COMPARING YIELD GOAL AND MAXIMUM RETURN TO N BASED METHODS IN PREDICTING CORN ECONOMIC OPTIMAL NITROGEN RATES

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INTRODUCTION

Nitrogen (N) is an essential plant nutrient commonly applied to South Dakota (SD) corn crops and is critical for optimizing corn yield. For commercial agriculture, there are two main sources of N for corn—N from decomposing manure, residue, and soil organic matter (mineralization) and synthetic N fertilizers. Each year, corn plants take up 98 to 250 lbs N/ac (average = 150 lbs N/ac) (Sierra, 1992; Kuzyakova et al., 2006; Blagodatskaya and Kuzyakov, 2008; Wu et al., 2008). Nitrogen derived from decomposing organic matter (i.e., mineralization) can provide 20 to 100% of the N required to optimize yield depending on factors like weather, soil type, previous crop, and management practices (Khan et al., 2001; Ros et al., 2011; Yost et al., 2012). The crop N need that is not supplied through mineralization is most often supplied by N fertilizer. However, excessive N fertilizer applications can reduce fertilizer efficiency, create environmental contamination issues, and reduce grower profits (Ribaudo et al., 2011; Cavigelli et al., 2012; Helmers et al., 2012; Struffert et al., 2016; USEPA, 2018). Thus, it is imperative to continually improve the accuracy of our corn N rate recommendations. At this time, there are two main N rate recommendation systems used in the U.S.–Yield goal and maximum return to N (MRTN) (Morris et al., 2018).

The yield goal approach was developed in the 1970s and was the main system for creating corn N recommendations until the maximum return to N approach was developed in 2005 (Sawyer et al., 2006; Morris et al., 2018). One of the greatest strengths of the yield goal approach is its simplicity, but that simplicity is likely not able to account for some of the challenges in using the yield goal approach, including being able to estimate yield, internal N efficiency (i.e., lbs N/bu corn) and other fertilizer use efficiency factors at the beginning of the season (Morris et al., 2018). The MRTN approach was developed to determine N rate recommendations based on N response data from each state or region. For more details see Sawyer et al. (2006). Data that initially went into creating the MRTN database did not include data from SD. Additionally, the current yield goal based system in SD has not been reevaluated for accuracy since 2013 (Kim et al., 2013). Therefore, the objective of this project was to 1) evaluate the accuracy of the current yield goal-based equation used in SD, which includes yield potential (goal), 1.2 lbs N/bu corn multiplier (coefficient), pre-plant soil test N (0 to 24 inches), previous crop, manure application, and tillage type and 2) create a database of N response trials for SD and evaluate the accuracy of using the MRTN approach for predicting N requirements.

MATERIALS AND METHODS

Forty-five corn N rate response trials were conducted at field locations across central and eastern SD from 2018-2022. Site locations varied in tillage practice, crop rotation, and soil type. Specifically, 32 in conventional till and 13 in no-till fields. The previous crop was soybean at 35 locations, and wheat, corn, or sunflower at 10 locations. Nitrogen fertilizer was applied before planting at rates from 0 to 200 lbs N ac^{-1} in 40 lb increments. Nitrogen fertilizer as urea (46-0-0) with a urease and nitrification inhibitor to minimize N loss potential was broadcast on the soil surface. Fertilizer was incorporated if conventional tillage practices were used or remained on the soil surface when no tillage was used. Soil samples were collected before planting and fertilizer application from the 0-6 and 6-24 in. depth increments and analyzed for nitrate-N (Nathan et al., 2015). Corn grain yield was determined by harvesting the center two rows of each plot and adjusting grain weight to 15.5% moisture.

Economic optimal N rates were determined by modeling the relationship between corn yield and N fertilizer rate by averaging the results from both the linear-plateau and quadratic-plateau models using a N fertilizer price to corn price ratio of 0.1 (Miguez and Poffenbarger, 2022). If no plateau was reached within the N rates used in the study, the economic optimal N rate was set to the maximum N rate used at that location. The lbs N/bu corn multiplier (coefficient) was calculated for each site by adding the amount of N fertilizer needed to optimize corn yield and the nitrate-N in the soil from 0 to 24 in. and dividing it by the optimal corn yield (e.g., (soil test N + economic optimal N fertilizer rate) / optimal grain yield). Four of the 45 sites were not included due to extreme drought conditions. For the yield goal approach, the N rate recommendation for each of the remaining 41 locations was calculated using three multipliers (1.2, 1.0, and 0.8). The 41 site-years of response trials were input into a database developed by John Sawyer at Iowa State University (Sawyer et al., 2006, personal communication). This spreadsheet was used to calculate an MRTN for all of SD as well as divided into a central and eastern region. The accuracy of the N recommendation for the yield goal and MRTN approaches was calculated by subtracting the actual EONR from the predicted EONR. The closer these numbers were to 0, the more accurate the recommendation. If numbers were positive, it meant an over application of N was recommended while negative numbers meant an under application of N was recommended. The mean, median, lower 25th quartile, upper 75th quartile and root mean square error (RMSE) of these calculations was completed to help in comparing the accuracy of each N recommendation approach.

