A Regional Investigation of Nitrogen Rate Prescription, Hybrid, and Population on Maize Yield and Nitrogen Use

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Introduction

Nitrogen, an essential element, is often limiting to plant growth. There is great value in determining the optimum quantity and timing of N application to meet crop needs while minimizing losses. Growing conditions may vary greatly by year and location resulting in differing N needs and complicating N recommendations. Applying a portion of the total N during the growing season allows for adjustments which can be responsive to actual field conditions. The Maize-N model was developed to estimate the economically optimum N fertilizer rates for maize by taking into account soil properties, indigenous soil N supply, local climatic conditions and yield potential, crop rotation, tillage and fertilizer formulation, application method and timing (Setiyono, et al., 2011). Active crop canopy sensors are responsive to canopy N status during the growing season and can also be used to determine in-season N application rates. The objective of this study is to evaluate these two approaches for determining in-season N rates and specifically: (i) determine the utility of active optical ground-based sensors over a 3-state region, including sites in Missouri, Nebraska and North Dakota in predicting N need and enhancing corn yield, (ii) determine the effect of plant population on the effectiveness of in-season N-rate prediction and application, (iii) determine the effect of using a hybrid with high drought tolerance versus low drought tolerance on in-season N-rate prediction and application, (iv) determine the effect of using the sensor-based approach in a highly productive soil compared to a site with lower soil productivity, (v) investigate the interactions of the sensor approach versus traditional N management, plant population, soil productivity and hybrid type on corn yield and (vi) compare the performance of the recently released Maize-N decision tool (Setiyono, et al., 2011) economic optimum N rate (EONR) calculations to in-season, sensor-based N management.

Materials and methods

Two experimental sites per state were selected, located in relatively close proximity to each other in order to minimize weather interactions. In Nebraska, sites were located at the South Central Agricultural Research Laboratory near Clay Center (NE-CC), and in Merrick County, near Grand Island (NE-MC). Missouri sites were both near Columbia, identified as Rollins (MO-RO) and Lone Tree (MO-LT). North Dakota sites were located near Durbin (ND-DN) and Valley City (ND-VC). Site selection was based on expected corn yield potential at that location. A high yield potential and lower yield potential site was chosen for each state. The lower expected yield site was chosen due to a limiting feature such as drainage, soil texture or rooting depth. Sites are depicted in Figure 1. Weather data is shown in Figure 2. Soil information is in Table 1.

Figure 1: Site locations.

The experiment was conducted in a randomized complete block with four replications at each site. Two corn hybrids were used at each location, characterized by having a low drought score (LDS) and high drought score (HDS). Each hybrid was planted at a moderate and high population. Population and drought scores by site are in Table 2. Plots were approximately 50 feet long and varied from 4 to 6 rows wide depending on location. Tillage and previous crop varied by location. Pre-plant soil samples for pH, OM, P, K and NO_3-N were obtained for each site (Table 3). Pre-plant, at-planting and in-season N application method and N source varied by state.

Figure 2: Precipitation, Irrigation and Air Temperature for all sites for the 2012 growing season.

