A Novel Spectral-Structural Analysis Method based on Corn Leaf Hyperspectral Images for the Identification of Nitrogen Deficiencies

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Abstract

As one of the largest supplied grain crops, corn plants often require a significant amount of nitrogen fertilizer for optimal yield. However, excessive fertilizer usage can lead to adverse environmental consequences, especially for the nearby hydrological network. To precisely manage nitrogen application, accurate measurement of corn crop nitrogen deficiency is necessary. Hyperspectral imaging (HSI) techniques are widely applied in plant phenotyping to effectively measure plant traits caused by biotic or abiotic stresses. While previous HSI processing methods primarily focus on the overall color change, they rarely analyze the signal from the leaf-level spatial domain. However, early-stage nitrogen deficiency symptoms may not significantly alter the overall color, resulting in limited model performance in such cases. A newly developed HSI device called LeafSpec can scan an entire corn leaf with a high signal-over-noise ratio paired with high spatial-spectral resolution, capturing the detailed color changes at the leaf structure level. This study focused on identifying distinctive nitrogen deficiency indicators using an innovative methodology that applies spectral analysis to the details of leaf venation structures. The study started with developing an automated venation segmentation algorithm to separate a whole corn leaf into structural components. An in-depth examination of the spectral profiles associated with different leaf components introduced a new spatial-spectral index, demonstrating a higher correlation with the nitrogen content data than the averaged spectral indices. The high-resolution spectral-structural features discovered with this method provided new potential to improve the performance of the nitrogen prediction model in terms of both accuracy and robustness.

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