IMPACT OF PREDICTED VS. DYNAMIC IN-SEASON NITROGEN MANAGEMENT STRATEGIES ON CORN YIELD IN NEBRASKA

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ABSTRACT

Improving nitrogen (N) management in corn (*Zea mays* L.) requires strategies that synchronize N supply with crop demand while maintaining yield, N use efficiency (NUE), and profitability. Sensor-based management supports in-season N decisions, but many producers lack access to sensing technology, which makes it important to identify effective N rates and application timing between the V8 and R2 growth stages. In 2025, field experiments with 12 N rate and timing treatments, including the UNL Nitrogen Calculator rate applied preplant or in splits, reduced rates, and sensor-based management, were established at five Nebraska research sites; hail damage at one site (PHREEC) limited this report to four sites. Economic optimum N rate (EONR), estimated from plateau yield-response models, ranged from 56 to 160 lb N ac^{-1} among sites. Sensor-based management reduced the N rate relative to the UNL Calculator at three of four sites, by up to 21 lb N ac^{-1}, but neither approach consistently matched EONR; the Calculator and sensor-based rates differed from EONR by an average of 41 and 34 lb N ac^{-1}, respectively. Grain yield and NUE (0.45 to 0.67 lb N bu^{-1}) did not differ between the two approaches at any site. Fertilized treatments generally out-yielded the unfertilized control, with the smallest response at WCREEC, and no consistent yield advantage of split applications over preplant application was evident. Marginal net return was similar for the Calculator and sensor-based approaches except at WCREEC, where the Calculator returned \$24 ac^{-1} more. These one-year results show large site-to-site variability in N requirement and suggest that several in-season strategies can maintain corn productivity; additional site-years are needed to confirm their consistency.

INTRODUCTION

Nitrate contamination of groundwater has been a concern in Nebraska for decades and is driven largely by N fertilizer use in irrigated corn production (Juntakut et al., 2019). Improvements in NUE have slowed in recent years, which has increased interest in synchronizing fertilizer N with crop demand rather than applying the full rate before planting.

Sensor-based in-season N management is one way to make that adjustment, but cost, equipment access, and management complexity limit adoption by many producers. For those growers, the best timing and number of in-season N applications between V8 and R2 remain poorly defined. A previous trial in northeast Nebraska found no yield benefit from additional split applications, but the result was confounded by drought (Singh et al., 2024), so it is unclear whether optimized split timing can match sensor-guided management across a wider range of soils and seasons. Because the UNL Nitrogen Calculator and sensor-based algorithms are both used to set N rates, it is also useful to compare their recommendations with the site-specific economic optimum.

The objectives of this first-year study were to (i) compare UNL Nitrogen Calculator and sensor-based N recommendations with the retrospectively estimated EONR and with each other for yield, NUE, and economic return; and (ii) evaluate the effect of N application timing (preplant versus one to three in-season splits) on grain yield, N uptake, and N efficiency.

MATERIALS AND METHODS

Sites and Experimental Design

Field experiments were established in 2025 at five University of Nebraska–Lincoln research locations: the Eastern Nebraska Research, Extension and Education Center (ENREEC, Mead), Haskell Agricultural Laboratory (HAL, Concord), South Central Agricultural Laboratory (SCAL, Clay Center), West Central Research, Extension and Education Center (WCREEC, North Platte), and the Panhandle Research, Extension and Education Center (PHREEC, Scottsbluff). Corn was grown in the corn phase of a corn–soybean rotation at all sites, and N was applied only to corn. Hail damage at PHREEC prevented the collection of usable data, so four sites are reported. Baseline soil properties differed substantially among sites (Table 1). Composite soil samples were collected from each replication at 0–8, 8–24, and 24–36 in before treatments were applied.

