Determining In-Season Nitrogen Requirements for Maize Using Model and Sensor Based Approaches

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Introduction

There is great value in determining the optimum quantity and timing of nitrogen (N) application to meet crop needs while minimizing losses. Applying a portion of the total N during the growing season allows for adjustments which can be responsive to actual field conditions which result in varying N needs. A crop model-based approach and a crop canopy sensor-based approach have been proposed as ways to determine in-season N need.

Objectives

The objective of this study was to evaluate these two approaches for determining in-season N rates: model and sensor. Utility in predicting N need is evaluated for both approaches over a 3-state region, including sites in Missouri, Nebraska, and North Dakota. Additionally, the study investigated effects of maize hybrid and population on the efficacy of the two N recommendation strategies.

Methods

- The study was conducted over 12 site years, located in 3 states (Missouri, Nebraska, and North Dakota), with 2 sites per state. Soil test data for all site years is shown in Table 1.
- The experimental design was a RCBD with four replications per site.
- The treatment design was a 2x2x4 factorial with: 2 hybrids, 2 populations, and 4 N strategies (unfertilized check, N-rich reference ranging from 224 – 280 kg ha^{-1}, sensor-based, and model-based).
- The sensor-based and model-based N treatments had a base N rate applied at planting, and an in-season N application at V9-V11.
- For the sensor-based treatments, the normalized difference red edge index (NDRE) and sufficiency index (SI) were obtained using a RapidSCAN CS-45 Handheld Crop Sensor (Holland Scientific, Lincoln, NE). The modified Holland-Schepers algorithm used SI values to determine in-season N application rates (Holland and Schepers, 2010).
- For model-based treatments, Maize-N: Nitrogen Rate Recommendation for Maize tool (Setiyono, et al., 2011) was used to determine in-season N application rates.
- All treatments were scanned to obtain NDRE and SI values at the time of in-season N application and ~2 weeks following N application.
- Grain yield, grain N content, partial factor productivity of N, and agronomic efficiency were obtained.

Table 1: Pre-plant soil test values as reported, arranged by site.

Field ID	Texture	Organic Matter (%)	P	K	pH	NO_3-N (lb N/ac 3 ft)
MO-RO-12	Silt Loam	1.50	106 lb/ac *B1P	217 lb/ac	7	45
MO-LT-12	Silt Loam	3.60	26 lb/ac B1P	145 lb/ac	5.7	38
MO-TR-13	Silt Loam	1.70	69 lb/ac B1P	359 lb/ac	6.8	<20
MO-BY-13	Silt Loam	1.90	27 lb/ac B1P	182 lb/ac	6.8	<20
ND-DN-12	Silty Clay	5.30	32 ppm **OP	600 ppm	7.6	45
ND-VC-12	Loam	3.60	10 ppm OP	300 ppm	6.3	73
ND-AR-13	Silty Clay Loam	3.40	5 ppm OP	120 ppm	8.0	66 *top 2 feet
ND-VC-13	Sandy Loam	3.60	19 ppm OP	160 ppm	6.4	113 *top 2 feet
NE-CC-12	Silt Loam	3.88	27 ppm ***M3P	482 ppm	6.35	132
NE-MC-12	Sandy Loam	1.65	41 ppm M3P	326 ppm	6.65	68
NE-CC-13	Silt Loam	3.1	23 ppm M3P	428 ppm	6.4	27 *top 2 feet
NE-MC-13	Sandy Loam	2.1	29 ppm M3P	212 ppm	7.5	64 *top 2 feet

