Kansas Agricultural Experiment Station Research Reports

Volume 9
Issue 8 *Kansas Fertilizer Research* — Article 6

2023

Evaluation of Plant Tissue Analysis to Assess Phosphorus Nutritional Status for Corn and Soybean

Gustavo A. Roa
Kansas State University

Edmond B. Rutter
Kansas State University

Dorivar A. Ruiz Diaz
Kansas State University, ruizdiaz@ksu.edu

Recommended Citation

Roa, Gustavo A.; Rutter, Edmond B.; and Ruiz Diaz, Dorivar A. (2023) "Evaluation of Plant Tissue Analysis to Assess Phosphorus Nutritional Status for Corn and Soybean," *Kansas Agricultural Experiment Station Research Reports*: Vol. 9: Iss. 8. https://doi.org/10.4148/2378-5977.8548

Evaluation of Plant Tissue Analysis to Assess Phosphorus Nutritional Status for Corn and Soybean

Funding Source

Funding for this project was provided in part by the Kansas Fertilizer Research funds.

Evaluation of Plant Tissue Analysis to Assess Phosphorus Nutritional Status for Corn and Soybean

G.A. Roa, E.B. Rutter, and D.A. Ruiz Diaz

Summary
Plant tissue samples can be used to assess nutrient concentrations and the response to phosphorus fertilization. This study aimed to identify critical phosphorus tissue concentrations for corn and soybean at different growing stages. The experiment was conducted at 23 locations for corn in 2021–2022 and 12 locations for soybean in 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. Data from plots that received no phosphorus fertilization were used to investigate the relationships between plant tissue P concentration and relative yield. Linear-plateau models were used to determine the critical values: whole corn plants at V6 = 0.41%; corn ear leaves at R1 = 0.27%; whole soybean plants at V4 = 0.34; and trifoliate leaves at R2 = 0.39%. The study found a moderate correlation between the concentration at V6 and R1 for corn ($R^2 = 0.54$) and a weak correlation between the concentration of whole plants at V4 and trifoliate at R2 for soybean ($R^2 = 0.40$).

Introduction
Phosphorus (P) is a critical macronutrient that crops require in relatively large amounts. However, the available fraction of total soil phosphorus is often low, requiring phosphorus fertilization to meet crop needs (Preston et al., 2019). While soil testing is the most common diagnostic tool for assessing phosphorus nutrition, plant tissue analysis can also be used to identify P deficiencies and evaluate P management programs (Reuter and Robinson, 1997). However, there has been relatively little research on using tissue analysis to assess phosphorus nutrition in corn and soybean in Kansas, particularly for identifying critical values. Since the concentration of P in plants varies by plant part and growth stage, it's essential to establish relationships between nutrient content and yield response for each stage and part. These relationships can help graph the relative yield against nutrient concentration to identify critical values (Munson and Nelson, 1990).

While tissue testing can be a valuable diagnostic tool for evaluating crop nutrient status, it has some limitations. One significant disadvantage is that tissue testing can only be performed in-season while the crop is actively growing, limiting the time growers have to take corrective actions if deficiencies are found. Early season tissue sampling would be ideal as it would provide a larger time window for corrective actions. Additionally, later in the growing season, it becomes more uncertain whether in-season P amendment correction practices will be successful since P is considered immobile in both soil and plants. Despite these limitations, in-season tissue testing can still be useful for evaluating corn and soybean cropping systems. The aim of this study is to determine critical P tissue concentration at different growing stages for corn and soybean in Kansas. The critical values can aid in interpreting tissue analysis results and guide growers to optimize their P management practices.

Procedures

Field experiments were conducted at 23 locations for corn in 2021–2022 and 12 locations for soybean from 2017–2020 across Kansas (Table 1). The experiment design was a randomized complete block design with four replications; plots were 10-ft width by 40-ft length. Tissue samples were collected as a whole plant in the V6 stage, 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 to 120 lb 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 (Miguez, 2021).

Results

Critical Phosphorus Concentrations for Corn

The critical tissue P levels for the whole plant at the V6 growth stage were 0.41% (Figure 1a) as determined by a linear plateau model. The critical P levels for the ear leaf at the R1 stage were 0.27% (Figure 1b) compared with the first report with fewer locations (Roa-Acosta and Ruiz Diaz, 2022), in which the values were slightly higher. Both R^2 values are low, with the ear leaf at R1 having lower values than the whole plant at V6. Stammer and 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 $R^2 = 0.54$ (Figure 3a). The P tissue concentrations ranged from 0.18% to 0.73% for V6 and 0.14% to 0.39% for R1. The tissue P concentrations at the V6 stage were higher than at the R1 stage; this indicates that the value of tissue testing to assess plant phosphorus nutritional status for corn could differ during the growing season.