Twelve N treatments (Table 2) were arranged in a randomized complete block design with four replications at each site. They included an unfertilized control, a high-N reference, the UNL Nitrogen Calculator rate applied preplant, the Calculator rate split into one, two, or three in-season applications, Calculator-based rates reduced by 30, 60, or 90 lb N ac^{-1}, and sensor-based management. The Calculator rates were 130, 158, 170, and 110 lb N ac^{-1} at ENREEC, HAL, SCAL, and WCREEC, respectively. Sensor-based treatments received 30% of the Calculator rate near planting, and in-season rates were triggered by the sensor algorithm using canopy reflectance measured before each application. The comparisons of N timing in this paper use the control, preplant, one-, two-, and three-split, and sensor-based treatments; yield response to N rate was described using the control, rate-reduced, Calculator, and high-N reference treatments (0 to 300 lb N ac^{-1}).

Table 1. Baseline soil properties at the experimental sites in 2025.

Site	Texture	pH	OM (%)	Nitrate-N (ppm)	Available N (lb ac^{-1})	Mehlich-III P (ppm)	K (ppm)	CEC
ENREEC	Silt loam	5.9	3.45	3.4	8.5	6.5	274	23.2
HAL	Loamy fine sand	6.6	1.15	4.8	11.5	11	60	6.6
SCAL	Silt loam	6.8	3.15	6.2	15	38.5	335	13.3
WCREEC	Silt loam	6.9	3.2	15.4	37	161	594	17.4

OM, organic matter; CEC, cation exchange capacity.

Table 2. Nitrogen treatments and distribution of total N among application times, 2025.

Trt.	Treatment	Near planting (%)	V8 (%)	V14 (%)	R2 (%)
1	Control	0	0	0	0
2	All preplant (UNL Calculator rate)	100	0	0	0
3	High-N reference	50	25	25	0
4	UNL Calculator, 1 split	30	70	0	0
5	UNL Calculator, 2 splits	30	40	30	0
6	UNL Calculator, 3 splits	30	40	20	10
7	UNL Calculator − 30 lb N ac^{-1}, 1 split	30	70	0	0
8	UNL Calculator − 30 lb N ac^{-1}, 2 splits	30	40	30	0
9	UNL Calculator − 30 lb N ac^{-1}, 3 splits	30	40	20	10
10	UNL Calculator − 60 lb N ac^{-1}, 1 split	30	70	0	0
11	UNL Calculator − 90 lb N ac^{-1}, 1 split	30	40	30	0
12	Sensor-based	30	†	†	†

† In-season N applications and rates were triggered by the sensor algorithm. V8, eight-leaf stage; V14, fourteen-leaf stage; R2, blister stage.

Measurements and Calculations

RapidScan canopy reflectance was measured in every plot before each N application, and drone-based multispectral imagery was collected at V4, V8, V12, V14, R1, R2, R4, and R6. Whole-plant biomass and plant N content were measured at R1 and R6 (physiological maturity), and grain yield and grain N content were determined at harvest. Post-harvest residual soil nitrate-N was sampled by plot at 0–8, 8–24, and 24–36 in and is not reported here. Nitrogen use efficiency was expressed as lb of applied N per bu of grain (lower values indicate greater efficiency). Agronomic efficiency (AE), partial factor productivity (PFP), and N recovery efficiency (NRE) were calculated relative to the unfertilized control.

Yield response to total N rate was described with plateau models at each site, and EONR was estimated from the fitted models using a corn price of \$5 bu^{-1} and an N price of \$0.50 lb^{-1}. Because EONR was estimated after harvest from end-of-season yield, it served as a retrospective benchmark for the Calculator and sensor-based rates. Marginal net return (MNR) was calculated as (grain yield × corn price) − (N rate × N price), using \$4.00 bu^{-1} corn and \$0.50 lb^{-1} N. Treatment effects were evaluated by analysis of variance within each site, and means were separated using Tukey's honestly significant difference test ($P \leq 0.05$).