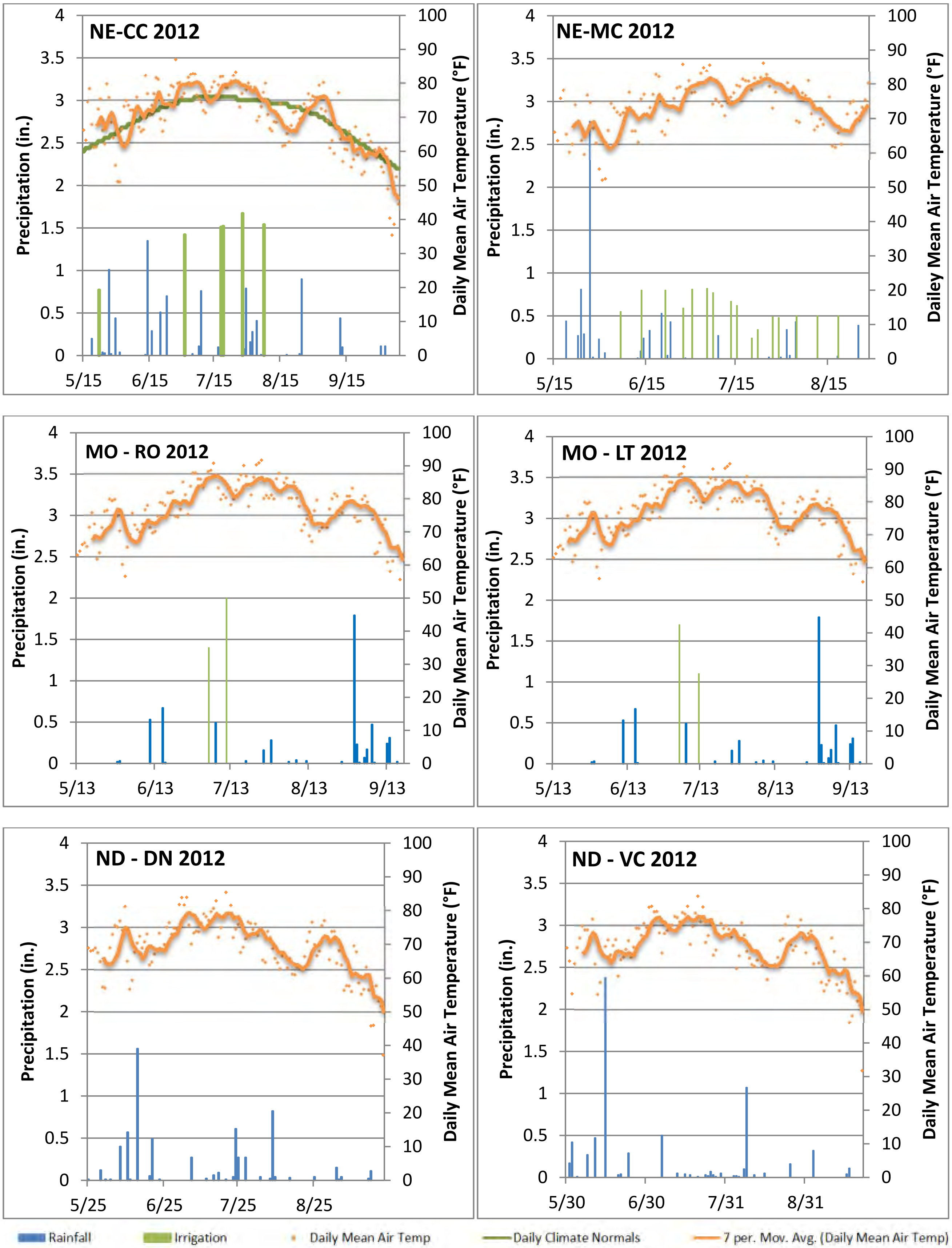


Table 1: Soil series and taxonomic class arranged by site. Site relative expected productivity is indicated.

Site	Series	Taxonomic Class	% Trt Area
NE - CC *High yield potential*	Crete silt loam, 0-1%	Fine, smectitic, mesic Pachic udertic Argiustolls	100%
NE - MC *Low yield potential*	Fonner sandy loam, rarely flooded	Sandy, mixed, mesic Cumulic Haplustolls	80.5%
	Novina sandy loam, rarely flooded	Coarse-loamy, mixed, superactive, mesic Fluvaquentic Haplustolls	19.5%
MO - RO *High yield potential*	Haymond silt loam, 0-3%	Coarse-silty, mixed, superactive, mesic Dystric Fluventic Eutrudepts	100%
MO - LT *Low yield potential*	Mexico silt loam, 1-4%, eroded	Fine, smectitic, mesic Vertic Epiaqualfs	100%
ND - DN *High yield potential*	Fargo silty clay, 0-1%	Fine, smectitic, frigid Typic Epiaquerts	100%
ND - VC *Low yield potential*	Barnes loam, 3-6%	Fine-loamy, mixed, superactive, frigid Calcic Hapludolls	100%

Table 2: Hybrid and planting population arranged by site.

Site	Hybrid		Planting Population (seeds per acre)	
	HDS	*LDS*	*High*	*Low*
NE – CC	Pioneer 1498	Pioneer 33D49	42,000	32,000
NE – MC	Pioneer 1498	Pioneer 33D49	42,000	32,000
MO – RO	Pioneer 1498	Pioneer 33D49	41,000	31,000
MO – LT	Pioneer 1498	Pioneer 33D49	41,000	31,000
ND – DN	Pioneer 8906	Pioneer 39N99	42,000	32,000
ND – VC	Pioneer 8906	Pioneer 39N99	42,000	32,000

Table 3: Pre-plant soil samples arranged by site. Phosphorus test used is indicated below value.

