Validating Weather and Sensor-Based N Prediction Models for Michigan Corn Production
FINAL Report 2016

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Location: South Campus Research Farm	**Tillage**: Conventional
Planting Date: May 18, 2016; 30 in. rows (previous soybean)	**Treatments:** See below
Soil Type: Capac Loam; 3.4 OM; 51 ppm P; 131 ppm K; 6.7 pH	**Population**: 34,000 seeds/ acre
Variety: DKC48-12RIB	**Replicated**: 4 replications

Introduction:

Accurately predicting the economic optimum nitrogen rate (EONR) remains a challenge due to seasonal and geographic variables impacting N cycling and corn growth. One approach to provide N recommendations, referred to as MRTN (i.e., Maximum Return To Nitrogen), has been utilized by seven Midwestern states and provides N rate recommendations based on yield response to applied N while simultaneously accounting for fertilizer and grain prices. MRTN is considered a regional approach to N recommendations as the research trials from which they are derived are conducted within individual states. Research trials occur over multiple sites and years allowing growers to adjust N rates within a profitable range based on crop rotation, soil productivity potential, N fertilizer to corn price ratios, and application timing. However spatial variability in N response is known to exist from site to site as well as within a single location from year-to-year. Variability creates additional risk when determining the N rate that will be economically optimal for a specific location.

The MRTN is a pre-season general N recommendation model (as compared to a field-specific or site-based model) that does not account for individual site variability nor variable in-season weather trends. Incorporating weather data may result in a more precise N rate decision. One specific site- and model-based approach, *Adapt-N* (http://adapt-n.cals.cornell.edu), was developed to provide field-specific locally-adjusted sidedress N recommendations based on soil and management factors while also accounting for climate-influenced N dynamics. The Adapt-N program has the potential to adjust side-dress N rates and increase the accuracy of site-specific N recommendations. There is potential risk for post-application fertilizer N losses which may impact the site economic optimum yield if N becomes a limiting factor. Previous studies have found Adapt-N to under recommend N to a greater extent than MRTN in Indiana and Iowa, and the model failed to adequately account for excessive rainfall and mineralization.

Plant canopy sensors (i.e., Minolta SPAD 502 chlorophyll meter (CM)) have been used to detect N stress and guide in-season recommendations. Scharf et al. (2006) related CM readings with EONR and corn yield response to N. Other studies have utilized remote sensors such as the Greenseeker to develop in-season yield potential estimates and the likely yield response to added N fertilizer when the N recommendation was based on additional obtainable yield (Raun et al., 2005). Few data exist in Michigan utilizing canopy sensors to determine in-season N requirements but may offer another opportunity for site-specific estimation of in-season N needs as influenced by early-season weather.

Design

Nine (9) treatments including a control were arranged in a randomized complete block design with four replications; plot size = 15 x 40 feet; 30" row spacing.

Objective

1) Evaluate site- and year-specific model-based approaches to identify strengths and weaknesses for predicting economic N-fertilization rates for corn. Compare pre-plant to sidedress application for achieving equivalent yield potential. Utilizing model-based approaches may begin to validate effectiveness and provide opportunities for improvement. (Incorporating weather data into site-recommendations may impact N rate accuracy, but could limit economic potential where post-application weather patterns are extreme.)

Hypotheses: 1) Application of N at V4 can produce yields as high as those achieved with a non-limiting rate applied at planting, and 2) Adapt-N rate using site-specific soil and weather information up to V8 is closer to EONR than MRTN prediction at planting.

2) Utilize Minnesota-based N rate calculator to develop economic optimum in-season N recommendation for Greenseeker sensor-based treatment at multiple growth stages. Optimum growth stage for sensing is estimated at V8 based on previous literature. Externally-derived data from similar latitude may produce similar recommendations to site yield-based EONR.

Hypothesis: Greenseeker rate based on Minnesota algorithm using sensor data at V8 is closer to EONR than MRTN prediction at planting.

