Hyperspectral Image-Based Spatial and Spectral Feature Mining for Phosphorus Deficiency Symptom Differentiation at Corn's Early Vegetative Stage

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Abstract

Phosphorus (P) is a vital macronutrient for building up essential biomolecules in plants, and its accurate quantification can guide effective crop management and increase crop growers' profit. Traditional chemical reaction-based methods for measuring P levels in plants are destructive and complex. Hyperspectral imaging offers a real-time, non-destructive avenue for assessing crop nutrient status. While these images are rich in both spatial and spectral information, limitations in current devices and analytical algorithms have led most studies to concentrate solely on the spectral features. In this study, a novel algorithm to combine features in spatial and spectral domains is proposed and implemented to differentiate phosphorus deficiency symptoms in corn plants. At the V6 vegetative stage, leaf-level hyperspectral images from three P levels and two leaf positions were collected using the handheld proximal hyperspectral imager, LeafSpec. Spatial and spectral features that exhibit significant differences between the P treatments were generated by integrating pre-designed spatial partitions with spectral index maps. The correlation coefficient between the P content and elected spatial and spectral features was treated as the standard to further refine the mining results. The spatial and spectral joint effects showed superior ability than spectral indices in differentiating P deficiency at both leaf positions, especially for medium P and sufficient P. Related visualization maps also gave out a preliminary insight into the differences in P deficiency symptoms. This study highlights the great potential and effectiveness of combining spatial and spectral features in differentiating P levels at corn's early vegetative stage.

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