UNIVERSITY OF HOHENHEIM

Funded by DFG Deutsche Forschungsgemeinschaft German Research Foundation

Detecting phosphorus deficiency in maize plant leaves using hyperspectral imaging

AUTHORS

Khandoker Tanjim Ahammad
Leon Hinrich Oehme
Alice-Jacqueline Reineke
Islam Gul Zeeshan
Saike Jiang
Prof. Joachim Müller

I. INTRODUCTION

Phosphorus (P) deficiency is widespread in tropical maize, driving costly fertiliser overuse. This study tests hyperspectral imaging (500-900nm) as a fast, non-destructive diagnostic by measuring leaf reflectance and absorbance across three different growing stages (VE-V3) under controlled P supply.

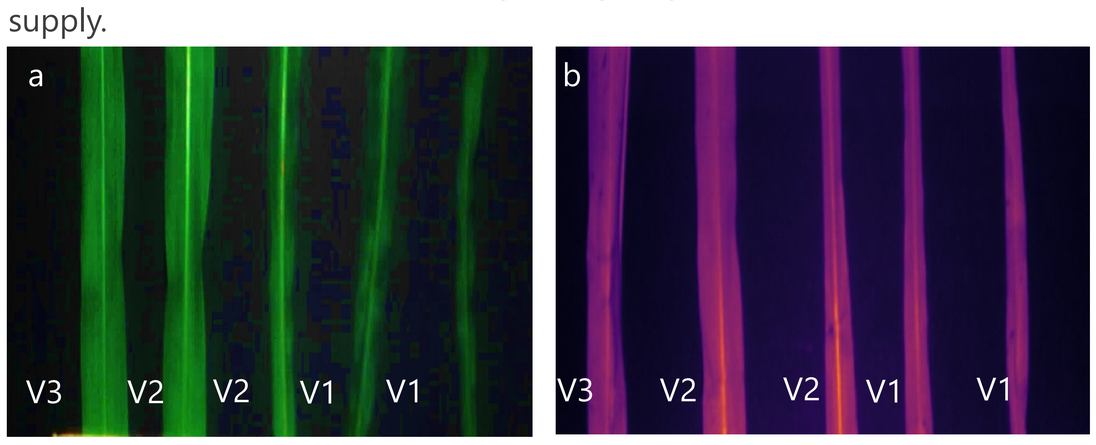

Fig. 1. Developmental stages of maize leaves(VE, V1:first leaf, V2:second leaf, third leaf). a)RGB image, b) Hyperspectral image (786nm band)

II. METHODS

1. Plant material and treatment

Maize seedlings were grown in a greenhouse under controlled P supply with two regimes: High-P and Low-P. Leaves were sampled at four development stages VE, V1 (first), V2 (second), V3 (third).

Table 1: P-treatment

Treatment	Amount(mg/kg)
High-P	130
Low-P	30

2. Spectral acquisition

Leaf-level hyperspectral data were collected in the range of 500-900nm under controlled illumination. A black background was used to standardize reflectance.

3. Preprocessing

Spectra were collected as reflectance from hyperspectral images. Absorbance was derived, then spectra were baseline-corrected and normalized to remove offsets and ensure comparability across leaves (see Table 2)

Table 2: Spectral preprocessing steps

Steps	Formula	Description
Reflectance	$R(\lambda) = {I_{ref}}/{I_{inc}}$	Fraction of incident light reflected by the leaf
Absorbence	$A(\lambda) = 1 - R(\lambda)$	Proxy for pigment uptake(inverse of reflectance)
Baseline+Normalization	$R'(\lambda) = \frac{R(\lambda) - \min(R)}{\max(R) - \min(R)}$	Flattens baseline and scales spectra 0-1

III. RESULTS AND DISCUSSION

This experiment quantified the spectral absorbance properties of maize to disentangle the effect of development stage and P nutrition. Results demonstrate that leaf ontogeny is the dominant factor governing light capture efficiency. A progressive decline in absorbance was observed from the V1 to V3 developmental stages, with most significant reductions occurring in the yellow and orange regions of the spectrum, under Low-P conditions. On the other hand, High-P, plays a vital role in boosting the absorption in the pigment-linked yellow, orange and red-edge regions by up to 4.5%, Interpreted as evidence of enhanced chlorophyll and carotenoid concentration.

