Crop Sensors as an In-Season Nitrogen Management Tool for Winter Wheat in Wisconsin

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Justification and Objective

Justification:
In Wisconsin, winter wheat nitrogen (N) rate guidelines are determined by soil type, previous crop, and optionally the fall pre-plant soil nitrate test. Nitrogen management may be improved through site-specific assessments of N need in the spring, offering a more effective use of top-dressed N.

Objective:
Determine if crop reflectance measurements can be used to determine optimal in-season N rate recommendations on silt loam soils in eastern Wisconsin.

Materials and Methods

Locations:

- Chilton (2014), Manawa silt loam (fine, mixed, active, mesic Aquollic Hapludalfs)
- Chilton (2015), Kewaunee loam (fine, mixed, active, mesic, Typic Hapludalfs)
- Lamartine (2014), Plano silt loam (fine-silty, mixed, superactive, mesic Typic Argiudolls)
- Lamartine (2015), Pella silt loam (fine-silty, mixed, superactive, mesic Typic Endoaquolls)

Treatments:
- 2014
  - 0 kg N ha^{-1}
  - At planting: 133 kg N ha^{-1} as SuperU®
  - Green-up (GU): NH_4NO_3 at 33, 67, 100, & 133 kg N ha^{-1}
  - Zadoks growth stage (GS) 30: NH_4NO_3 at 33, 67, 100, & 133 kg N ha^{-1}
- 2015
  - 0 kg N ha^{-1}
  - At planting: 133 kg N ha^{-1} SuperU®
  - GU : NH_4NO_3 at 33, 67, 100, 133, & 167 kg N ha^{-1}
  - GS 30: NH_4NO_3 at 33, 67, 100, 133, & 167 kg N ha^{-1}
- Four replications in a randomized complete block design
- Plot size: 2.4 m by 7.6 m (0.19-m row spacing)
- Harvest area: 1.5 m by 6.4 m (9.7 m^2)

Plant Sampling and Analysis:
- Sampling
  - GU: plant samples collected from the control (0 N) and fall applied SuperU® (133 kg N ha^{-1})
  - GS 30: Plant samples collected from the control and each plot where N was previously applied
  - GS 40: plant samples collected from the control (0 N) and 67 and 133 kg N ha^{-1} NH_4NO_3 broadcasted at GU
- Analysis
  - Total N concentration was determined on all tissue and grain samples using a Kjeldahl digestion (Nelson and Sommers, 1973)
  - Plant N uptake = (dry matter yield) x (N concentration)

Canopy Sensing:
- Holland Scientific Crop Circle ACS-430 (Holland Scientific, Inc., Lincoln, NE)
- Weekly data collection started approximately two weeks after GU fertilizer application and ended at GS 40
- Vegetative indices calculated include:
  - Normalized difference vegetation index (NDVI)
    $NDVI = (R_{670}-R_{780})/(R_{670}+R_{780})$
  - Normalized difference red-edge index (NDRE)
    $NDRE = (R_{670}-R_{730})/(R_{670}+R_{730})$