RESULTS AND DISCUSSION

Yield Goal Approach

Across the 41 locations, corn yields ranged from 75 to 255 bu/ac with an average of 185 bu/ac while the optimal N rate ranged from 0 to 200 lbs N/ac with an average of 96 lbs N/ac (Figure 1a). The lbs N/bu corn multiplier (coefficient) ranged between 0.4 and 1.8 lbs N/bu corn with an average near 1.0 lbs N/bu corn (Figure 1b). These results demonstrate that the average amount of N to produce a bushel of corn has decreased from the previous 1.2 value. The reduction of this value is not new. In 1975, the multiplier (coefficient) was 1.45 and was reduced to 1.3 in 1982, to 1.2 in 1991, and in

2023 our research supports it being reduced to 1.0.

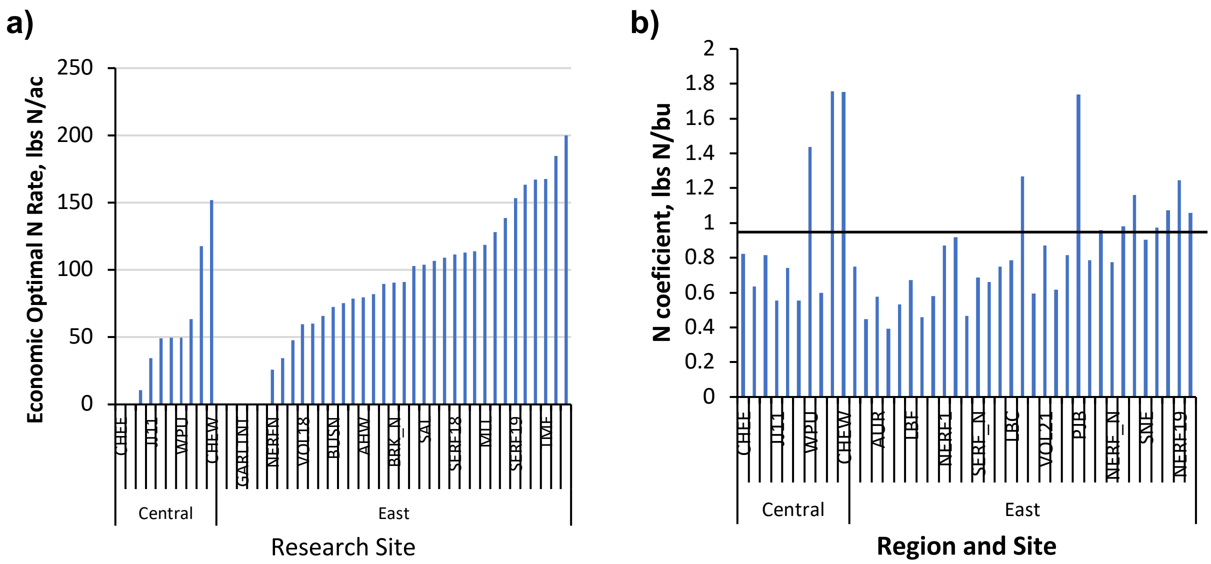

Figure 1. The a) corn economic optimal N rate (EONR) and b) amount of N fertilizer needed to produce one bushel of corn at research sites across South Dakota from 2018 to 2022. Black line represents the mean lbs N/bu corn multiplier value.

