Development and Validation of a Multispectral and Thermal Sensor System for In-Field Crop Drought Stress Monitoring in Wheat

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Abstract

Water scarcity profoundly affects crop growth in rain-fed regions, including the Pacific Northwest (PNW) of the USA. While unmanned aerial vehicles (UAVs) are integral for crop monitoring in breeding programs, their use is resource-intensive and necessitates pilot presence in the field. Alternatively, Internet of Things (IoT)-based sensor systems offer continuous, remote, and real-time monitoring, but their data integrity requires validation for field applications. This study developed a Raspberry Pi-based sensor system (AGIcam+) and compared its efficacy with UAV in discerning crop responses to drought conditions across various wheat varieties in the PNW region. Multispectral and thermal data were collected across wheat trials (Winter 2023; Spring 2022, 2023) at crucial growth stages – preheading, heading, and post-heading – under varied drought stress conditions. Key vegetation indices and temperature measurements were extracted for a comparative drought performance analysis. Results indicate significant correlations between AGIcam+ and UAV data, more pronounced during the heading and post-heading stages. Pearson's correlation coefficients for the average normalized difference vegetation index (NDVI) and the temperature data exhibited ranges of 0.81-0.88 and 0.77-0.96 ($P < 0.01$), respectively, across all trials during the heading stages. Yield prediction models using random forest regression analysis from both systems' data underscored AGIcam+'s accuracy in yield estimation, demonstrating performance comparable to UAV, as evidenced in the Spring 2023 trial (AGIcam+: R^2 = 0.85, $RMSE$ = 796.9 kg/ha; UAV: R^2 = 0.84, $RMSE$ = 825.0 kg/ha). These findings underscore AGIcam+ as a resource-efficient crop monitoring alternative, effectively capturing responses to environmental conditions and facilitating accurate yield predictions under drought stress.

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