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Nitrogen Sensing Across Different Corn Growth Stages Using Soil Plant Analysis Development Meter

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Summary

The Soil Plant Analysis Development (SPAD) meter is a sensor widely utilized as an indirect method to monitor nitrogen (N) status in various crops. However, the sensor's accuracy can be affected by environmental and crop-specific factors. This study aimed to investigate the utility of employing the SPAD to monitor N in corn leaves at different growth stages, using the Nitrogen Sufficiency Index (NSI). For this reason, a trial was conducted in Topeka, KS (US), during the 2023 growing season featuring twelve treatments with varied N levels, rates, and fertilization timings. The study analyzed the relationship between 1) SPAD meter readings and leaf N concentration (Nc), and 2) Nc, NSI, and corn grain yield at V6, V10, V14, and R1 crop growth stages. The Nc was positively correlated with grain yield at V14, particularly at R1 when Nc accounted for most yield variations. The results suggest that the NSI approach, implemented via the SPAD meter from the V10 growth stage onward, serves as an effective predictor for estimating the Nc.

Introduction

Monitoring the corn's (*Zea Mays* L.) N status throughout the growing season validates the N fertilization's effectiveness. By monitoring, corrective actions can be taken when the N deficiency is detected, especially in early vegetative growth stages (Varvel et al., 1997). Beyond traditional plant analysis, sensor-based methods for in-season N status monitoring are gaining relevance due to their real-time and non-destructive capabilities. The Soil Plant Analysis Development (SPAD) meter, a hand-held device reflecting the relative content of leaf chlorophyll (Konica Minolta, 2009), has been widely utilized for calculating the N sufficiency index (NSI).

The SPAD meter's accuracy can be influenced by environmental and crop-specific factors, affecting its ability to estimate N content per leaf area (Xiong et al., 2015). This research explores the utility of the SPAD meter for monitoring N in corn leaves in different growth stages. The goals were to 1) re-examine the relationship between leaf N concentration (Nc) vs. SPAD readings, as well as Nc, NSI and corn grain yield, and 2) identify the earliest stage which the NSI can be effectively applied with the SPAD meter.

Procedures

A field experiment was conducted at the Kansas River Valley Experimental Field (39.08° North, 95.77° West, Topeka, KS) during the 2023 growing season. A characterization of the soil and a description of the general management are presented in Table 1. Weather parameters from sowing to harvest are presented in Figure 1.

The experiment was established under a randomized complete block design with four replications. The treatments came from a combination of five N rates (0, 90, 120, 150, and 180 lb/a) with different N fertilization times: planting (P), and split in P+V6, P+V10 or P+V14 growth stages (Ciampitti et al., 2016). The SPAD-502Plus meter (Konica Minolta, 2009) was used to study the range of corn N status scenarios provided by the treatments. Other nutrients were applied to ensure sufficiency.

In each experimental unit, twenty representative plants were previously tagged. The SPAD meter was used to take readings on the tagged plants at V6, V10, V14, and R1 by placing the sensor in the middle of the leaf blade and halfway between the leaf margin and the leaf midrib (Blackmer et al., 1993). The uppermost fully expanded leaf (collar visible) of each growth stage was sampled, except at R1, when ear-leaf was sampled (Peterson et al., 1993). All SPAD meter data were collected about the same time of day and the average was recorded. To obtain the NSI, SPAD meter readings were divided by the maximum reading from all treatments within each growth stage (Peterson et al., 1993).

Leaf punches were collected to determine the leaf N concentration (Nc, %) from the same plants and leaf positions used during the SPAD meter readings. After each sampling, the leaf punches were placed in a paper envelope and dried in an air-forced oven (149°F) until constant weight. The Nc was determined using the near infrared spectroscopy method. At physiological maturity, all the plots had mid-rows harvested by a combine, which provided grain yield adjusted to a moisture content of 15.5%.

Statistical Analysis

Linear regressions analysis was performed for each growth stage sampled to evaluate the relationships between 1) Nc and NSI, 2) grain yield and Nc, and 3) grain yield and NSI. Statistical analysis and figures were developed using the R software (R Core Team, 2019).

Results

The relationship between Nc and NSI showed a high association starting from V10 ($R^2 > 0.80$), specially at R1 ($R^2 = 0.90$) (Figure 2). The relationship shows that identifying the NSI by using the SPAD meter was an efficient predictor to estimate the Nc from V10 onward. Although a positive relationship between Nc and NSI was observed at V6, it was less robust ($R^2 = 0.25$).

