BUL 1033

Estimation of Wheat Yield and Grain Protein with Handheld and UAV-Mounted Sensors

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Introduction

ACCURATE PREDICTION OF CROP YIELD and grain quality in season represents important information growers can use to adjust nitrogen (N) fertilizer management for optimized production. Recently, improving N use efficiency by utilizing crop sensors has gained attention, focusing on optimizing N inputs while maintaining crop yields. This research bulletin reports the results from a fourteen-site-year field study in spring wheat (*Triticum aestivum* L.) conducted at five locations in southern Idaho during 2015–17. The objectives of this study were 1) to assess the feasibility of wheat yield and grain protein content prediction with in-season crop spectral-reflectance measurements and 2) to compare a handheld canopy sensor and a sensor-equipped unmanned aerial vehicle (UAV) for accuracy of wheat yield and grain protein content estimation.

Field Trials

Field trials funded by the Idaho Wheat Commission were conducted at five locations (Aberdeen, Ashton, Parma, Rupert, and Soda Springs) in southern Idaho in 2015–17. Soft white spring wheat (cv. Alturas) was planted at Parma and hard red spring wheat (cv. Cabernet) at all other sites. Granular urea (46-0-0) was surface broadcasted immediately after planting at five rates (0, 84, 168, 252, and 336 kg ha^{-1}). Each treatment was replicated four times in a randomized complete block design, resulting in a total of twenty plots (1.52 m wide by 4.27 m long). All sites were irrigated every 7–10 days using sprinkler irrigation systems, except at Soda Springs, a dryland site. At tillering, biomass production was estimated as Normalized Difference Vegetative Index (NDVI) using a GreenSeeker (GS) (Trimble Agriculture Division, Westminster, Colorado) handheld crop sensor to scan the two middle rows of wheat plants at 70 cm above the wheat canopy. At maturity, yield was determined by harvesting wheat with a small plot research

combine. Grain N concentration was measured using near infrared reflectance spectroscopy. Protein content was calculated by multiplying grain N content by 5.7 (Fowler et al. 1990) expressed in %. An octocopter UAV 3D Robotics 8X+ (3D Robotics, Berkeley, California) (Figure 1) was utilized to carry camera payloads to acquire ultra-high-resolution imagery. A MicaSense RedEdge 3 Multispectral Camera (MicaSense, Seattle, Washington) mounted on the octocopter was used to obtain the imagery (Figure 1). The relationship between GS NDVI and UAV NDVI and spring wheat yield and grain protein content was evaluated. Data were analyzed via analysis of variance (ANOVA) using programmed random occurrence general linear models (PROC GLM) (SAS 9.4). Figures and regressions were generated using Excel.

Results

Table 1 summarizes the Pearson correlation coefficients as a measure of the strength of the association between GS NDVI, UAV NDVI, wheat yield, and grain protein content. Wheat yield was most closely correlated with GS NDVI and UAV NDVI at Feekes 5. No apparent relationship between GS NDVI and UAV NDVI with grain protein content was observed (Table 1).

In this study, we observed a strong positive correlation between GS NDVI and UAV NDVI (R^2 = 0.78) (Figure 2). Work by Stone et al. (1996) has shown that NDVI measurements in wheat at tillering can provide reliable estimates of N uptake and biomass production. Reeves et al. (1993) used direct in-season measurements of total N uptake at tillering to predict wheat grain yield.

Figure 1. 3D Robotics 8X+ octocopter equipped with a MicaSense RedEdge 3 Multispectral Camera.

Table 1. Pearson correlation coefficients for spring wheat grain yield, grain N uptake, and grain protein content with GS NDVI and UAV NDVI at Feekes 5, for fourteen site-years in Idaho, 2015–17.

Parameter	GS NDVI	UAV NDVI
Grain yield	0.56*	0.66*
Grain protein	-0.03	0.001

**significant at 0.05 level.*

Wheat grain yield was positively linearly correlated with GS NDVI (R^2 = 0.42) and UAV NDVI (R^2 = 0.43) (Figure 3).

Walsh and Christiaens (2014) reported that wheat grain protein content was not strongly correlated (at three of eight site-years) with GS NDVI, which is typical for NDVI versus protein in cereal crops. Freeman et al. (2003) observed no consistent relationship between NDVI and wheat grain N at any growth stage. They concluded that wheat grain protein content could not be accurately predicted with NDVI. Indeed, the results of this study also showed that while NDVI can be utilized in estimating wheat grain yield in season, the prediction of grain protein content remains a challenge (Figure 4).