**B1P=Bray 1-P Extract, **OP=Olsen Extract, ***M3P=Mehlich-3 Extract*

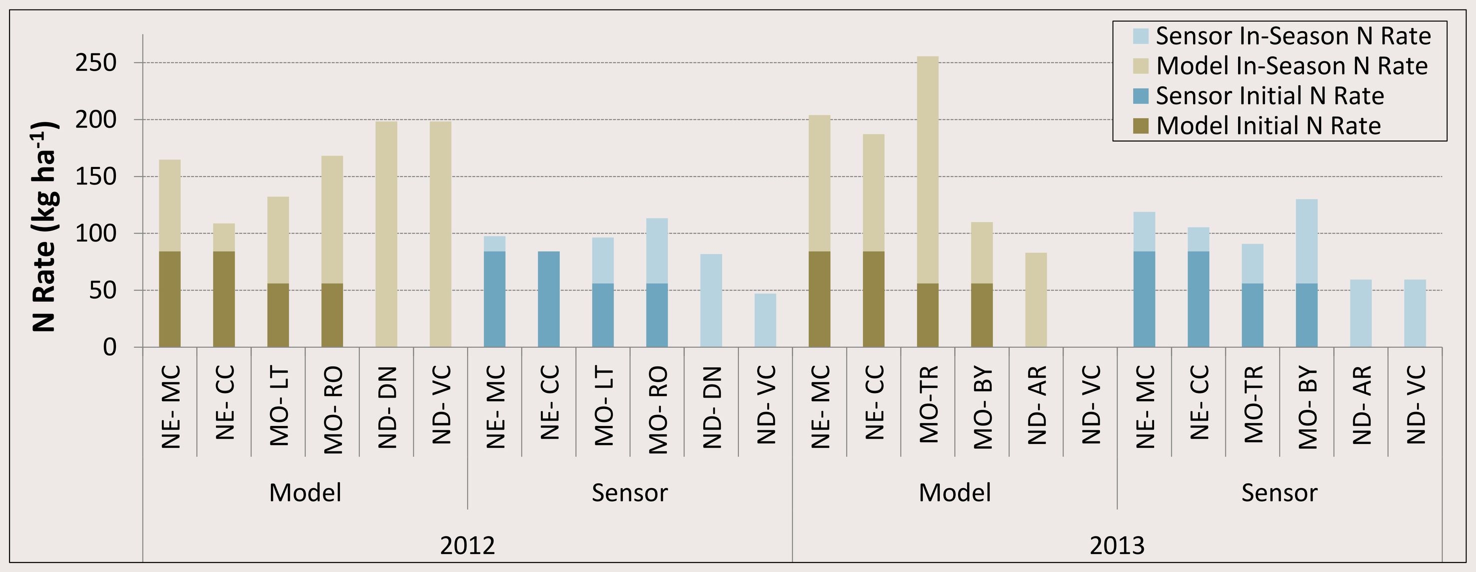

Figure 1: Initial and in-season N application rates for model and sensor treatments arranged by site.

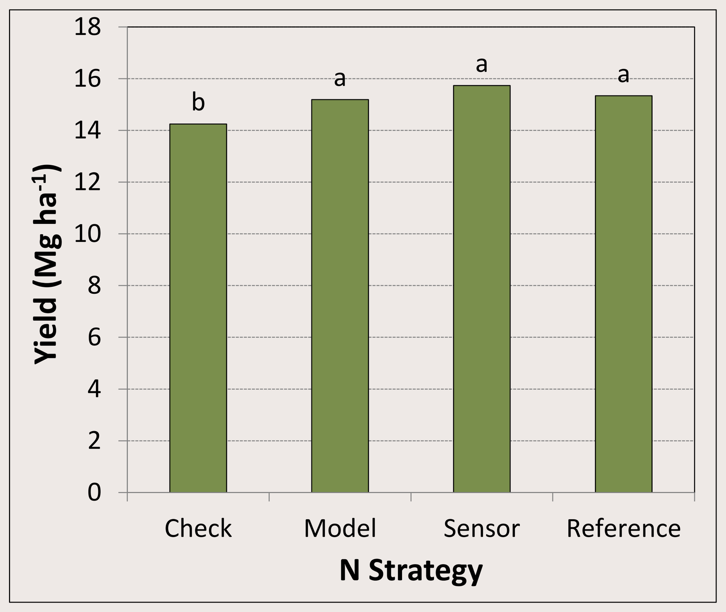

Figure 2: Yield arranged by N strategy for NE- MC-12 – representative of yield significance for 3 Nebraska site years and MO- LT- 12. Bars with the same letters are not significantly different at alpha = 0.05.

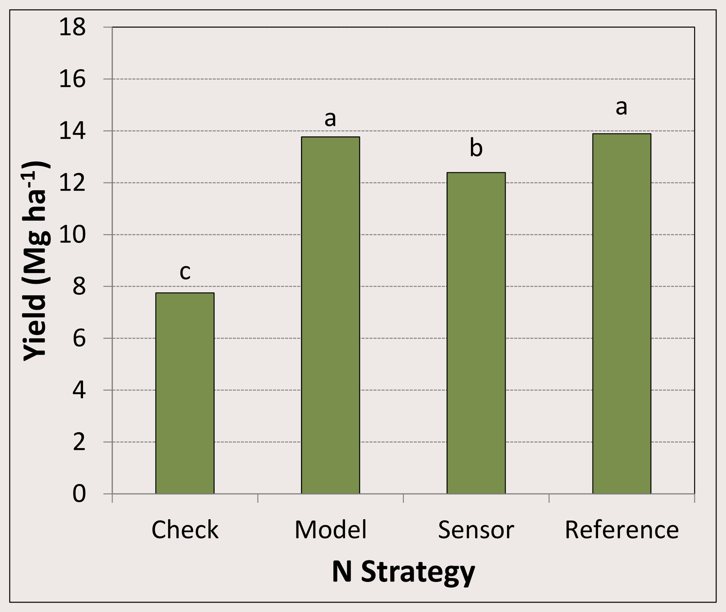

Figure 3: Yield arranged by N strategy for NE- MC-13. Bars with the same letters are not significantly different at alpha = 0.05.