Results

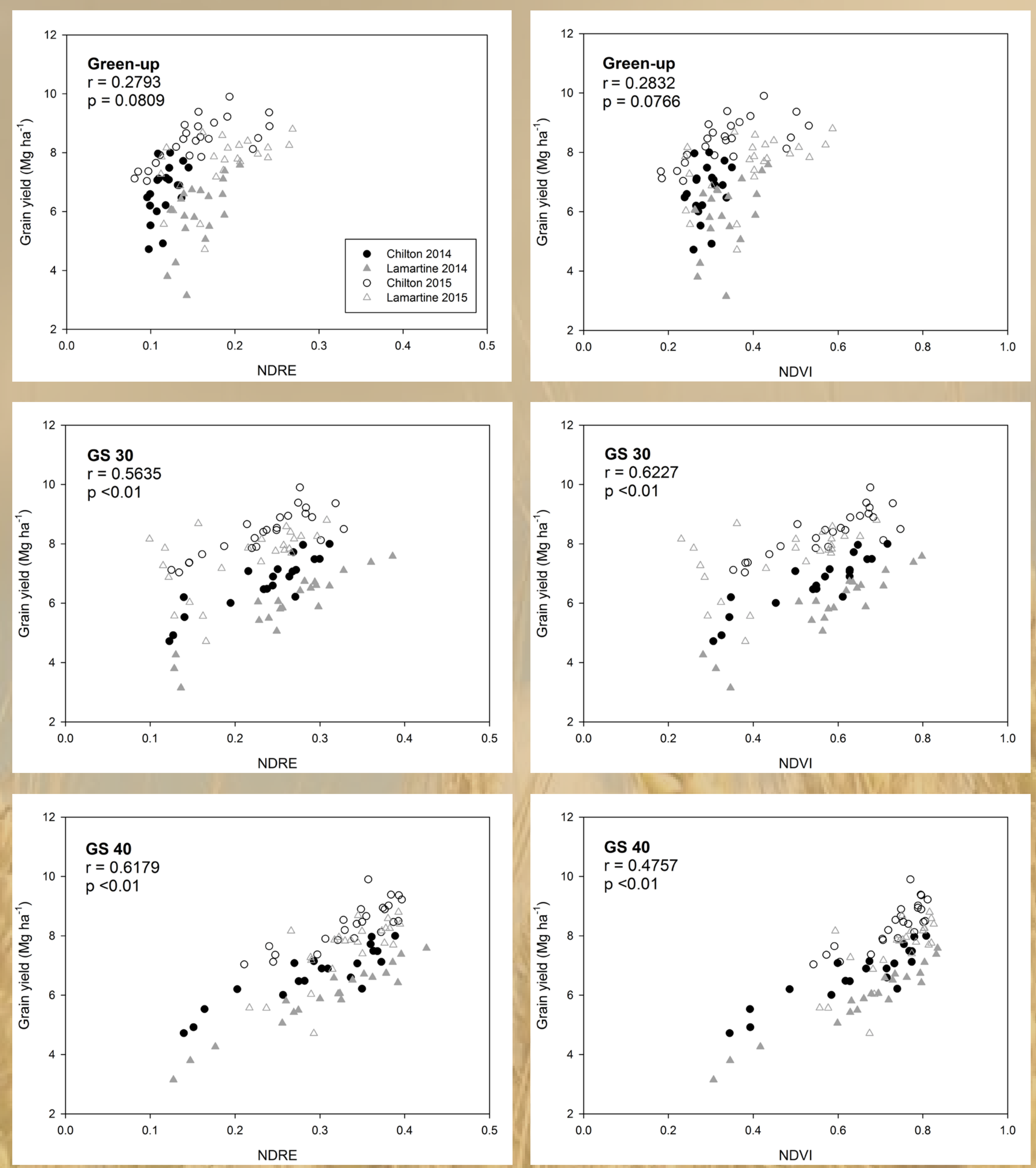

Figure 1. Wheat grain yield response to NDRE and NDVI vegetation indices at three different times (Green-up, GS 30, and GS 40).

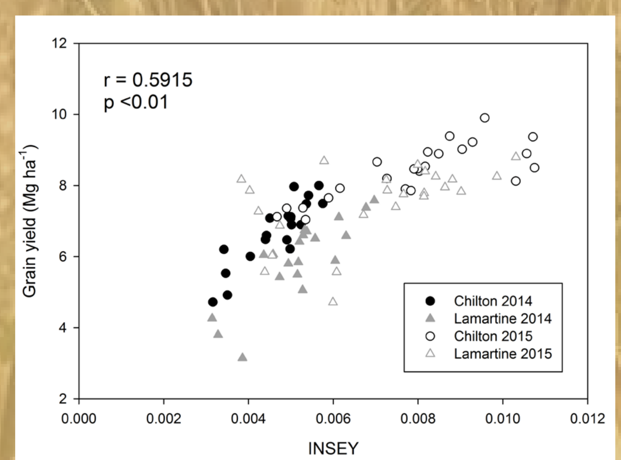

Figure 2. Wheat grain yield response to INSEY at Chilton and Lamartine in 2014 and 2015.

Table 1. Agronomic optimum N rate (AONR) and N rate recommendations created with different algorithms and modifications at GU and GS 30.

		Algorithm Method †				
		$NFOA_{UNMOD}$	$NFOA_{MOD}$	NRS_{UNMOD}	NRS_{MOD1}	NRS_{MOD2}
Site year and timing	AONR‡	N rate recommendation				
Green-up	kg N ha^{-1}	kg N ha^{-1}				
Chilton (2014)	76	-§	-	199	139	74
Lamartine (2014)	100	-	-	142	99	71
Chilton (2015)	67	-	-	220	154	79
Lamartine (2015)	80	-	-	132	93	71
GS 30						
Chilton (2014)	84	-21	-21	130	91	47
Lamartine (2014)	107	-24	-26	103	72	20
Chilton (2015)	0	-23	-27	36	26	59
Lamartine (2015)	118	-21	-22	113	79	51

† See Discussion section for algorithm modification descriptions.
‡ AONR, agronomic optimum N rate.
§ No N rate recommendation could be made because Raun's INSEY calculation requires two dates of sensing; green-up was the earliest sensing date considered for this analysis.

