EVALUATION OF PLANT TISSUE ANALYSIS TO ASSESS PHOSPHORUS NUTRITIONAL STATUS IN CORN AND SOYBEAN

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ABSTRACT

Nutrient concentrations in plant tissue samples can be used to identify the nutritional status and response to phosphorus fertilization. This study aimed to determine critical P tissue concentration at different growing stages for corn and soybean. The experiment was conducted at 12 locations for corn in 2021 and 12 locations for soybean from 2017-2020 across Kansas. Tissue samples were collected from whole corn plants at the V6 stage, corn ear leaves at the R1 stage; and whole soybean plants at the V4 stage, and upper trifoliate leaves at the R2 soybean stage. Relationships between plant tissue P concentration and relative yield were investigated using data from plots that received no phosphorus fertilization. Linear-plateau models were used to identify the following critical values: whole corn plants at V4 = 0.41%, corn ear leaves at R1 stage = 0.24%, whole plant soybean at V4 = 0.34%, and trifoliate leaves at R2 stage = 0.39%. The relationship between the concentration at V6 and R1 for corn was moderately correlated with R^2= 0.69. For soybean, the relationship between the concentration of whole plants at V4 and trifoliate at R2 had an R^2 of 0.40.

INTRODUCTION

Phosphorus (P) is an essential macronutrient required in relatively large quantities for crops. Usually, the available fraction of the total soil phosphorus is low, and phosphorus fertilizer needs to meet crop phosphorus needs (Preston et al., 2019). Soil testing is the most used diagnostic tool to asses phosphorus nutrition. However, plant tissue analysis can also be used as a diagnostic tool to identify P deficiencies in crops and evaluate current P management programs (Reuter & Robinson, 1997). There has been relatively little research into the use of tissue analysis to asses phosphorus nutrition in corn and soybean in Kansas, particularly to identify critical values. The concentration of P in plants varies depending on the plant part and the growth stage. So, relationships between nutrient content and yield or yield response are needed for each part and growth stage. Critical values can be identified from these relationships by graphing the relative yield vs nutrient concentration (Munson & Nelson, 1990).

One downside of tissue testing is that it can only be performed in-season, while the crop is actively growing. As such, the time-window in which growers can take corrective actions is limited if deficiencies are found. Early season tissue sampling would be preferred, as this time window may be larger. Later in the growing season, the success of a correction practice for in-season P amendment is uncertain as it is considered immobile in both soil and plants. Even with those potential limitations, in-season tissue testing can be a helpful diagnostic tool to evaluate corn & soybean cropping systems. This study aims to determine critical P tissue concentration at different growing stages for corn and soybean to aid with the interpretation of tissue analysis in Kansas.

MATERIALS AND METHODS

Field experiments were conducted at 12 locations for corn in 2021 and 12 locations for soybean during 2017-2020 across the state of Kansas (Table 1). The experiment design was a randomized complete block design with four replications; plots were 10 ft width per 40 ft length. Tissue samples were collected as a whole plant in the V6 stage and ear leaf in the R1 stage in corn, whole plant in the V4 stage, and trifoliate in the R2 stage for soybean. Plant tissue samples were dried at 140 °F (60°C) and were ground to pass a 2-mm sieve. The plant tissue samples were digested using nitric-perchloric acid digestion and analyzed using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Corn and soybean were harvested, and the yield was calculated and corrected to 15.5% moisture for corn and 13% for soybean. Critical levels in corn were determined using the control's relative yield by blocks and plant tissue concentrations; this was achieved using linear plateau models. Critical levels in soybeans were determined from plots receiving no phosphorus fertilization and potassium fertilization ranging from 40 lbs to 120 lbs K_2O per acre. The relationships between P concentrations in different stages were evaluated using linear regression models. Data analyses were performed in R version 4.1. Linear plateau models were fit using nonlinear least square regression implemented using self-starting functions from the ‘nlraa’ R package.

RESULTS AND DISCUSSION

Critical Phosphorus Concentrations for Corn

The critical tissue P levels for the whole plant at the V6 growth stage were 0.41 %, and the model R^2 value was 0.27 (figure 1a), as determined by a linear plateau. The critical P levels for the ear leaf at the R1 stage were 0.24%, and the model R^2 value was 0.19 (Figure 1b). Both R^2 values are low, with the ear leaf at R1 having lower than the whole plant at V6. Stammer & Mallarino (2018) found a similar critical P concentration with a linear plateau for the whole plant at growth stage V6 of 0.48% and 0.25% for the ear leaf at the R1.

The relationship between the concentration in the whole plant at V6 and the ear leaf at R1 was moderately correlated with $R^2 = 0.69$ (Figure 3a). 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 at the V6 stage were higher than at the R1 stage; this suggests that the value of tissue testing to assess plant phosphorus nutritional status for corn may differ during the growing season.