RESULTS AND DISCUSSION

Yield Response to N and Economic Optimum N Rate

Grain yield increased with N rate and then reached a plateau at all sites, a typical diminishing-return response (Fig. 1). The fitted models explained 97 to 98% of the yield variation at ENREEC, HAL, and SCAL, but only 59% at WCREEC ($P = 0.26$), where the unfertilized control yielded relatively high and the response across rates was flat. Estimated EONR ranged from 56 lb N ac^{-1} at ENREEC to 160 lb N ac^{-1} at HAL, with

intermediate values of 110 and 82 lb N ac⁻¹ at SCAL and WCREEC (Table 3), a nearly three-fold difference. Maximum predicted yield was 184 bu ac⁻¹ at ENREEC and 248 to 250 bu ac⁻¹ at the other sites.

The low EONR at three of four sites may be partly explained by high precipitation during the 2025 season, which likely increased N mineralization and plant-available N at the finer-textured, higher-organic-matter soils at ENREEC, SCAL, and WCREEC (Table 1). By contrast, HAL has a loamy fine sand with low organic matter, which likely increased its dependence on fertilizer N and its EONR.

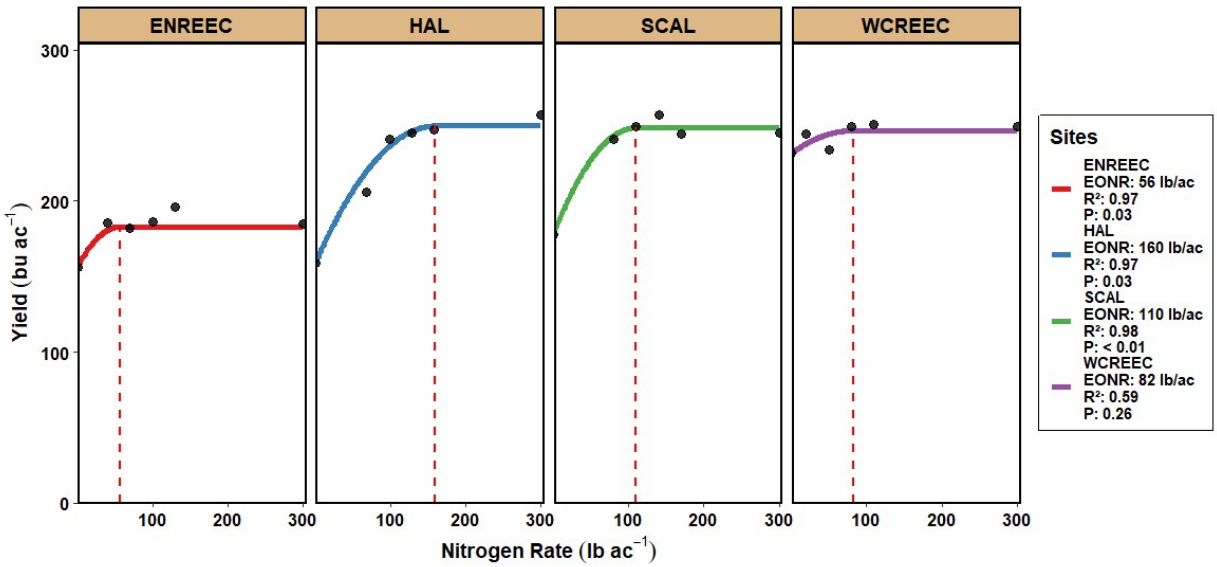


Figure 1. Corn grain yield response to total N rate at each site in 2025, fitted with plateau models. Vertical dashed lines indicate the economic optimum N rate (EONR; corn at $5 bu⁻¹, N at $0.50 lb⁻¹).

UNL Calculator, Sensor-Based Recommendations, and EONR

Sensor-based rates were lower than the UNL Calculator rates at three of four sites, by 5 lb N ac⁻¹ (3.2%) at HAL, 15 lb N ac⁻¹ (8.8%) at SCAL, and 21 lb N ac⁻¹ (16.2%) at ENREEC, which saved $3.00 to $12.60 ac⁻¹ in fertilizer cost (Table 3). At WCREEC the sensor-based rate was 3 lb N ac⁻¹ higher than the Calculator rate, and the average saving across sites was about $5.70 ac⁻¹.