Site	Organic Matter	P	K	pH	NO_3-N (lbs N/ac 3 ft)	Irrigation NO_3-N Credit
NE – CC	3.88%	27 ppm *M3P	482 ppm	6.35	132	~10 lbs/ac
NE – MC	1.65%	41 ppm M3P	326 ppm	6.65	68	~24 lbs/ac
MO – RO	1.50%	106 lbs/ac **B1P	217 lbs/ac	7	45	
MO – LT	2.60%	26 lbs/ac B1P	145 lbs/ac	5.7	38	
ND – DN	5.30%	32 ppm ***OP	600 ppm	7.6	45	
ND – VC	3.60%	10 ppm OP	300 ppm	6.3	73	

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

Four N treatments were used: unfertilized check, N-rich reference, sensor-based and model-based. All sites had an unfertilized check treatment. Missouri initial N application rates were 50 lbs/ac for the sensor and model-based treatments and 200 lbs/ac for the N-rich reference. Nebraska initial N application rates were 75 lbs/ac for the sensor and model-based treatments and 250 lbs/ac for the N-rich reference. North Dakota initial N application rates were 0 lbs/ac for the sensor and model-based treatments and 200 lbs/ac for the N-rich reference. In-season N application was done at V9-V11, depending on location. In-season N application rates for sensor treatments were determined using canopy reflectance data collected from all treatments immediately prior to fertilization. Canopy reflectance data was collected using a RapidSCAN CS-45 Handheld Crop Sensor (Holland Scientific, Lincoln, NE) (Figure 3). Two rows per plot were scanned and averaged to generate a value for that plot. The normalized difference red edge index (NDRE) was used to generate a sufficiency index (SI).

$$\mathrm{NDRE} = \frac{\mathrm{R_{NIR}} - \mathrm{R_{RED\ EDGE}}}{\mathrm{R_{NIR}} + R_{\mathrm{RED\ EDGE}}} \tag{1}$$

where

R_{NIR} = near-infrared reflectance (780 nm)

$R_{RED\ EDGE}$ = red edge reflectance (730 nm)

$$\mathrm{SI} = \frac{\text{NDRE of sensor based treatment}}{\text{NDRE of N rich reference}} \tag{2}$$

The SI was then used in the modified algorithm by Holland and Schepers (2010, modified 2012) to determine a N application rate. The in-season N application rates for the model treatments were determined using Maize-N: Nitrogen Rate Recommendation for Maize (Version 2008.1.0, Yang, H.S., et al., University of Nebraska – Lincoln, 2008). Model treatments were applied at the same date as the sensor treatments. Nebraska and North Dakota plots were hand harvested and Missouri plots were machine harvested. Harvest population was recorded at all sites and barren counts were taken in Nebraska. The partial factor productivity for N was calculated by dividing yield by total fertilizer N rate. Agronomic efficiency was calculated by taking the difference in yield between the fertilized treatment and the check and dividing by total N application. The data was analyzed using Statistical Analysis System (SAS).

Figure 3: RapidSCAN CS-45 Handheld Crop Sensor scanning corn.

Results and Discussion

In-season N recommendations for the model and sensor treatments are summarized in Table 4. For all sites, in-season N application for model treatments exceeded that of sensor treatments.

Table 4: Average nitrogen rate in lbs N/acre for sensor and model treatments arranged by site.

	Sensor				**Model**			
	LDS,Lpop TRT 3*	*LDS,Hpop TRT 7*	*HDS,Lpop TRT 11*	*HDS,Hpop TRT 15*	*LDS,Lpop TRT 4*	*LDS,Hpop TRT 8*	*HDS,Lpop TRT 12*	*HDS,Hpop TRT 16*
NE – CC	0	0	0	0	30	12	33	14
NE – MC	14	14	13	6	74	68	76	70
MO – RO	47	47	55	53	104	94	106	95
MO – LT	46	34	34	28	70	64	71	65
ND – DN	108	59	66	60	182	177	176	173
ND – VC	39	53	36	42	194	167	183	163

**LDS=low drought score, HDS=high drought score, Lpop=low population, Hpop=high population*

Table 5: Main treatment effects for yield, partial factor productivity of nitrogen and agronomic efficiency arranged by site.