Treatments:

Treatment	Rate (lbs N/A)	Description	Placement	Sidedress
1	250	Non-limiting N (control)	PPI	
2	150	N response – MRTN Rate	2x2 (46)	V4 (104)
3	46	N response – 31% MRTN	2x2 (46)	---------
4	100	N response – 67% MRTN	2x2 (46)	V4 (54)
5	200	N response – 133% MRTN	2x2 (46)	V4 (154)
6	250	N response – 167% MRTN	2x2 (46)	V4 (204)
7	151	Model dependent: Adapt-N	2x2 (46)	V8 (105)
8	161	Sensor Dependent: NDVI	2x2 (46)	V8 (115)
9	0	Untreated – no N added	---------	---------

A starter fertilizer was applied at planting, pre-plant incorporated (PPI), of 89 lbs K_2O.
Urea (46-0-0) used as N source for PPI applications.
Urea ammonium nitrate (UAN; 28%) used as N source for 2x2 and sidedress applications.
UAN injected at V4; V8 applications were surface banded mixed with Agrotain® Ultra urease inhibitor to prevent N volatilization.

Observations

1) Greenseeker (normalized difference vegetation index; NDVI) collected V4, V6, V8, V10, V12, V14, V16, R1, R2.
2) Pre-sidedress soil nitrate test (PSTN on trt 9; two soil samples collected from each rep at 0-12 inch depth and combined for composite analysis per rep).
3) MRTN recommendation for year-based N rate approach
4) Adapt-N regional N rate recommendation for V8 sidedress
5) Greenseeker-sensor based model N rate recommendation for V8 sidedress
6) Final population
7) Grain moisture
8) Grain test weight
9) Grain yield (adjusted to 15.5% moisture)

Protocol:

PPI N trt + starter fertilizer: May 18
Plant + 2x2 UAN applications: May 18
V4 sidedress: June 6
V6 PSNT: June 14
Adapt-N for V8 sidedress: June 21
Greenseeker sensor readings for V8 sidedress recommendation: June 23
V8 sidedress: June 24
Final population: Oct. 12
Harvest: Oct. 18

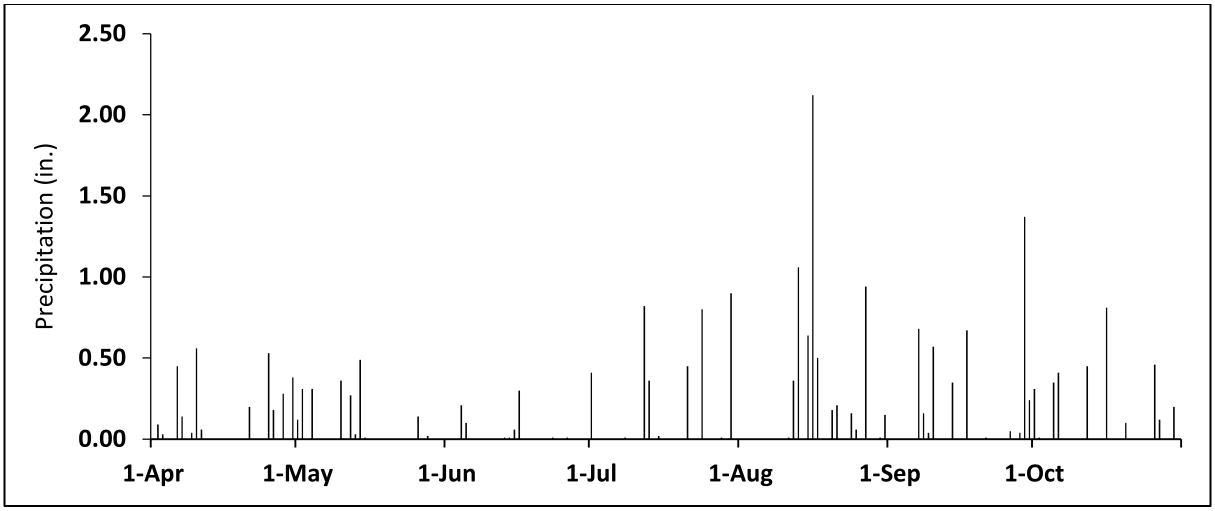

Figure 1. 2016 Lansing precipitation

Results:

Cumulative rainfall between April 1 and Oct. 31 was 23.3 inches with 15 rainfall events greater than 0.5 inches (Fig. 1). Total rainfall between PPI N application and V4 sidedress was 0.47 inches. Total rainfall between PPI N application and V8 sidedress was 0.86 inches. The V8 sidedress timing avoided an additional 0.39 inches of rainfall received by other treatments. Despite a cumulative seasonal rainfall similar to that of the 2015 season, a lack of rainfall events between May 18 and July 1 resulted in dry soil conditions following planting, V4, and V8 SD timings. Cumulative May and June rainfall was reduced 38.1 and 79.7% from the 30 yr-monthly average.

Response to N was best modeled with a linear plateau (LP) regression model (R^2=0.83) vs. either a quadratic (R^2=0.83) or quadratic plateau (QP) model (R^2=0.82) and included treatments 2-6. Models contained similar coefficients of determination and the LP model was chosen due to a lower root mean square error (RMSE). The LP model resulted in a site-specific EONR of 110 lbs N A^{-1}. The LP model is a production function independent of the N price to grain price ratio unlike the QP and quadratic models, and resulted in a lower EONR (39 to 60 lbs N A^{-1}, respectively) with a plateau at 214 bu A^{-1}. In 2015 the EONR was 173 lbs N A^{-1} with a plateau at 165 bu A^{-1} illustrating where opportunities for N loss are increased as the N rate to optimize crop yield is also increased.

The MRTN was set to 150 lbs N A^{-1} in 2016 which was 10 lbs N A^{-1} higher than 2015 due to a \$0.11/lb N cost decrease. Pre-sidedress soil nitrate test values sampled at V6 corn tested low (≤ 10 ppm) indicating no N credit was to be taken and a grower's total N rate be applied based on the MRTN approach. The mean Adapt-N recommended V8 sidedress N rate was 105 lbs N A^{-1} on June 21 with a range from 94 to 111 lbs N A^{-1} that growers could choose from to maximize yield. The mean Adapt-N recommendation was 15 lbs N A^{-1} less than in 2015 corresponding to model-based estimates of both increased N mineralization (8 lb N A^{-1}) and decreased N loss (9 lb N A^{-1}) in 2016.

The Greenseeker based N rate was derived in conjunction with the Sensor Based Nitrogen Rate Calculator (SBNRC) utilizing a Minnesota-based corn algorithm. The N rate produced by the calculator at sidedress V8 was 115 lbs N/A (52 lb N A^{-1} more than site EONR) based on N sufficiency of the 'grower practice' and corn yield potential of the nonlimiting-N control. This was determined using the highest NDVI value obtained per rep for the nonlimiting-N control and lowest grower practice NDVI value. Relative to the MRTN and Adapt-N models growers utilizing the sensor-based model will need to establish reference strips where corn is fertilized to nonlimited N conditions. The Greenseeker-recommended V8 N rate was increased 40 lbs N A^{-1} in 2016 vs. 2015 due to an increased NDVI interval between the nonlimiting-N control and grower practice resulting in a larger SBNRC response index (1.37 vs. 1.25, respectively). A larger interval in 2016 vs. 2015 was likely due to both reduced N loss conditions affecting the urea PPI application (trt 1) and dry soils affecting mass flow of N to corn roots. Use of the Minnesota-based algorithm will require additional validation for use in MI due to potential impacts of abnormal May and June rainfall on the nonlimiting-N control and grower practice encountered in 2015 and 2016.