Table 3. Economic optimum N rate (EONR), UNL Nitrogen Calculator and sensor-based N rates, and sensor-based N reduction and fertilizer cost savings relative to the Calculator, 2025.

Site	EONR (lb N ac⁻¹)	UNL Calculator (lb N ac⁻¹)	Sensor-based (lb N ac⁻¹)	Reduction (lb N ac⁻¹)	Reduction (%)	N cost savings ($ ac⁻¹)
ENREEC	56	130	109	21	16.2	12.60
HAL	160	158	153	5	3.2	3.00
SCAL	110	170	155	15	8.8	9.00
WCREEC	82	110	113	−3	−2.7	−1.80

Savings calculated at $0.50 lb⁻¹ N. Negative values indicate a higher sensor-based rate than the Calculator rate.

Neither approach consistently matched the site-specific EONR. On average, the Calculator and sensor-based rates differed from EONR by 41 and 34 lb N ac^{-1}, respectively. At ENREEC, SCAL, and WCREEC, both approaches exceeded EONR (Calculator by 74, 60, and 28 lb N ac^{-1}; sensor-based by 53, 45, and 31 lb N ac^{-1}), whereas at HAL both were slightly below it (158 and 153 versus 160 lb N ac^{-1}). This pattern indicates that both tools may benefit from local calibration, although EONR from a single site-year, particularly in a wet season, should be interpreted cautiously.

Grain yield did not differ between the Calculator and sensor-based treatments at any site (Fig. 2A). Nitrogen use efficiency also did not differ between approaches and ranged from 0.45 to 0.67 lb N bu^{-1} across sites, lowest at WCREEC and highest at ENREEC and SCAL (Fig. 2B). Both values were below the Nebraska statewide average of about 0.80 lb N bu^{-1}, which indicates efficient use of applied N in this season. Overall, the two approaches performed similarly for yield and NUE, and the sensor-based approach used less N at three sites without a yield penalty.