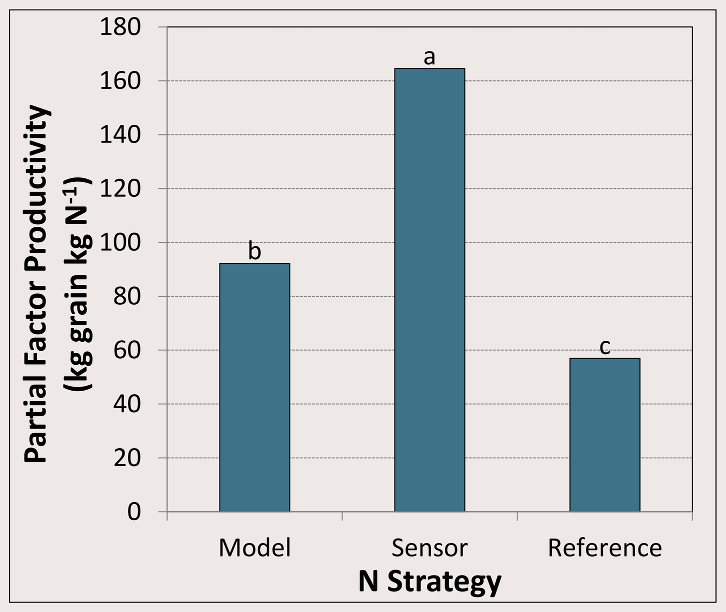

Figure 4: Partial factor productivity of N arranged by N strategy for NE- MC-12 – representative of partial factor productivity of N significance for all Nebraska site years. Bars with the same letters are not significantly different at alpha = 0.05.

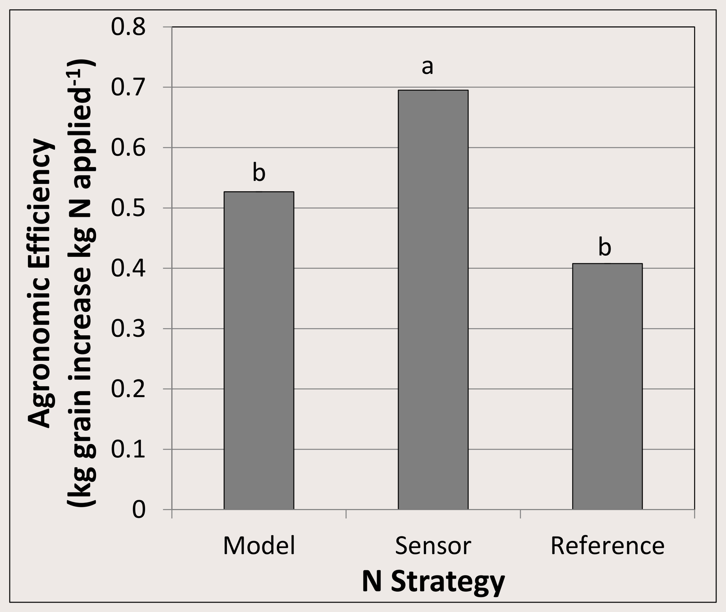

Figure 5: Agronomic efficiency of N arranged by N strategy for NE- MC-13 – representative of 3 Nebraska site years. For one site year, NE- CC- 13, results were the same with the exception of the reference being significantly lower than the model. Significance is at an alpha level of 0.05.