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Discussion

Effect of N Application on Yield
- For all site years, grain yields were significantly greater ($p < 0.10$) when N was applied at green-up (8.1 Mg ha^{-1}) compared to GS 30 (7.2 Mg ha^{-1}).
- Nitrogen applied at green-up had significantly ($p < 0.01$) greater yields than N applied at planting at both locations in 2014.

Crop Canopy Reflectance and Yield Parameters
- Reflectance at the 730, 780, and 670 wavelengths was correlated to GS 30 N uptake, grain N uptake, grain yield, and relative yield.
  - Reflectance collected at GU at the 780 wavelength was significantly correlated ($p < 0.01$) with GS 30 N uptake ($r = 0.44$), grain N uptake ($r = 0.30$), grain yield ($r = 0.26$), and relative yield ($r = 0.43$)
  - Correlation coefficients increased with later sensing dates (data not shown)
- NDVI and NDRE were correlated to GS 30 N uptake, grain N uptake, grain yield (Figure 1), and relative yield.
  - Correlation coefficients increased as the season progressed

Validating the Use of N Algorithms From Other Growing Regions

Oklahoma: N Fertilization Optimization Algorithm (NFOA)
- A major portion of the NFOA is the in-season estimate of yield (INSEY) relationship developed by Raun et al. (2001, 2002).
  - INSEY is calculated by summing NDVI values, the only input in this algorithm, collected at GU and GS 30 and dividing by the change in growing degree days between the two sensing dates
  - In this study, the relationship between grain yield and INSEY produced a significant positive correlation with GS 30 N uptake, yield (Figure 2), and relative yield.
- **$NFOA_{UNMOD}$**: Wisconsin sensing data was entered into the NFOA
  - Nitrogen recommendations were negative for all site years (Table 1)
- **$NFOA_{MOD}$**: An exponential relationship was observed between grain N uptake and NDVI in Wisconsin and was used to replace the INSEY and grain N content portion of the NFOA
  - Nitrogen rate recommendations were still negative for all site years (Table 1)

Kansas: No Reference Strip v1.5 Algorithm
- The no reference strip (NRS) v1.5 algorithm was created by Asebedo (2015)
  - Inputs: NDVI collected at the desired time of N application, yield history, and a nitrogen use efficiency (NUE) term
- **NRS_{UNMOD}**: Nitrogen rate recommendations were made using NRS v1.5 algorithm with Wisconsin's sensor data, NUE value of 0.7, and average Wisconsin yield of 7.0 Mg ha^{-1}
  - Recommendations over estimated N (Table 1)
- **NRS_{MOD1}**: The NUE value in NRS_{UNMOD} was modified to 1.0 which assumes every unit of applied fertilizer was taken up by the crop
  - Nitrogen was still over recommended but was closer to the AONR
- **NRS_{MOD2}**: Algorithm modifications for GU timing included substituting Wisconsin specific equations for the yield potential with fertilizer and the product efficiency. Algorithm modifications for GS 30 included substituting Wisconsin specific equations for the yield potential with and without fertilizer and the product efficiency.
  - GU relationships: N recommended within 10 kg N ha^{-1} of the AONR for all site years, except at Lamartine in 2014 (Table 1)
  - GS 30 relationships: N recommendations did not improve (Table 1)

Conclusions

- Regional differences caused algorithms developed in Oklahoma and Kansas to be unsatisfactory for use in Wisconsin
  - For example, GU in Kansas occurs at GS 30 but at GS 20 (tillering) in Wisconsin
  - Modification of the Kansas algorithm improved accuracy; however, sensor based GU N rate recommendations using the modified algorithm were not much different than the current N recommendation system.
- Unrecoverable yield loss occurred when N was applied at GS 30
  - An algorithm developed using reflectance measured at GU is preferred
  - Unfortunately, sensor data collected at GU in Wisconsin does not have strong significant correlations with yield data; therefore, creation of algorithms may be difficult.

Literature Cited

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