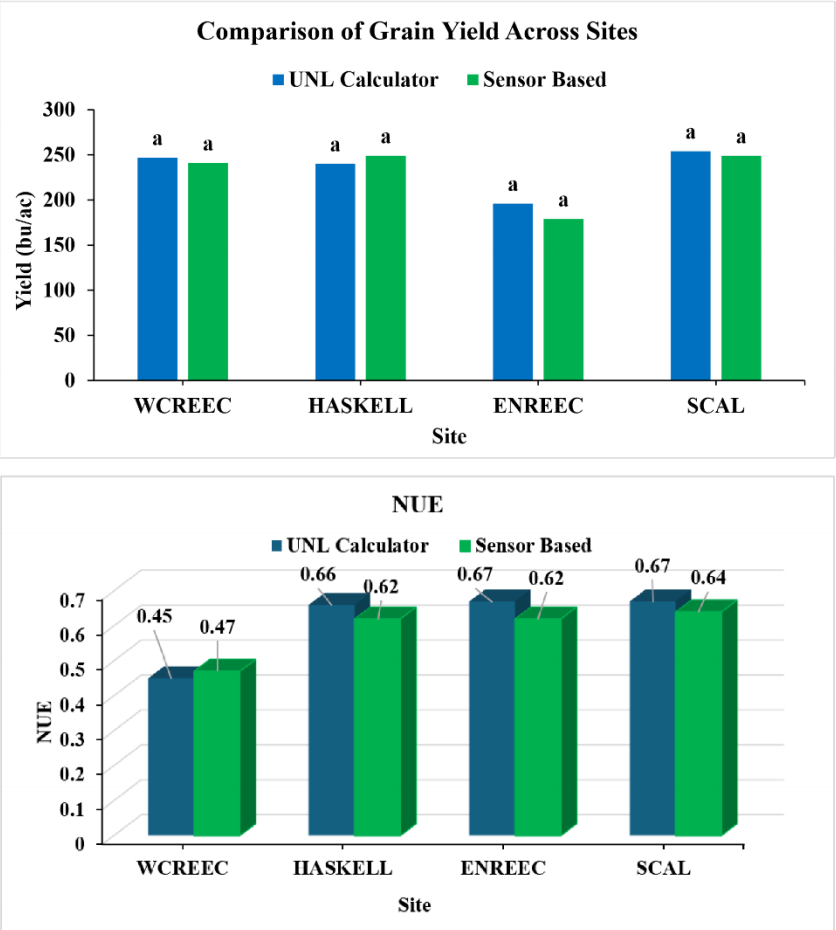


Figure 2. Grain yield (A) and nitrogen use efficiency (B; lb applied N per bu grain) for the UNL Nitrogen Calculator and sensor-based treatments in 2025. Bars with the same letter within a site are not significantly different ($P \leq 0.05$).

Effect of N Application Timing

Fertilized treatments generally out-yielded the unfertilized control, indicating that N supply limited yield without fertilizer, although the response at WCREEC was small (Fig. 3). Yield tended to increase with the number of split applications at some sites, but preplant, split-application, and sensor-based treatments did not differ consistently, and the rate × timing interaction was not significant at any site ($P \geq 0.178$). Yield responded to N rate at HAL and SCAL ($P < 0.001$) but not at ENREEC or WCREEC. These results suggest that once fertilizer was applied, crop N demand was largely satisfied regardless of strategy. Greater soil N supply from mineralization in the wet 2025 season may have reduced sensitivity to the timing of fertilizer N.

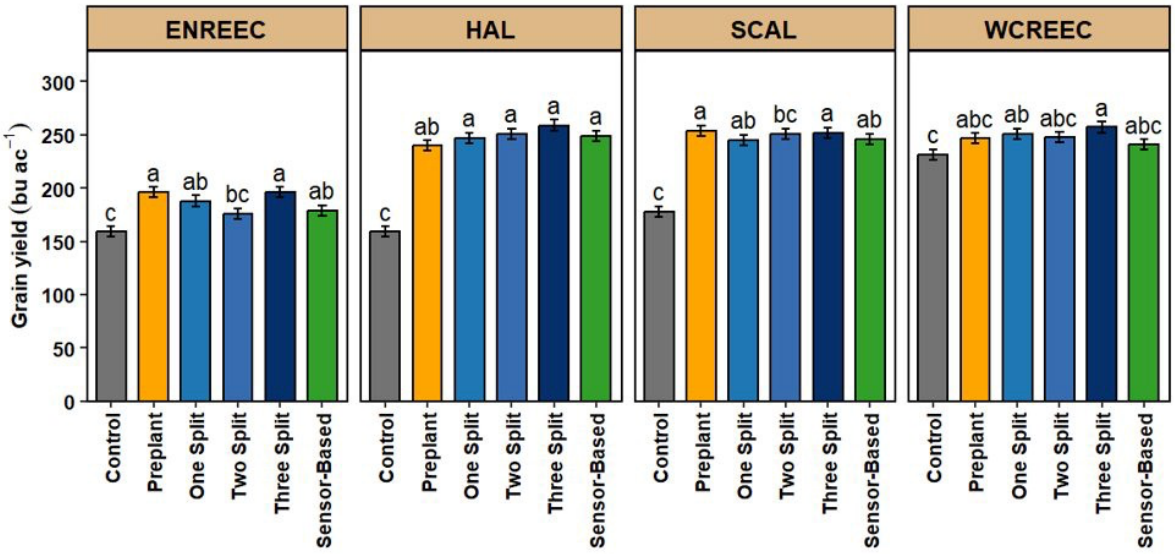


Figure 3. Corn grain yield response to N application timing and sensor-based management in 2025. Bars with a common letter within a site are not significantly different ($P \leq 0.05$). Error bars are standard errors.