Site	Hybrid	N strategy	Plant population	Hybrid x N strategy	Hybrid x plant population	N strategy x plant population	Hybrid x N strategy x plant population
Main treatment effects on yield (check, N rich reference, sensor and model treatments included)							
NE – CC	NS*	NS	NS	NS	NS	NS	NS
NE – MC	<0.0001	0.0013	NS	NS	NS	NS	NS
MO – RO	0.0146	NS	NS	NS	NS	NS	NS
MO – LT	0.0004	<0.0001	0.0008	NS	NS	NS	NS
ND – DN	NS	0.0215	NS	NS	NS	NS	NS
ND – VC	NS	0.0114	NS	NS	NS	NS	NS
Partial factor productivity of nitrogen main effects (includes N rich reference, sensor and model treatments)							
NE – CC	NS	<0.0001	0.0140	NS	NS	0.0078	NS
NE – MC	0.0026	<0.0001	NS	NS	NS	NS	NS
MO – RO	NS	<0.0001	NS	NS	NS	NS	NS
MO – LT	0.0097	<0.0001	NS	NS	NS	NS	NS
ND – DN	NS	0.0026	NS	NS	NS	NS	NS
ND – VC	NS	<0.0001	NS	NS	NS	NS	NS
Agronomic efficiency main effects (includes N rich reference, sensor and model treatments)							
NE – CC	NS	NS	NS	NS	NS	NS	NS
NE – MC	0.0122	0.0043	NS	NS	NS	NS	NS
MO – RO	0.0282	NS	NS	NS	NS	NS	NS
MO – LT	NS	0.0091	NS	NS	NS	NS	NS
ND – DN	NS	NS	0.0061	NS	0.0400	NS	NS
ND – VC	NS	NS	NS	NS	NS	NS	NS
Partial factor productivity of nitrogen main effects (only sensor and model treatments)							
NE – CC	NS	<0.0001	0.0147	NS	NS	0.0200	NS
NE – MC	0.0113	<0.0001	NS	NS	NS	NS	NS
MO – RO	NS	0.0005	NS	NS	NS	NS	NS
MO – LT	0.0168	0.0088	NS	NS	NS	NS	NS
ND – DN	NS	0.0122	NS	NS	NS	NS	NS
ND – VC	NS	<0.0001	NS	NS	NS	NS	NS
Agronomic efficiency main effects (only sensor and model treatment)							
NE – CC	NS	NS	NS	NS	NS	NS	NS
NE – MC	0.0327	0.0233	NS	NS	NS	NS	NS
MO – RO	0.0320	NS	NS	NS	NS	NS	NS
MO – LT	NS	NS	NS	NS	NS	NS	NS
ND – DN	NS	NS	0.0333	NS	NS	NS	NS
ND – VC	NS	NS	NS	NS	NS	NS	NS