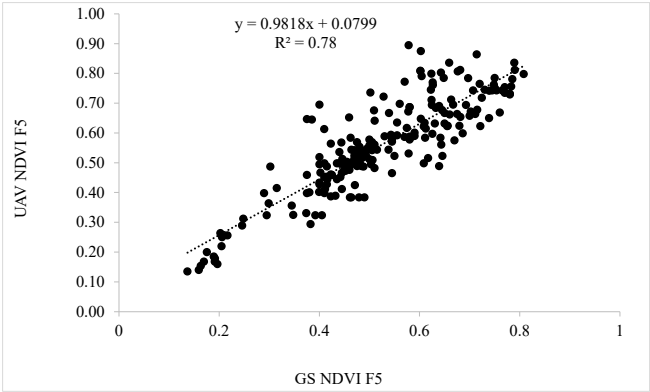
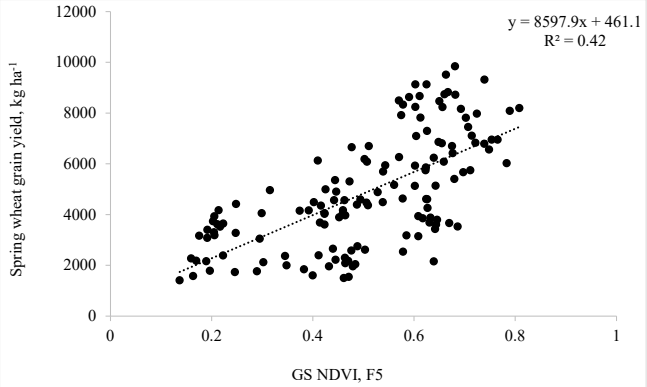


Figure 2. Relationship between NDVI collected at Feekes 5 (F5) using the GS sensor and the UAV 3D Robotics 8X+ octocopter equipped with a MicaSense RedEdge 3 Multispectral Camera for fourteen site-years in Idaho, 2015–17.



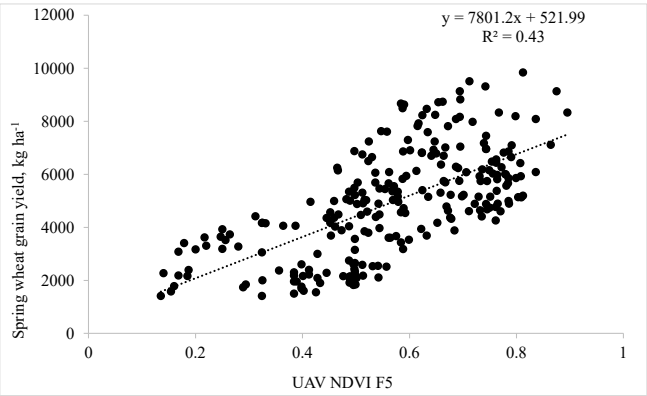
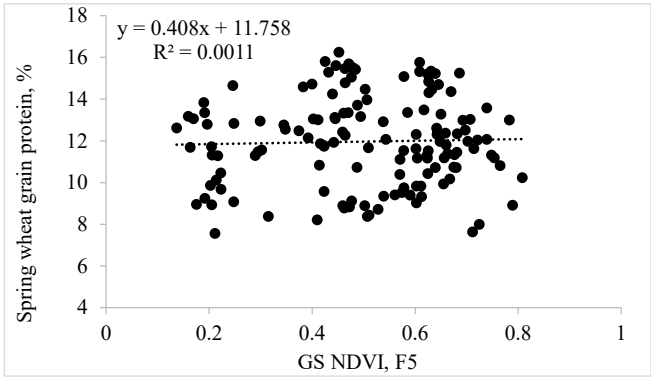


Figure 3. Relationship between spring wheat grain yield (kg ha^{-1}) and NDVI collected at Feekes 5 (F5) using the GS sensor (top) and the UAV 3D Robotics 8X+ octocopter equipped with MicaSense RedEdge 3 Multispectral Camera for fourteen site-years in Idaho, 2015–17.



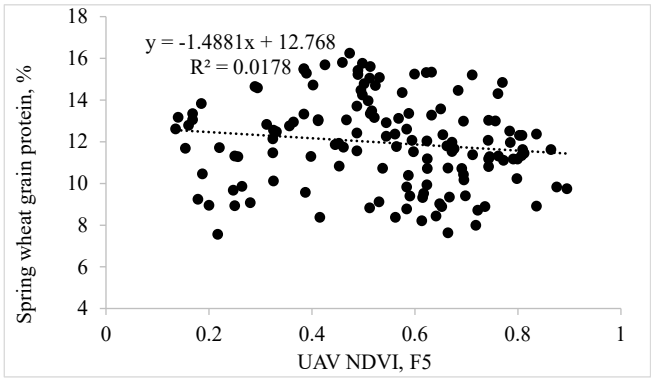


Figure 4. Relationship between spring wheat grain protein content (%) and NDVI collected at Feekes 5 (F5) using the GS sensor (top) and the UAV 3D Robotics 8X+ octocopter equipped with MicaSense RedEdge 3 Multispectral Camera for fourteen site-years in Idaho, 2015–17.

Conclusion

- Strong linear relationship was observed between GS NDVI and UAV NDVI.
- Wheat yield was estimated in season with both GS NDVI and UAV NDVI with comparable accuracy.
- Although the GS and UAV NDVI explained <50% variation in wheat yield, remote sensing is a promising tool for improving N management in wheat. Please see University of Idaho Extension Bulletin 896, *Nitrogen Management in Field Crops with Reference Strips and Crop Sensors,* for detailed information.
- In-season NDVI-based prediction of wheat grain protein remains a challenge.

Further Reading

*This report summarizes the findings to be published in "Sensor-Based Estimation of Wheat Yield and Grain Protein with Handheld and Unmanned Aerial Vehicle-Mounted Sensors," *Agronomy Journal* (in review).

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