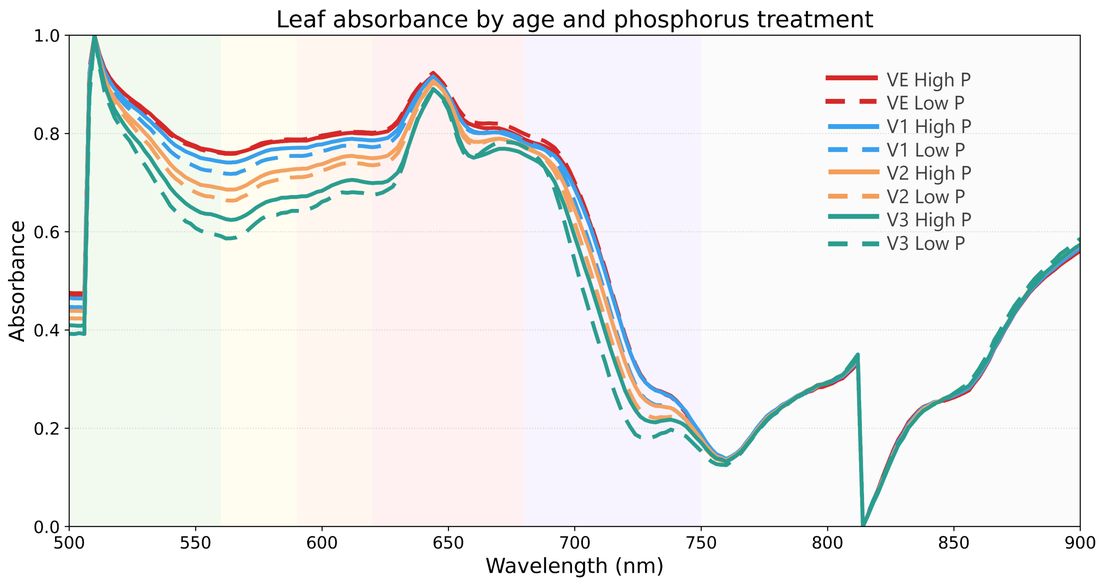

Fig. 2 Leaf reflectance by age and P treatment

Key takeaway:

- **Age effect:** Older leaves (V3) show lower absorbance across green, orange, and red-edge than VE-V2, with the largest drops in orange and red-edge (10-15% under low P)
- **P effect:** High P modestly increases absorbance in the visible and red-edge (up to 4.5%).
- **Red band:** Absorbance stays high due to chlorophyll and changes little with P.
- **NIR:** Minimal P sensitivity, typically less than 1%.

Prediction of P treatment:

In Fig. 3 shows PLS-DA of leaf absorbance for P treatment. Points shows the predicted high P probability vs observed class, clustering at 0 (Low-P) and 1 (High-P) with $R^2 = 0.96$, which indicates 96% of variance and delivers near perfect discrimination between P.

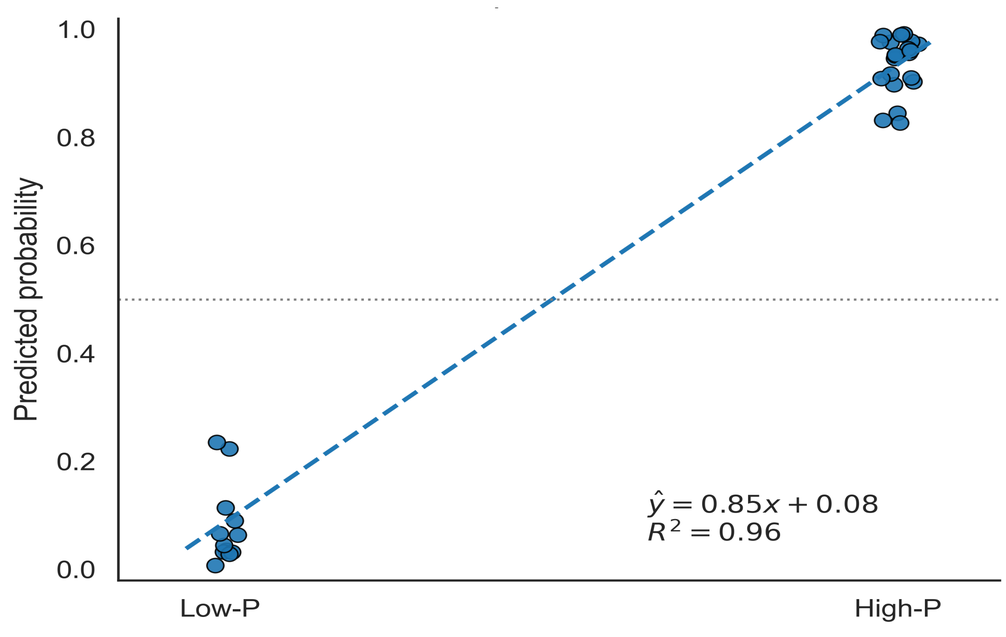

Fig. 3. Partial Least Squares-Discriminant Analysis (PLS-DA) of P treatment

IV. CONCLUSION

P-deficiency reduced chlorophyll and pigment synthesis, lowering the leaf's ability to absorb photosynthetically active radiation (PAR). Effects are most evident in older leaves (e.g., V3), while NIR bands mainly reflect structure rather than pigments. PLS-DA of hyperspectral absorbance separated treatments with $R^2 = 0.96$, supporting early P-status detection in maize. Further investigation is needed in tropical regions to validate the performance under field conditions.

References

Wu, Y., Gao, Q., Zhang, Y., 2015. A robust baseline elimination method based on community information. Digital Signal Processing 40, 53–62. https://doi.org/10.1016/j.dsp.2015.02.015

Park, B., Lu, R. (Eds.), 2015. Hyperspectral Imaging Technology in Food and Agriculture, Food Engineering Series. Springer New York, New York, NY. https://doi.org/10.1007/978-1-4939-2836-1

CONTACT

Khandoker Tanjim Ahammad
khandoker.ahammad@uni-hohenheim.de
Garbenstr. 9, 70599 Stuttgart, Germany
info440e@uni-hohenheim.de