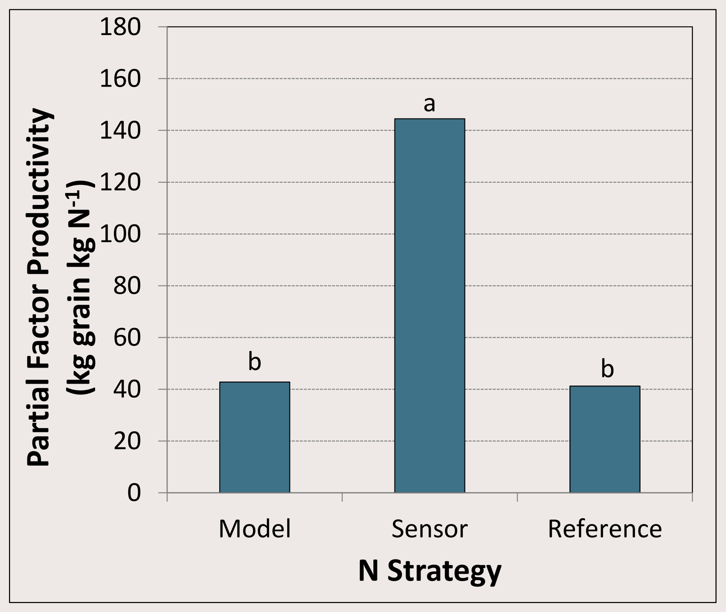

Figure 6: Partial factor productivity of N arranged by N strategy for ND- VC- 12 – representative of partial factor productivity of N significance for both North Dakota sites in 2012. Bars with the same letters are not significantly different at alpha = 0.05.

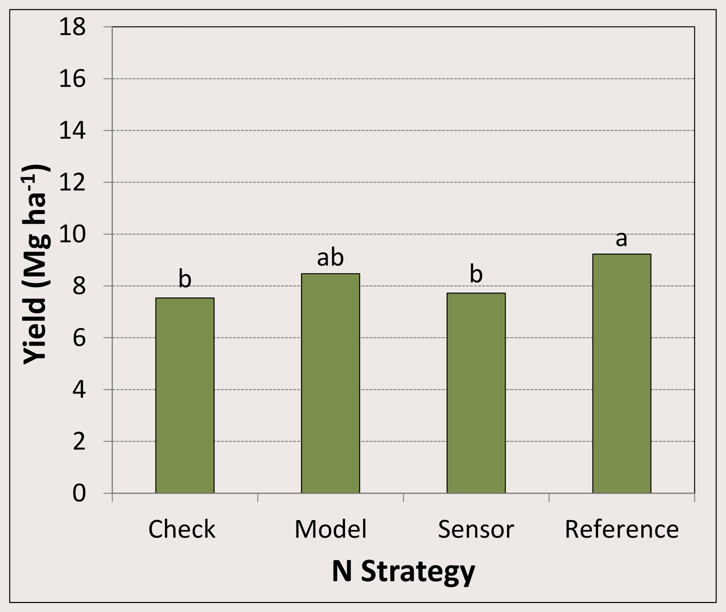

Figure 7: Yield arranged by N strategy for ND- VC-12 – representative of yield significance for both North Dakota sites in 2012. Bars with the same letters are not significantly different at alpha = 0.05.

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Results and Discussion

Nebraska

- For all site years, the sensor approach called for less in-season N than the model approach (Figure 1).
- Yields were not statistically different between the model, sensor, and reference treatments for 3 of 4 site years (Figure 2). Yield of the differing site year, NE- MC-13, is shown in Figure 3.
- For all site years the sensor approach had a statistically higher partial factor productivity of N (PFP_N) than the model approach (Figure 4).
- For all sites, the sensor approach had a significantly greater agronomic efficiency than the model approach and reference (Figure 5). For one site the model approach was significantly greater than the reference in agronomic efficiency.
- No N was recommended by the sensor approach for site NE-CC in 2012 where high mineralization occurred, therefore the sensor approach appears more responsive to in-season growing conditions.

Missouri

- Both 2012 sites had lower N recommendations using the sensor-based approach than the model-based approach (Figure 1).
- The MO-LT site showed no significant yield differences between the model, sensor, and reference N strategies and the sensor had a higher PFP_N (P>0.05). The 2012 MO-RO site was lost due to water stress.
- In 2013, at the MO-BY site, the sensor approach recommended a higher N application than the model approach; at the MO-TR site, the sensor approach recommended a lower N application than the model approach (Figure 1). Yield data is not yet available for these sites.

North Dakota

- For all site years, no initial N was applied prior to in-season N application. In 2012, both sites had lower N applications using the sensor approach than the model approach; in 2013, the sensor approach recommended higher N application at the ND-VC site, and lower N application at the ND-AR site (Figure 1).
- For 2012, the sensor strategy had a higher PFP_N (Figure 6), but lower N rate resulted in yield values for the sensor treatment which were significantly lower than the reference (Figure 7). The model approach estimated N needs that reduced overall N application from the reference amount, without significantly reducing yield.
- In 2012, there was no significant economic advantage to either the model or sensor strategy, given $5 corn prices and $0.50 fertilizer N price (P>0.05).
- In 2013, no significant yield differences were seen at either site for any N strategy, including between the check which received 0 kg ha^{-1} and the reference which received 224 kg ha^{-1} (P>0.05). It is believed that there were other factors which limited yield potential and masked N treatment differences.