In Iowa studies the MRTN and Adapt-N models have been compared with regard to their ability to over- or under-estimate the site-specific EONR within 25 lb N A^{-1}. The Adapt-N, MRTN, and sensor-based model-recommended N rates were 41, 40, and 51 lb N A^{-1} more than EONR, respectively (Table 1). This did not correspond to a significant difference in grain yield albeit the difference in sidedress timings. No differences in grain yields resulting from model-based approaches were observed relative to the urea PPI treatment (Table 1). This demonstrates that similar yield levels were attainable with 89 (Greenseeker), 99 (Adapt-N), and 100 lbs N A^{-1} (MRTN) less as compared to a single urea PPI application. A lack of statistical difference was likely due to below average cumulative rainfall for May and June. During the 20-d period from PPI to V4 SD only 0.47 in. of rainfall occurred relative to 3.60 inches of potential evapotranspiration creating a 3.12-in. deficit. The deficit was increased to 5.93 in. at V8 SD on June 24. Arid soil conditions likely increased downward moisture-seeking root growth and a simultaneous upward soil solution mass flow from increased water potential thus reducing positional availability of fertilizer N. Substantial rainfall events > 0.41-inches did not occur until July 12 where SD rates of 154 (trt 5) and 204 (trt 6) lbs N A^{-1} were required to elicit a significant grain yield response relative to a urea PPI application (trt 1). The MRTN rate remained static with no in-season N adjustments. In a dry year the sensor-based approach resulted in an N recommendation approx. 10 lb N A^{-1} greater vs. other model-based approaches with no sig. yield increase. In a wet year the Greenseeker reduced grain yield relative to the Adapt-N and MRTN models. In both years the Greenseeker did not generate N rates closer to EONR than a year-based approach disproving hypothesis #2. This could have implications to a grower's bottom line.

In both years of this study the year-based (MRTN) and regional (Adapt-N) N rate approaches offered alternatives to reduce N rates ≥ 79 lbs N A^{-1} and still achieve yields equivalent to a 250 lb N A^{-1} urea spring PPI application. The year-based approach did not provide recommendations within 25 lbs N A^{-1} of the site EONR suggested by Iowa studies in either year. In a dry year all model-based approaches achieved equivalent yields, but overestimated site-specific EONR ≥ 40 lbs N A^{-1} and all within 11 lbs N of each other. In a wet year the year-based approach accounted for N loss and fell within the Iowa criteria, but achieved similar yields to the year-based approach though at an additional cost of 31 lbs N A^{-1}. This has financial implications and illustrates two points: 1) the 25 lbs N A^{-1} criteria suggested by Iowa studies may not be a feasible criterion in the northern corn belt to gauge approaches, and 2) the cost of using a mass-balance based approach such as Adapt-N may not be necessary to fine-tune N management where split N applications are already a best management practice.

Table 1. 2016 sensor study grain yields (15.5% moisture)

Treatment		Total N	ΔEONR[†]	Moisture	TestWeight	Grain Yield[‡]
number	name	---------lbs N A^{-1}--------		--- % ---	-- lbs/bu --	---bu A^{-1}---
1	Non-limiting N	250	+140	18.7 b[*]	53.3	190 b
2	MRTN	150	+40	19.2 ab	52.8	207 ab
3	31% MRTN	46	-64	15.9 c	52.7	160 c
4	67% MRTN	100	-10	19.0 ab	53.1	206 ab
5	133% MRTN	200	+90	19.5 a	52.7	216 a
6	167% MRTN	250	+140	19.8 a	52.8	218 a
7	Adapt-N	151	+41	19.0 b	53.5	206 ab
8	Greenseeker	161	+51	18.8 b	53.6	209 ab
9[*]	Untreated[§]		46	16.5	53.2	124
			*P*r>F	0.0827	0.6130	0.0159

[†]Change in economic optimum N rate of 110 lbs N A^{-1} where ΔEONR = Total N applied - EONR
[‡]Grain yield at EONR = 214 bu A^{-1}.
[*]Values followed by the same letter are not statistically different at $P \leq 0.10$.
[§]Not included in statistical analysis.