Critical Phosphorus Concentrations for Soybean

The results show that the critical tissue P level for the whole plant at the V4 growth stage was 0.34% (Figure 2a) as determined by a linear plateau regression. The critical P levels for trifoliate leaves at the R2 stage were 0.39% (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 and Jones (1996) and Stammer and 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 the results are ranges and not specific values.

Acknowledgments

Funding for this project was provided in part by the Kansas Fertilizer Research funds.

References

Miguez, F. (2021). nlraa: Nonlinear regression for agricultural applications. R Package Version 0.98.

Mills, H. A., & Jones, J. B. (1996). Plant Analysis Handbook II: A Practical Sampling, Preparation, Analysis, and Interpretation Guide. Micro-Macro Pub.

Munson, R. D., & Nelson, W. L. (1990). Principles and Practices in Plant Analysis. In Soil Testing and Plant Analysis (pp. 359–387). John Wiley & Sons, Ltd. *https://doi.org/10.2136/sssabookser3.3ed.c14*

Preston, C. L., Ruiz Diaz, D. A., & Mengel, D. B. (2019). Corn Response to Long-Term Phosphorus Fertilizer Application Rate and Placement with Strip-Tillage. Agronomy Journal, 111(2), 841–850. *https://doi.org/10.2134/agronj2017.07.0422*

Reuter, D. J., & Robinson, J. (Eds.). (1997). Plant Analysis: An Interpretation Manual (2nd ed.). CSIRO Publishing. *https://doi.org/10.1071/9780643101265*

Roa-Acosta, G., & Ruiz Diaz, D. A. (2022). Evaluation of Soil Test Phosphorus Extractants and Tissue Analysis for Corn. Kansas Agricultural Experiment Station Research Reports, 8(9). *https://doi.org/10.4148/2378-5977.8347*

Stammer, A. J., & Mallarino, A. P. (2018). Plant Tissue Analysis to Assess Phosphorus and Potassium Nutritional Status of Corn and Soybean. Soil Science Society of America Journal, 82(1), 260–270. *https://doi.org/10.2136/sssaj2017.06.0179*

Table 1. Study sites, crops and soil properties

Location	County	Crop	pH	P	OM	Sand	Silt	Clay
				ppm	---------------------		%	---------------------
1	Dickinson	Corn	5.8	23	3.5	22	52	26
2	Riley	Corn	6.3	46	2.0	36	54	10
3	Gove	Corn	6.2	40	3.1	21	58	21
4	Gove	Corn	6.6	26	2.7	21	54	25
5	Gove	Corn	7.2	21	2.5	20	59	21
6	Brown	Corn	6.3	47	3.1	18	66	16
7	Logan	Corn	6.4	22	2.8	20	56	24
8	Franklin	Corn	6.0	11	3.4	14	62	24
9	Shawnee	Corn	7.6	20	1.9	46	42	12
10	Saline	Corn	5.4	43	2.9	30	46	24
11	Republic	Corn	6.1	7	2.7	20	61	19
12	Republic	Corn	6.5	5	3.3	28	57	15
13	Riley	Corn	6.5	13	2.8	14	58	28
14	Shawnee	Corn	6.8	2	2.1	46	43	11
15	Franklin	Corn	5.6	5	3.6	11	62	27
16	Republic	Corn	6.3	3	3.5	14	66	20
17	Republic	Corn	6.1	4	3.0	14	68	18
18	Reno	Corn	7.4	6	2.8	42	32	26
19	Reno	Corn	6.9	24	3.2	31	41	28
20	Jefferson	Corn	7.1	20	3.8	40	38	22
21	Jewell	Corn	5.2	19	3.4	12	62	26
22	Jewell	Corn	6.7	13	3.7	11	65	24
23	Jewell	Corn	7.0	13	5.5	10	58	32
24	Franklin	Soybean	5.8	21	3.0	23	6	66
25	Mitchell	Soybean	5.3	70	2.8	20	18	56
26	Mitchell	Soybean	7.7	9	2.7	27	16	44
27	Shawnee	Soybean	6.6	12	1.7	11	30	60
28	McPherson	Soybean	7.9	65	1.8	14	30	56
29	Republic	Soybean	7.1	8	2.8	15	32	48
30	Clay	Soybean	5.8	28	3.1	18	30	47
31	Franklin	Soybean	6.2	15	2.9	23	14	62
32	Mitchell	Soybean	5.7	25	3.1	22	18	60
33	Mitchell	Soybean	4.8	35	3.5	21	22	48
34	Republic	Soybean	6.1	12	3.0	14	27	56
35	Shawnee	Soybean	6.8	31	1.8	12	45	44

Samples were collected at 0- to 6-in. depth.
OM = organic matter.

