Winter Durum Wheat Disease Severity Detection with Field Spectroscopy at Leaf and Canopy Level

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Accurate disease severity assessment is critical for plant breeders, as it directly impacts crop yield. While hyperspectral remote sensing has shown promise for disease severity assessment in breeding experiments, most studies have focused on either leaf or canopy levels, neglecting the valuable insights gained from a combined approach. Moreover, many studies have centered on experiments involving a single disease and a few genotypes. However, this approach needs to accurately represent the challenges encountered in field conditions, where multiple diseases could occur simultaneously. To address these gaps, our current study analyses a combination of diseases, yellow rust, brown rust, and yellow leaf spots, collectively evaluated as the percentage of the diseased leaf area relative to the total leaf area (DA) at both leaf and canopy levels, using hyperspectral data from an ASD field spectrometer. We quantitatively estimate overall disease severity across fifty-two winter durum wheat genotypes categorized into early (medium milk) and late (late milk) groups based on the phenophase. Chlorophyll content (CC) within each group is studied concerning infection response, and a correlation analysis is conducted for each group with nine vegetation indices (VI) known for their sensitivity to rust and leaf spot infection in wheat. Subsequent parametric (linear and polynomial) and nonparametric (partial least squares and kernel ridge) regression analyses were performed using all available spectral bands. We found a significant reduction in Leaf CC (>30%) in the late group and Canopy CC (<10%) for both groups. YROI and LRDSI_1 are the VIs that exhibited notable and strong negative correlations with Leaf CC in the late group, with a Pearson coefficient of −0.73 and −0.72, respectively. Interestingly, spectral signatures between the early and late disease groups at both leaf and canopy levels exhibit opposite trends. The regression analysis showed we could retrieve leaf CC only for the late group, with R^2 of 0.63 and 0.42 for the cross-validation and test datasets, respectively. Canopy CC retrieval required separate models for each group: the late group achieved R^2 of 0.61 and 0.37 (cross-validation and test), while the early group achieved R^2 of 0.48 and 0.50. Similar trends were observed for canopy DA, with separate models for early and late groups achieving comparable R^2 values of 0.53 and 0.51 (cross-validation) and 0.35 and 0.36 (test), respectively. All of our models had medium accuracy and tended to overfit. In this study, we analyzed the spectral response mechanism associated with durum wheat diseases, offering a novel crop disease severity assessment approach. Additionally, our findings serve as a foundation for detecting resistant wheat varieties, which is the most economical and environmentally friendly management strategy for wheat leaf diseases on a large scale in the future.

Keywords: disease severity; hyperspectral data; leaf spectroscopy; field spectroscopy; rust; winter durum wheat