Critical Phosphorus Concentrations for Soybean

The critical tissue P level for the whole plant at the V4 growth stage was 0.34%, and the model R2 value was 0.02 (Figure 2a), as determined by a linear plateau. The critical P levels for trifoliate leaves at the R2 stage were 0.39%, and the model R2 value was

0.08 (Figure 2b). The relationship between the concentration in the whole plant at V4 was moderately correlated with that measured from the trifoliate leaves at the R2 growth stage (R^2 = 0.40, Figure 3b). The P tissue concentrations ranged from 0.25% to 0.45% for V4 and 0.25% to 0.54% for R1.

While the critical values identified in this study were in agreement with those reported by Mills & Jones (1996) and Stammer & Mallarino (2018), the overall model fits were relatively poor for both maturity stages and plant parts. These results suggest that in-season tissue analysis can have value when used as a diagnostic tool for identifying nutrient deficiencies during the growing season, but it is important to recognize they are ranges and not specific values.

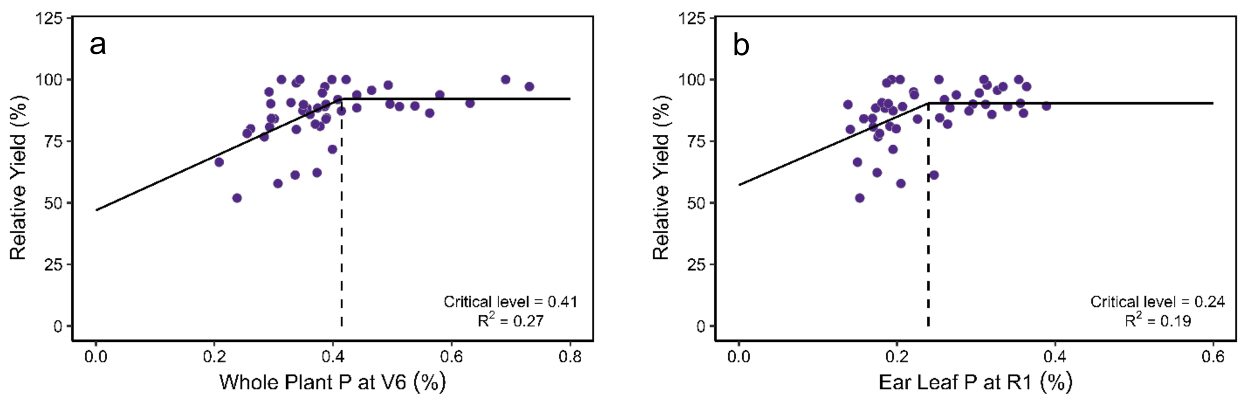

Figure 1. Relationship between relative yield and the P concentration of (a) whole plants at the V6 growth stage or (b) ear leaf blades at the R1 stage. Vertical lines indicate a critical P level with a linear plateau model.

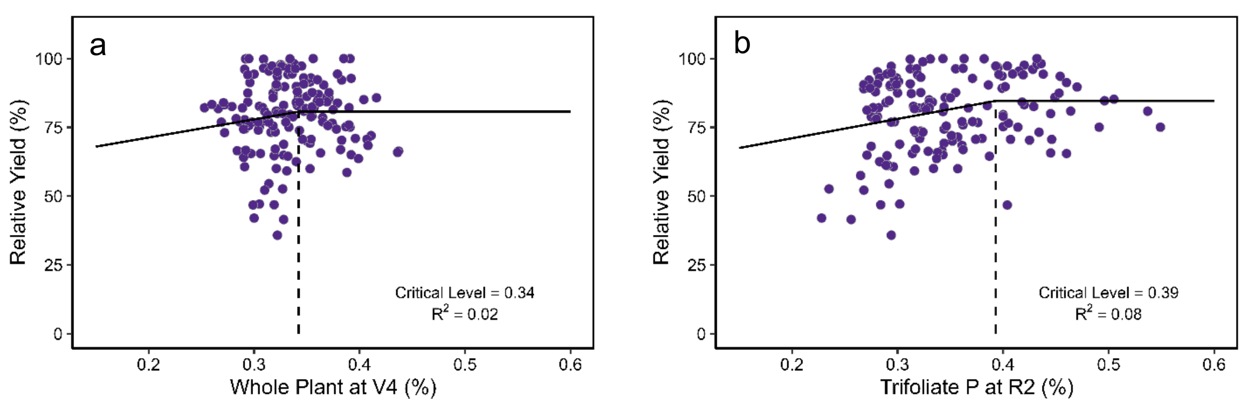

Figure 2. Relationship between relative yield and the P concentration of (a) whole plants at the V4 growth stage or (b) trifoliate at the R2 stage. Vertical lines indicate a critical P level identified with a linear plateau model.