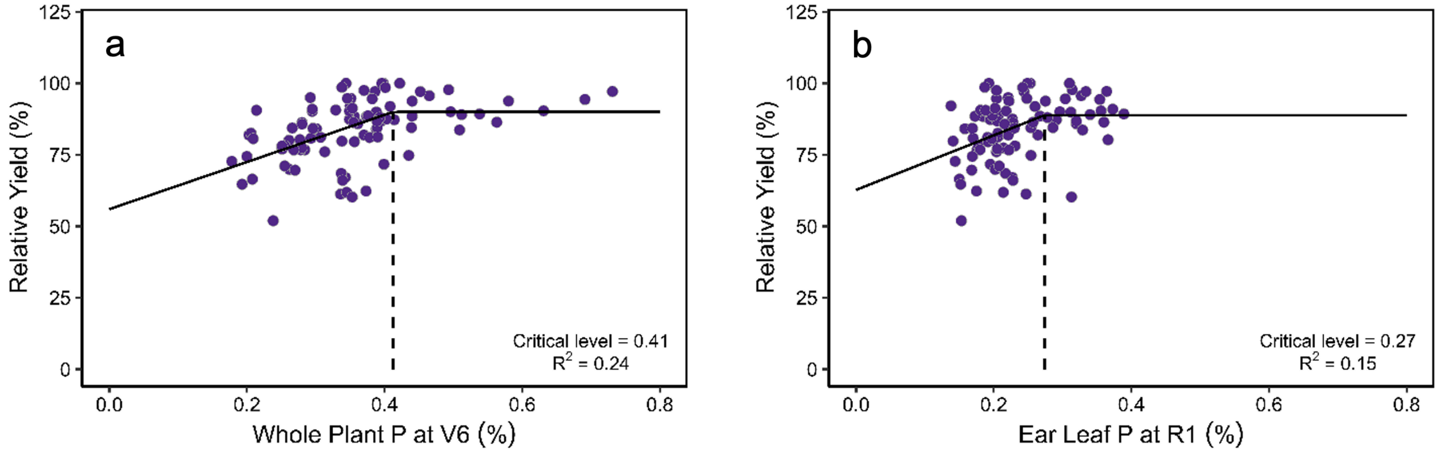

Figure 1. Relationship between relative yield and the P concentration of (a) whole corn plants at the V6 growth stage or (b) ear leaf blades at the R1 stage. Vertical lines indicate a critical P level with a linear plateau model.

