Tropentag, September 10-12, 2025, hybrid conference

"Reconcile land system changes
with planetary health"

Detecting phosphorus deficiency in maize plant leaves using hyperspectral imaging

Khandoker Tanjim Ahammad[1], Leon Hinrich Oehme [2], Alice-Jacqueline Reineke[3], Islam Gul Zeeshan[4], Saike Jiang[5], Joachim Müller[6]

[1] *University Hohenheim, Agricultural Engineering in the Tropics and Subtropics, Germany*
[2] *University Hohenheim, Agricultural Engineering in the Tropics and Subtropics,*
[3] *University of Hohenheim, Agricultural Engineering in the Tropics and Subtropics, Germany*
[4] *Institute of Agricultural Science in the Tropics (Hans-Ruthenberg-Institute), Management of Crop Water Stress in the Tropics and Subtropics,*
[5] *China Agricultural University, Collage of Science, China*
[6] *University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, Germany*

Abstract

In tropical regions, where soil frequently lacks sufficient plant-available phosphorus (P), farmers are often prompted to overapply P fertilisers, elevating agriculture expenses and exacerbating ecological consequences. This study establishes hyperspectral imaging (500–900 nm) as a non-destructive approach for indirectly detecting P stress in maize via chlorophyll and pigment dynamics. Using controlled P treatments, leaf-level reflectance and absorbance at three developmental stages (first leaf(V1), second leaf(V2) and third leaf(V3) were measured. Spectral trends demonstrated age-dependent responses to deficit in absorbance changes associated with chlorophyll redistribution were most prominent in three spectral regions: (1) Green (500–560 nm), where older leaves exhibited reduced absorption compared to middle leaves, contrasting with elevated signals in younger leaves indicating age-stratified reallocation of carotenoids/anthocyanins; (2) Red (620–680 nm), marked by chlorophyll a/b degradation in older leaves and compensatory absorption in younger ones; and (3) NIR (750–900 nm), reflecting structural adjustments in mesophyll tissue.

These trends were supported by a red-edge shift, shorter chlorophyll absorbance troughs, and decreased NIR reflectance, resulting in a spectral signature of P-mediated stress. Critically, conflicting absorbance patterns between leaf ages in green and red areas emphasise the need for developmental-stage sampling. By using chlorophyll and pigment redistribution as proxies for P restriction, this strategy avoids direct or destructive P measurement, providing a fast and scalable tool for early stress screening. The strategy offers particular potential for tropical maize systems, where low-P soils increase dependency on wasteful fertiliser inputs, allowing for tailored interventions to reduce environmental impacts while maintaining output. This study promotes hyperspectral imaging as a climate-smart technique for precision fertiliser management in P-deficient agroecosystems in tropical areas.

Keywords: Hyperspectral imaging, leaf age, maize, phosphorus deficiency, precision agriculture

Contact Address: Khandoker Tanjim Ahammad, University Hohenheim, Agricultural Engineering in the Tropics and Subtropics, Garbenstraße 9, 70599 Stuttgart, Germany, e-mail: khandoker.ahammad@uni-hohenheim.de