Grain, stover, and total aboveground biomass and total N uptake were greater with N than without N at ENREEC, HAL, and SCAL, whereas biomass at WCREEC did not differ among treatments. Total N uptake increased from roughly 95, 120, 130, and 175 lb N ac^{-1} in the controls to 205–245, 245–295, 250–285, and 245–290 lb N ac^{-1} in fertilized treatments at ENREEC, HAL, SCAL, and WCREEC, respectively, with similar uptake among most fertilized treatments within a site. Grain contained 65 to 70% of total plant N, harvest index ranged from 0.48 to 0.55, and N harvest index from 0.64 to 0.70, so N management changed total biomass and N uptake more than the allocation to grain. Across all plots, grain biomass increased linearly with total N uptake ($r = 0.93$, $P < 0.001$).

Efficiency metrics showed site-specific responses to timing (Fig. 4). At HAL, the sensor-based treatment had the highest AE (about 43 kg grain kg^{-1} N), PFP (about 98 kg grain kg^{-1} N), and NRE (about 102%), exceeding the preplant and one-split treatments. At WCREEC, sensor-based management also had the numerically highest AE, PFP, and NRE (about 69%), but differences were not significant. At ENREEC and SCAL, preplant and sensor-based applications generally maintained efficiency equal to or higher than multiple in-season splits.

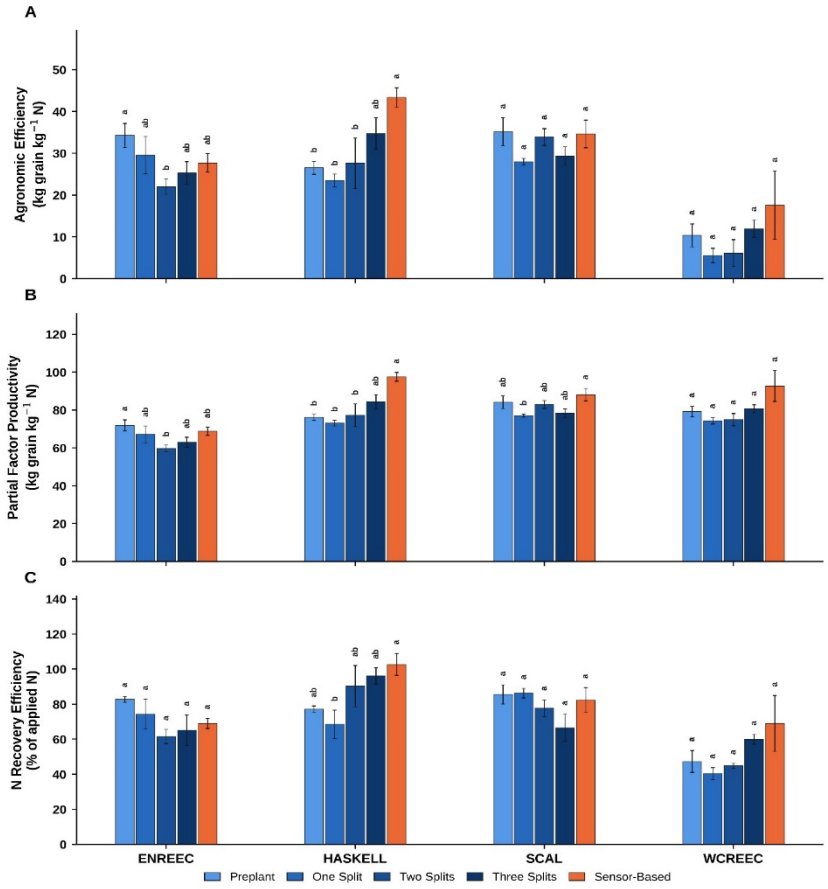


Figure 4. Agronomic efficiency (A), partial factor productivity (B), and N recovery efficiency (C) by N management strategy in 2025. Bars with a common letter within a site are not significantly different (Tukey's HSD, $P \leq 0.05$).

Marginal Net Return

Marginal net return did not differ between the UNL Calculator and sensor-based treatments at HAL, ENREEC, or SCAL (Fig. 5). At WCREEC, the Calculator treatment returned \$24 ac^{-1} more than the sensor-based treatment, reflecting the combined effects of fertilizer cost and grain revenue. These results are based on one site-year and are preliminary; application costs and the number of field passes were not included.