The N fertilizer rate equation accuracy was assessed using three different multipliers—the previously used 1.2 lbs N/bu corn, the new average of 1.0 lbs N/bu corn and a multiplier of 0.8 lbs N/bu corn. We calculated the N rate recommendation for each of the 41 locations using the three multipliers (1.2, 1.0, and 0.8). The recommended N rate was then subtracted from the actual rate determined at each location. The closer these numbers were to 0, the more accurate the recommendation. If numbers were positive, it meant an over application of N was recommended while negative numbers meant an under application of N was recommended. On average across all locations, using a multiplier of 1.2 resulted in an over application of 48 lbs N/ac, a multiplier of 1.0 an over application of 13 lbs N/ac, and a multiplier of 0.8 an under application of 22 lbs N/ac. These results demonstrate that reducing the multiplier from 1.2 to 1.0 or 0.8 improved the accuracy of N rate recommendations by 35 and 26 lbs N/ac, respectively. However, using the 1.0 multiplier compared to the 1.2 and 0.8 multipliers more evenly distributed the accuracy results around the 0-difference value (Figure 3). This result is demonstrated as using the 1.2 multiplier overestimated 78% and underestimated 22% of the time, the 0.8 multiplier overestimated 34% and underestimated 66% of the time, and the 1.0 multiplier overestimated 63% and underestimated 37% of the time. Thus, the 1.2 multiplier most frequently overestimated, while the 0.8 multiplier underestimated, and the 1.0 multiplier most evenly split whether it over- or underestimated N fertilizer requirement. Therefore, the multiplier (coefficient) of 1.0 instead of 1.2 or 0.8 provides the most accurate N fertilizer rate recommendations. Economically, the 35 lbs N/ac improvement in N rate recommendations by changing from a multiplier of 1.2 to 1.0 can save SD farmers $36/ac.

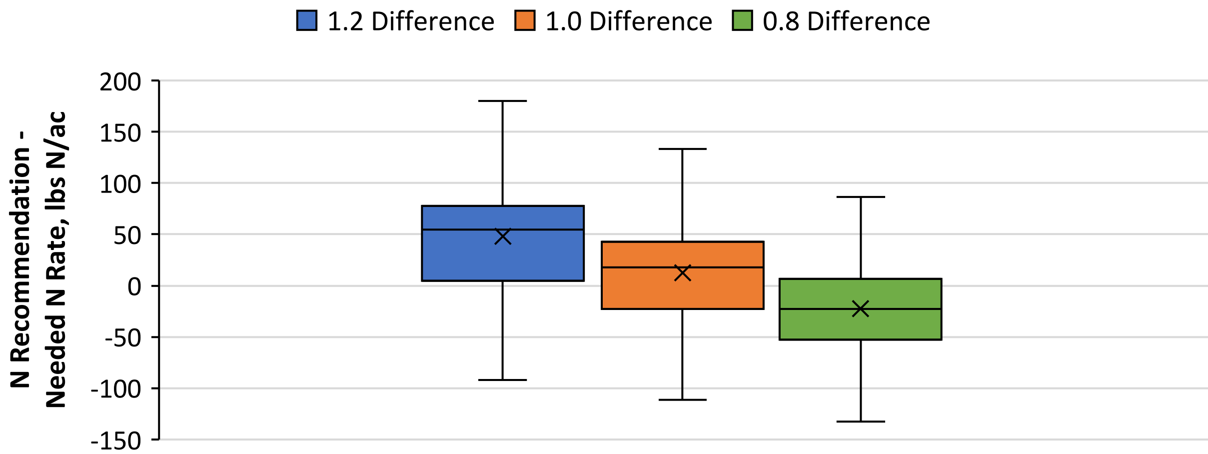

Figure 2. The accuracy of N fertilizer recommendations using three different lbs N/bu corn multipliers (1.2, 1.0, and 0.8) across 45 locations from 2018 to 2022. Accuracy as shown by the Y axis is determined by taking the N recommendation calculated using each of the multipliers and subtracting it from the N fertilizer rate needed at each location. Values closest to 0 are most accurate. Values above 0 are over applications and values below 0 are under applications. The box midline represents the median, the 'x' marks the mean, the upper and lower edges of the box represent the 25th to 75th percentiles, and the whiskers represent the range of data.

MRTN Approach

The MRTN for the state of SD at a N price to corn price ratio of 0.15 was 97 lbs. N/ac and when divided into regions it was 60 lbs. N/ac for central and 102 lbs. N/ac for eastern SD. On average across all locations using the MRTN for all of SD, the accuracy ranged between -103 and +97 lbs N/ac (Figure 3 and Table 1). For only the eastern region the accuracy ranged between -98 and +102 lbs N/ac while the central region ranged between -92 and +60 lbs N/ac. Averaged across all sites, there was a mean over application of 8 lbs N/ac, and when divided into eastern and central regions a mean overapplication of 1 and 7 lbs N/ac, respectively. The RMSE also decreased from ±51 lbs N/ac when using an MRTN for the entire state to ±46 and ±47 lbs N/ac when divided into eastern and central regions, respectively. These results indicate that the MRTN approach is most accurate when dividing SD into central and eastern regions, most likely due to the greater chance of moisture limiting corn yields in central compared to eastern SD.