**Actual probability level up to 0.05, NS indicates probability level >0.05*.

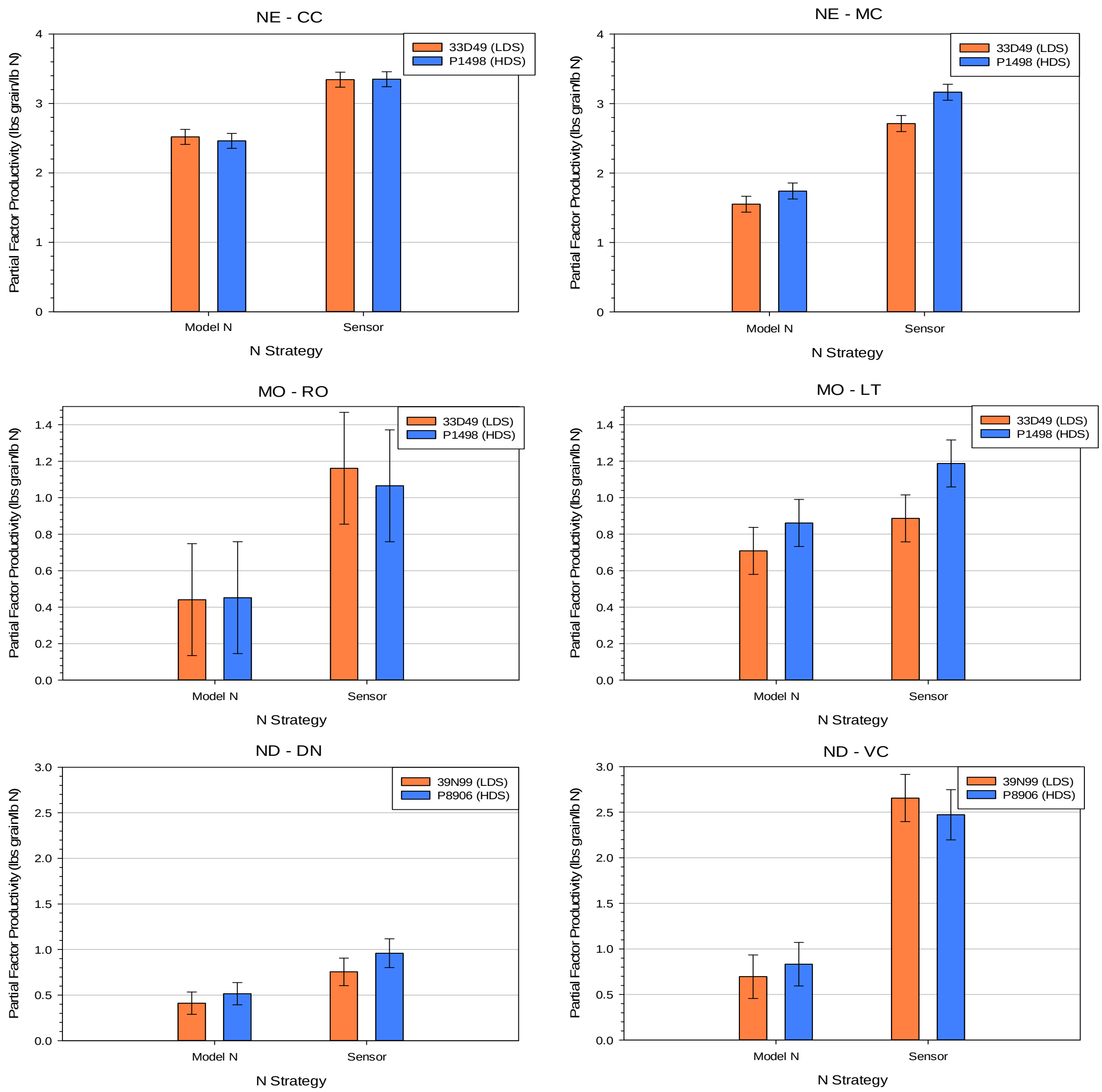
Agronomic efficiency was not correlated to N strategy for many of the sites. However, partial factor productivity was correlated with N application strategy for all sites (Table 5). Additionally, the sensor treatment appears to have higher nitrogen use efficiency (NUE) as seen by partial factor productivity (Fig. 4). Treatment mean values for yield, partial factor productivity of N and agronomic efficiency are in Table 6.

Table 6: Treatment means for yield, partial factor productivity of nitrogen and agronomic efficiency arranged by site.

