Developing a decision support model for informing N fertilization in corn

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Abstract.
Assessing crop nitrogen (N) status is crucial for optimizing the application of N fertilizers in corn (Zea mays L.). The Critical Nitrogen Dilution Curve (CNDC) stands as a fundamental model supporting diagnostic tool for identifying the corn nitrogen (N) status. However, there is a need for efficient, non-destructive methods to estimate the crop N status. The objective of this study was to evaluate the potential of three handheld sensors: SPAD, LI-600, and Green Seeker to diagnose corn N deficiencies at early growth stages. This study was conducted in an irrigated field in Topeka, Kansas, during the 2023 growing season with five N rates (0, 90, 120, 150, and 180 kg N ha^{-1}) all applied at sowing or split between sowing and V6, V10 or V14 corn stage. Sensing data was collected 3 times during the vegetative season (V6, V10, and V14) on the last developed leaf for SPAD and LI-600, while Green Seeker was placed above the crop canopy to obtain NDVI data. Hierarchical Bayesian modeling and linear regression models were employed to study the Nitrogen Nutrition Index (NNI) and its correlation with sensor readings respectively. The results of this study indicate that NNI values below 1 (N deficiency) were associated with yield penalties, and the V10 corn growth stage emerged as a potential timing to diagnose corn N status using SPAD sensing data. From an early season standpoint, the V10 growth stage could be an opportune timing for detecting N deficiencies. The results present an excellent opportunity to assess N status at early corn growth stages for improving N application. Future research should focus on analyzing the deficiency timing effect on corn yield components.

Keywords.
Nitrogen nutrition index NNI, precision nitrogen management, proximal sensor, corn.

1. Introduction

Nitrogen (N) is crucial for optimal growth and grain yield in corn (Zea mays L.) cropping systems, but managing it is complex due to soil conditions, plant physiology, and weather variability (Briat et al., 2020). Overapplication of N can lead to environmental issues such as greenhouse gas emissions and N leaching (Ramos, 1996), underscoring the need for precise nitrogen management practices.

The N nutrition index (NNI), the ratio of measured to critical plant N concentration, is a promising tool for assessing crop N status (Ciampitti et al., 2022). NNI can indicate N surplus or deficit and optimize fertilizer applications during critical growth stages. However, frequent NNI measurements are impractical in farm fields due to time-consuming procedures, necessitating the development of non-destructive methods like remote sensing (Lemaire et al., 2008). This study aimed to evaluate three handheld sensors—SPAD meter, LI-600, and GreenSeeker—for diagnosing corn N deficiencies.

2. Material and methods

2.1 Experimental site and design

A field experiment was conducted at the Kansas River Valley Experimental Field (39.08° North, 95.77° West, Topeka, KS, USA), in 2023. The experiment was established under a randomized complete block design with four replications, combining 12 treatments as a combination of five N rates (0, 90, 120, 150, and 180 kg ha^{-1}) and different timing of application – planting (P) and split in P+V6, P+V10, or P+V14 growth stages (Ritchie et al., 1996).

2.2 Plant and sensor measurements

Plant and sensor measurements were conducted at four stages throughout the season (V6, V10, V14, and R1) by collecting 9 whole plants at ground level. Aboveground biomass was dried at 60°C until constant mass and weighed to determine dry biomass (W, Mg ha-1). Whole plant N content (%Nc) was analyzed using the combustion method (Matejovic, 1995). Grain yield was determined by harvesting the two center rows of each experimental unit, with weights adjusted to 155 g kg-1. Relative yield (RY) was calculated by dividing the yield of each experimental unit by the highest yield observed.

In each experimental unit, twenty consecutive plants were tagged for sensing. SPAD meter, LI-600, and GreenSeeker readings were taken simultaneously with biomass sampling. Sensors were placed on the uppermost fully expanded leaf (collar visible) at each growth stage, except at R1, where the ear leaf was sampled.

2.3 Statistical analysis

Hierarchical Bayesian modeling and linear regression models were employed to study the Nitrogen Nutrition Index (NNI) and its correlation with sensor readings. Statistical analysis and figures were performed using the R software (*R Core Team, 2023*).

3. Results

The final model of the N dilution curve was described by the negative power equation $Nc = 4.15\ W^{-48}$, Figure 1 (A), and the observations were evenly spread out along the sufficiency curve. The relationship between RY and NNI at V10 corn growth stage was described by a linear plateau model, Figure 1 (B). The NNI threshold value when RY reached a plateau was 1.07.