In comparing the MRTN and yield goal results, the mean accuracy improved by 4 to 12 lbs N/ac and the RMSE improved by ±4 to ±9 lbs N/ac (Table 1). Further, the MRTN compared to the yield goal approach is slightly more accurate using the current dataset from 2018-2022. However, the results between the yield goal and MRTN approach are not large enough to say one approach is definitively better than the other. Nitrogen response trials will continue to be conducted and added to the yield goal and MRTN databases to see how these approaches differ over time and with an increased number of sites in the database.

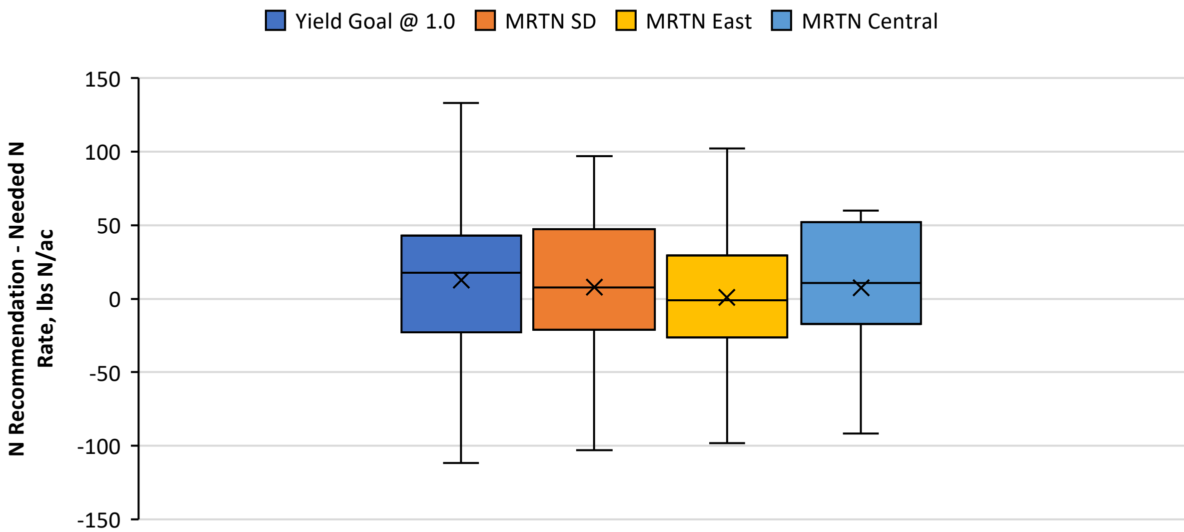

Figure 3. The accuracy of N fertilizer recommendations using yield goal approach with the 1.0 lbs N/bu corn multiplier and three maximum return to N methods across all sites or divided into eastern and central regions. Accuracy as shown by the Y axis is determined by taking the N recommendation calculated using each method and subtracting it from the N fertilizer rate needed at each location. Values closest to 0 are most accurate. Values above 0 are over applications and values below 0 are under applications. The box midline represents the median, the 'x' marks the mean, the upper and lower edges of the box represent the 25^{th} to 75^{th} percentiles, and the whiskers represent the range of data.

Table 1. Descriptive statistics regarding the accuracy of N rate recommendations using yield goal approaches with three different lbs N/bu corn multipliers and the maximum return to N (MRTN) approach with the state as one region and divided into east and central regions.

Statistic	Yield Goal @ 1.2	Yield Goal @ 0.8	Yield Goal @ 1.0	MRTN SD	MRTN East	MRTN Central
	lbs N/ac					
Min	-92	-133	-112	-103	-98	-92
Max	180	86	133	97	102	60
Mean	47	-23	13	8	1	7
Median	55	-23	18	8	-1	11
Upper 75th quartile	76	6	42	47	28	43
Lower 25th quartile	9	-52	-17	-20	-21	-0.12
RMSE, ±	76	55	55	51	46	47

ACKNOWLEDGEMENT

Research funded by the SD Nutrient Research and Education Council and NIFA Hatch project SD000H676-18.

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