Treatment	Yield (bu/ac)	Nitrogen Partial Factor Productivity	Agronomic Efficiency	Yield (bu/ac)	Nitrogen Partial Factor Productivity	Agronomic Efficiency
		NE – CC			**NE - MC**	
LDS-Lpop-C*	249.8			224.2		
LDS-Lpop-R	236.8	0.9470	-0.05223	221.2	0.9218	-0.01241
LDS-Lpop-S	250.7	3.3431	0.01216	241.5	2.7682	0.2189
LDS-Lpop-M	245.0	2.3332	-0.04603	223.5	1.4997	-0.00500
LDS-Hpop-C	225.2			219.2		
LDS-Hpop-R	245.4	0.9817	0.08103	239.3	0.9969	0.08353
LDS-Hpop-S	250.6	3.3419	0.3395	232.0	2.6578	0.1483
LDS-Hpop-M	235.3	2.7050	0.1167	229.4	1.6043	0.07144
HDS-Lpop-C	241.1			232.8		
HDS-Lpop-R	251.8	1.0072	0.04296	259.8	1.0827	0.1129
HDS-Lpop-S	250.4	3.3379	0.1239	271.9	3.1325	0.4423
HDS-Lpop-M	245.9	2.2766	0.04465	259.6	1.7195	0.1781
HDS-Hpop-C	238.6			231.5		
HDS-Hpop-R	249.1	0.9965	0.04195	257.0	1.0710	0.1063
HDS-Hpop-S	252.0	3.3596	0.1779	257.3	3.1955	0.3221
HDS-Hpop-M	235.7	2.6482	-0.03305	255.5	1.7623	0.1655
		MO – RO			**MO – LT**	
LDS-Lpop-C	48.7			52.1		
LDS-Lpop-R	72.6	0.2900	0.09549	97.5	0.3894	0.1812
LDS-Lpop-S	65.8	1.0225	0.2863	88.8	0.9216	0.3882
LDS-Lpop-M	87.3	0.5660	0.2502	90.4	0.7524	0.3187
LDS-Hpop-C	66.3			29.8		
LDS-Hpop-R	57.9	0.2312	-0.03352	68.2	0.2726	0.1535
LDS-Hpop-S	84.5	1.3004	0.2270	68.7	0.8511	0.4903
LDS-Hpop-M	45.7	0.3168	-0.1427	75.8	0.6644	0.4032
HDS-Lpop-C	93.2			70.8		
HDS-Lpop-R	98.8	0.3945	0.02225	106.3	0.4248	0.1418
HDS-Lpop-S	75.1	1.0277	-0.2708	101.0	1.1960	0.3500
HDS-Lpop-M	76.8	0.4918	-0.1047	97.3	0.8027	0.2180
HDS-Hpop-C	93.1			47.7		
HDS-Hpop-R	94.6	0.3779	0.006057	87.8	0.3509	0.1603
HDS-Hpop-S	72.5	1.1032	-0.2300	91.5	1.1793	0.5880
HDS-Hpop-M	59.8	0.4118	-0.2294	105.9	0.9199	0.5057
		ND – DN			**ND – VC**	
LDS-Lpop-C	58.9			109.3		
LDS-Lpop-R	107.8	0.5387	0.3144	142.4	0.7121	0.1654
LDS-Lpop-S	64.1	0.6507	0.2549	125.4	2.4881	0.1692
LDS-Lpop-M	78.8	0.4330	0.1865	134.1	0.6914	0.1278
LDS-Hpop-C	65.6			119.9		
LDS-Hpop-R	93.4	0.4668	0.1388	157.9	0.7893	0.1899
LDS-Hpop-S	83.9	0.8596	0.3259	130.5	2.8219	0.3440
LDS-Hpop-M	69.2	0.3908	0.02020	116.9	0.7002	-0.01761
HDS-Lpop-C	54.3			122.6		
HDS-Lpop-R	88.8	0.4439	0.1724	143.8	0.7187	0.1058
HDS-Lpop-S	85.6	1.3635	0.8126	120.2	2.5831	0.2515
HDS-Lpop-M	100.2	0.5694	0.2609	150.8	0.8239	0.1541
HDS-Hpop-C	83.1			127.5		
HDS-Hpop-R	81.1	0.4055	-0.01019	145.1	0.7257	0.08840
HDS-Hpop-S	55.5	0.5550	-0.4115	114.1	2.3592	-0.2877
HDS-Hpop-M	79.7	0.4610	-0.01959	137.1	0.8408	0.05886

**LDS = low drought score hybrid, HDS = high drought score hybrid, Lpop = low population, Hpop = high population, C = nitrogen check, R = nitrogen rich reference, S = sensor based nitrogen, M = model based nitrogen*

Figure 4: Partial factor productivity of nitrogen by treatment, for all six sites.



Summary

Weather conditions played a large role this year. Water stress masked N treatment effects at some sites which were not fully irrigated. The Nebraska sites experienced a large amount of mineralization, particularly in March, which resulted in all treatments, including the control, having very high available N. Additionally, leaf curling due to drought stress and low populations due to soil crusting likely impacted the sensor readings in North Dakota.

For the future, involving Haishun Yang, developer of the Maize-N model will provide valuable expertise for model treatments. It is also possible that weather data for the growing season up to the application date could be included in the model recommended N rate. Obtaining grain N content for all sites next year would have value as fertilizer recovery efficiency could then be calculated. There is also the prospect of collecting sensor data at other sites where N rate by hybrid experiments are underway. The target N application will be slightly earlier, around V8, in order to be able to conduct a post application sensing prior to corn tasseling at all locations. There is also a possibility to increase uniformity of the experiment across the locations, potentially by using the same type and method of N fertilizer and using the same harvest method. The target N available at pre-plant will also be adjusted. North Dakota locations will increase pre-plant N as necessary to ensure a total of 100 lbs of N is available pre-plant.

Publications

N/A

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