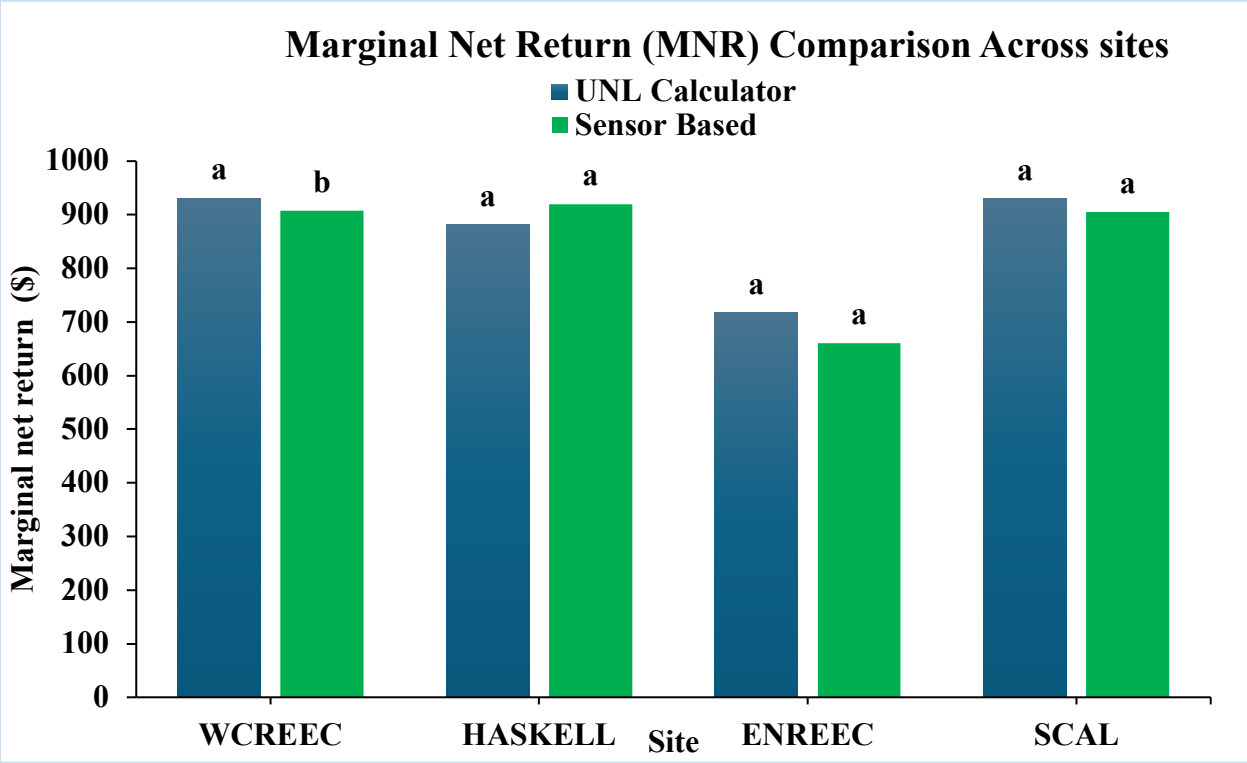


Figure 5. Marginal net return (grain yield × corn price − N rate × N price; corn at \$4.00 bu^{-1}, N at \$0.50 lb^{-1}) for the UNL Nitrogen Calculator and sensor-based treatments in 2025. Bars with the same letter within a site are not significantly different ($P \leq 0.05$).

CONCLUSIONS

In 2025, economic optimum N rates varied nearly three-fold among four Nebraska sites, and neither the UNL Nitrogen Calculator nor sensor-based recommendations consistently matched them. Sensor-based management reduced N use at three sites without affecting grain yield or NUE and produced similar marginal net return except at WCREEC. Fertilized corn out-yielded unfertilized corn at most sites, but split applications offered no consistent yield advantage over preplant application in this wet season. Because these conclusions rest on a single site-year, additional years and sites are needed to determine how consistent the responses are across weather, soil, and N-response conditions and to support updated in-season N recommendations.

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