. Bray 1, (b) Mehlich 3 vs. H3A, (c) Bray 1 vs. H3A, (d) Mehlich 3 vs. Bray 2, (e) Bray 1 vs. Bray 2 and (f) H3A vs. Bray 2. Soils with a pH > 7.0 are indicated by red points.

Table 1: Study sites, soil properties, and production system information for corn studies in 2021. Samples were collected at 0-6 in depth.

Location	County	Soil Series	pH	Mehlich 3	Bray 1	Bray 2	H3A
				ppm			
1	Republic	Crete	6.5	5	6	31	5
2	Republic	Crete	6.1	7	8	41	7
3	Franklin	Woodson	6.0	9	11	28	9
4	Dickinson	Geary	5.8	21	23	65	14
5	Shawnee	Bismarckgrove	7.6	21	19	70	23
6	Gove	Keith	7.2	20	19	183	25
7	Logan	Keith	6.4	22	21	145	23
8	Gove	Keith	6.6	25	23	160	30
9	Gove	Ulysses	6.2	35	37	148	26
10	Salina	Longford	5.4	38	41	79	23
11	Riley	Bourbonais	6.3	45	34	134	55
12	Brown	Kennebec	6.3	45	43	96	40

Critical Phosphorus concentrations

The critical tissue P levels for the whole plant at the V6 growth stage were determined by linear Plateau was 0.42 %, and model R^2 value was 0.26 (figure 2a). The critical P levels for the ear leaf at the R1 stage were 0.22%, and the model R^2 value was 0.18 (figure 1b). Both R^2 values are low, the ear leaf at R1 having lower than the whole plant at V6. Stammer & Mallarino (2018) found a similar critical P concentration in Iowa for the whole plant V5-V6 with a linear Plateau of 0.48 % (R^2= 0.35), and 0.25 % (R^2= 0.64) for ear leaf blades at the R1.

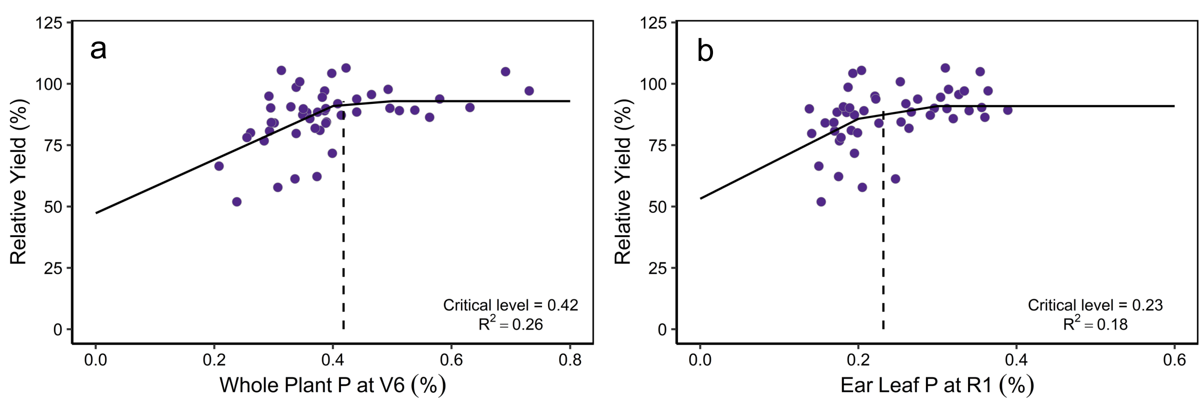

Figure 2. Relationship between relative yield and the P concentration of (a) whole plants at the V6 growth stage or (b) ear leaf blades at the R1 stage. Vertical lines indicate a critical P level with a linear plateau.

Critical soil test P values at the V6 stage was determined for the different P extractants by linear Plateau (table 2), and provided critical levels of 24 and 21 ppm for the Mehlich 3 and Bray 1 methods, respectively, both having an R^2 of 0.50. For the H3A, the critical level was estimated at 13 ppm with the highest R^2 of 0.51. The Bray 2 method has the lowest R^2 value (0.36) and an estimated critical value of 75 ppm. The relationship between the concentration in the whole plant at V6 and in ear leaf in R1 was moderately correlated with R^2 = 0.62 (figure 3). The P tissue concentrations ranged from 0.25 to 0.64 % for V6 and 0.15 to 0.42 % for R1. The tissue P concentrations in the V6 stage were higher than at the sample at the R1 stage; this suggests that the value of tissue testing to assess plant P nutritional status may differ during the growing season.

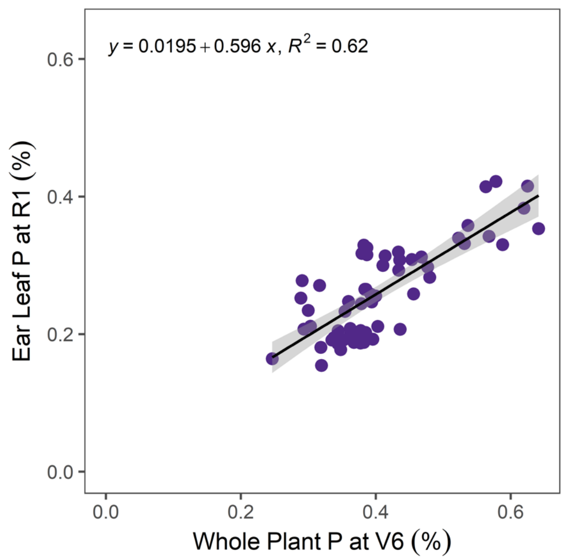

Figure 3. Relationships between P concentrations in-ear leaf at the R1 stage and whole plant at the V6 growth stage.

Table 2: Relationships between relative P uptake at V6 (%) and different soil test P (ppm).

Soil test method	Critical level	Std. Error	R^2
Mehlich 3	24	2.78	0.50
Bray 1	21	2.49	0.50
H3A	13	1.97	0.51
Bray 2	75	11.22	0.36

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