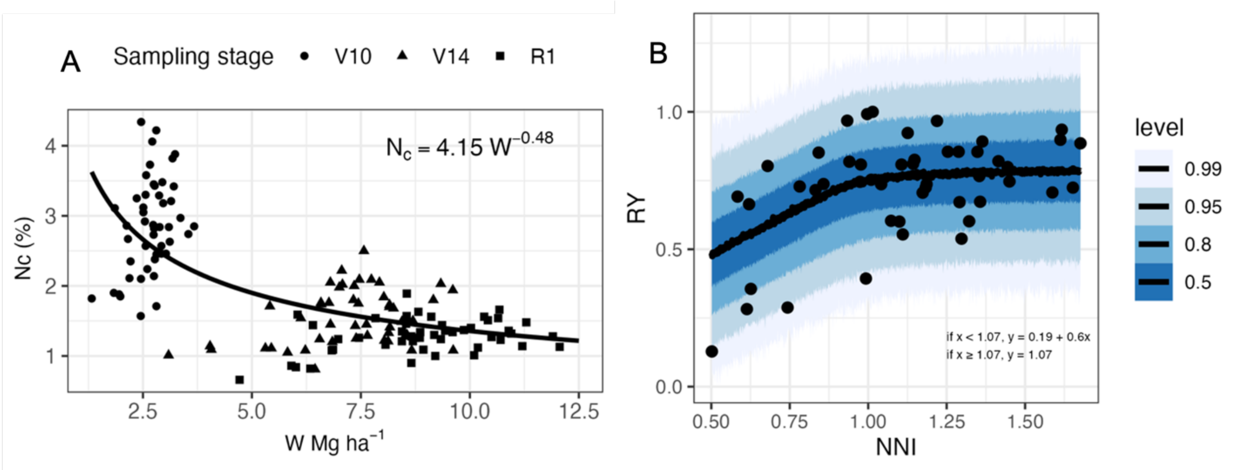

Fig 1. A) Critical N dilution curve, described by the relationship of Nc (%) and aboveground biomass (W, Mg ha^{-1}). B) Relationship between relative grain yield (RY) and NNI at V10 corn growth stage. The shaded areas represent the credible interval levels of the linear plateau model.

A positive linear relationship between sensor reading and NNI was identified. The V10 corn growth stage emerged as a potential timing for N diagnosis and as the earliest moment to identify N status through NNI using two of the three sensors, SPAD and GreenSeeker. Regarding the LI-600 sensor, it did not present a statistically significant relationship with NNI.

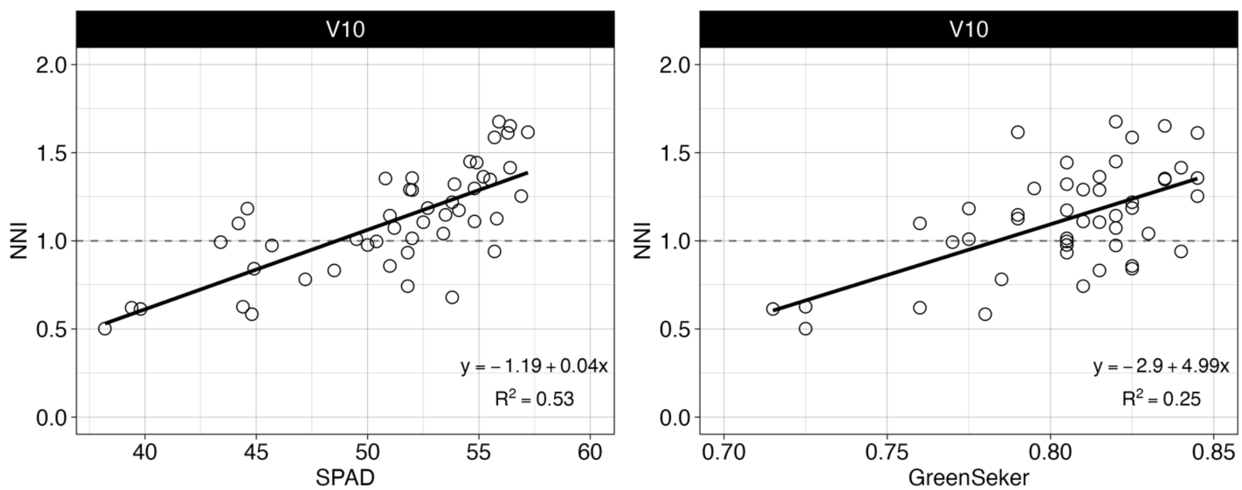

Fig 2. Relationship between sensor reading (left-SPAD, right-GREENSEEKER) and NNI at V10 corn growth stage.

4. Conclusion

These results provide a valuable opportunity to evaluate nitrogen status during early corn growth stages to optimize nitrogen application. Future research should investigate the NNI path throughout the season and the ability of sensors to capture N status changes.

5. References

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