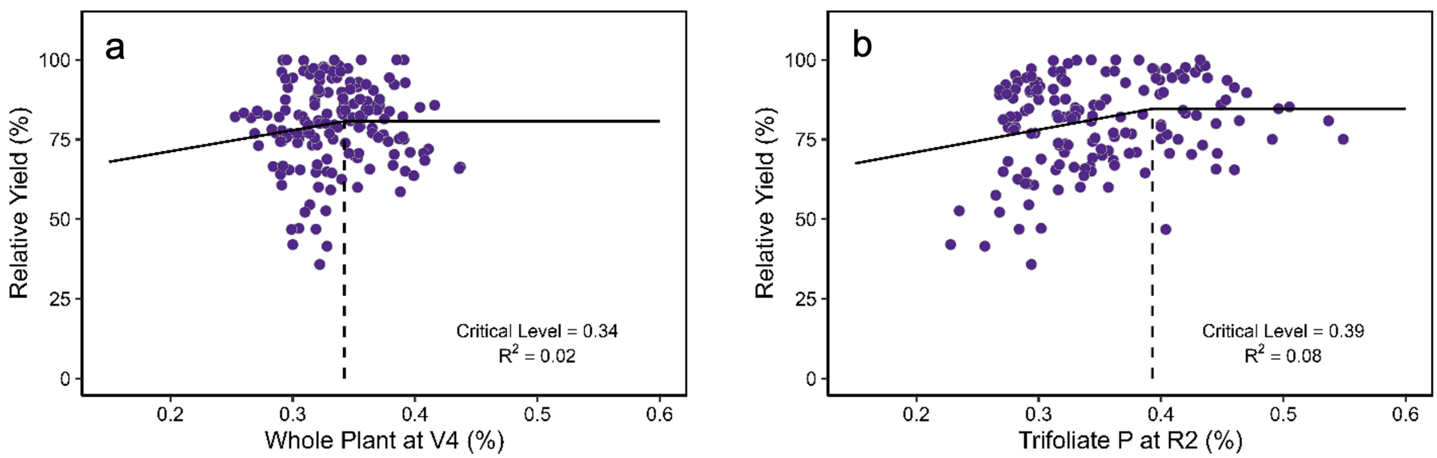

Figure 2. Relationship between relative yield and the P concentration of (a) whole soybean plants at the V4 growth stage or (b) trifoliate at the R2 stage. Vertical lines indicate a critical P level identified with a linear plateau model.

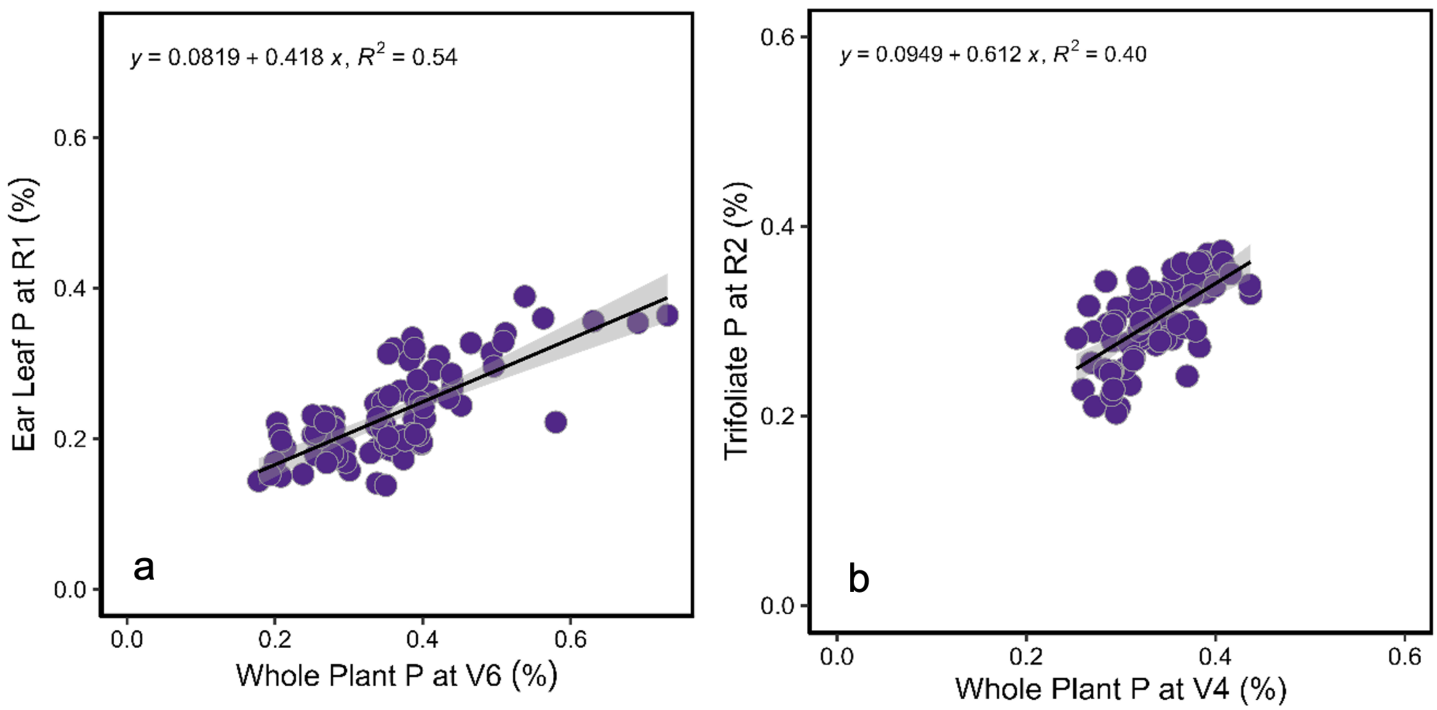

Figure 3. A) Relationship between P concentrations in the ear leaves of corn at the R1 stage and the whole plant at the V6 corn growth stage. B) Relationships between P content of whole soybean plants at the V4 growth stage and trifoliates at the R2 growth stage.