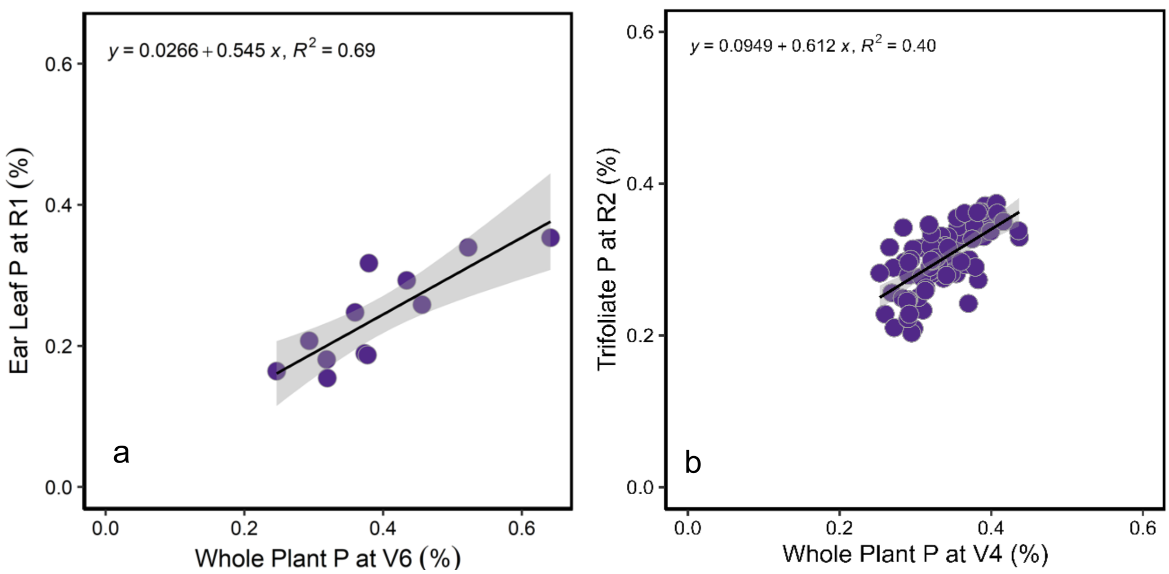

Figure 3. A) Relationship between P concentrations in the ear leaves of corn at the R1 stage and the whole plant at the V6 corn growth stage. B) Relationships between P content of whole plants at the V4 growth stage and trifoliates at the R2 growth stage.

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Table 1. Study sites, crops and soil properties. Samples were collected at 0- to 6-in. depth.

Location	County	Crop	pH	P	OM	CEC	Sand	Silt	Clay
				ppm			%		
1	Republic	Corn	6.5	5	3.3	13	28	57	15
2	Republic	Corn	6.1	7	2.7	13	20	61	19
3	Franklin	Corn	6.0	9	3.4	23	14	62	24
4	Dickinson	Corn	5.8	21	3.5	23	22	52	26
5	Shawnee	Corn	7.6	21	1.9	12	46	42	12
6	Gove	Corn	7.2	20	2.5	22	20	59	21
7	Logan	Corn	6.4	22	2.8	17	20	56	24
8	Gove	Corn	6.6	25	2.7	16	21	54	25
9	Gove	Corn	6.2	35	3.1	14	21	58	21
10	Salina	Corn	5.4	38	2.9	24	30	46	24
11	Riley	Corn	6.3	45	2.0	9	36	54	10
12	Brown	Corn	6.3	45	3.1	13	18	66	16
13	Franklin	Soybean	5.8	21	3.0	23	6	66	28
14	Mitchell	Soybean	5.3	70	2.8	20	18	56	26
15	Mitchell	Soybean	7.7	9	2.7	27	16	44	40
16	Shawnee	Soybean	6.6	12	1.7	11	30	60	10
17	McPherson	Soybean	7.9	65	1.8	14	30	56	14
18	Republic	Soybean	7.1	8	2.8	15	32	48	20
19	Clay	Soybean	5.8	28	3.1	18	30	47	23
20	Franklin	Soybean	6.2	15	2.9	23	14	62	24
21	Mitchell	Soybean	5.7	25	3.1	22	18	60	22
22	Mitchell	Soybean	4.8	35	3.5	21	22	48	30
23	Republic	Soybean	6.1	12	3.0	14	27	56	17
24	Shawnee	Soybean	6.8	31	1.8	12	45	44	11