Moreover, the relationship between grain yield and Nc was described by a positive linear function starting from V14, considering the range of plant N status results provided by the treatments. The R1 growth stage had the strongest relationship ($R^2 = 0.68$) (Figure 3). Similar results were observed in the relationship between grain yield and the NSI (Figure 4).

Final Considerations

Our results suggested that the SPAD meter, within the experimental conditions analyzed, was a useful tool for monitoring N status in corn leaves from the V10 growth stage onward employing the NSI. Additionally, we observed a significant relationship between Nc, NSI, and grain yield at V14 and R1.

Acknowledgments

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Table 1. Soil parameters and management practices description for the experimental area

Soil[a]		Practices	
SOM[b], %	1.48 ± 0.14	Irrigation[c]	Yes
Clay, %	14 ± 0	Planting date	04/16/2023
Sand, %	49.5 ± 4.10	Hybrid CRM[d]	105
Silt, %	36.5 ± 4.10	Seeding rate, seeds/a	35,000
N-NO_3^-, ppm	4.62 ± 1.12	Row spacing, inches	30
N-NH_4^+, ppm	9.47 ± 1.41	Harvest	09/07/2023

Soil parameters were measured prior to sowing from an 8-inch depth layer.
[a]Parameters have a mean and standard error (n = 4).
[b]Soil organic matter via loss-on-ignition (LOI).
[c]The irrigation system was activated whenever precipitation levels were insufficient during the cropping season.
[d]Comparative relative maturity.

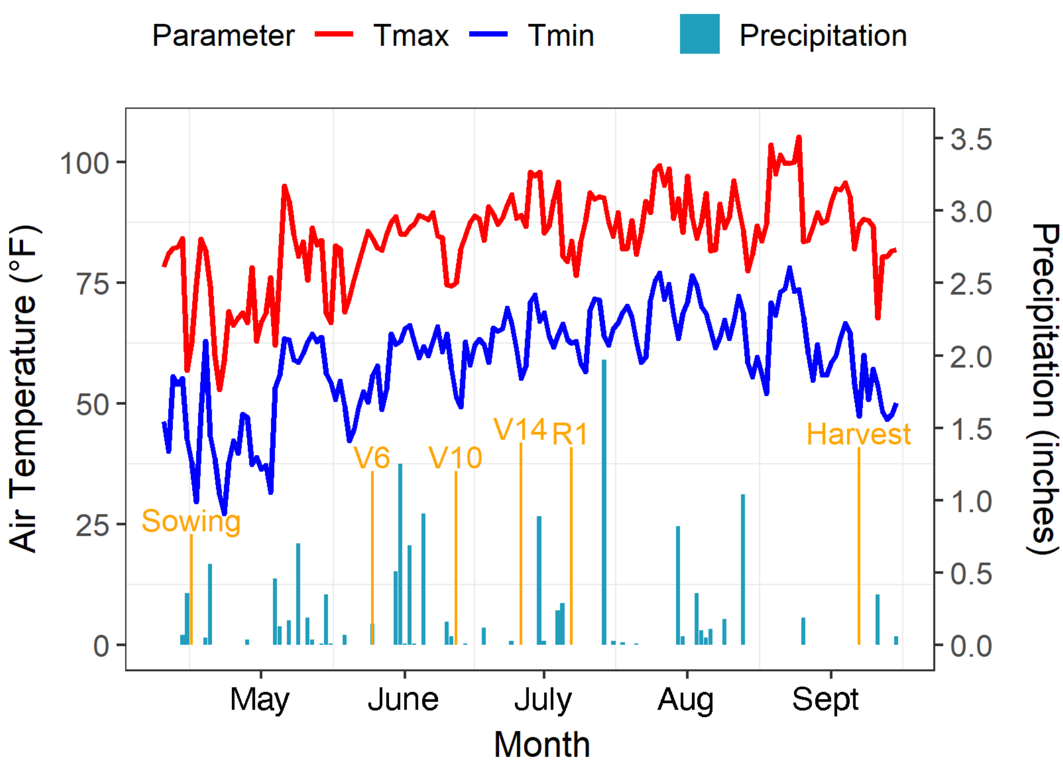

Figure 1. Air temperature (°F) and daily precipitation (inches) during the 2023 cropping season at Topeka, KS. Data obtained from Kansas Mesonet (2024).

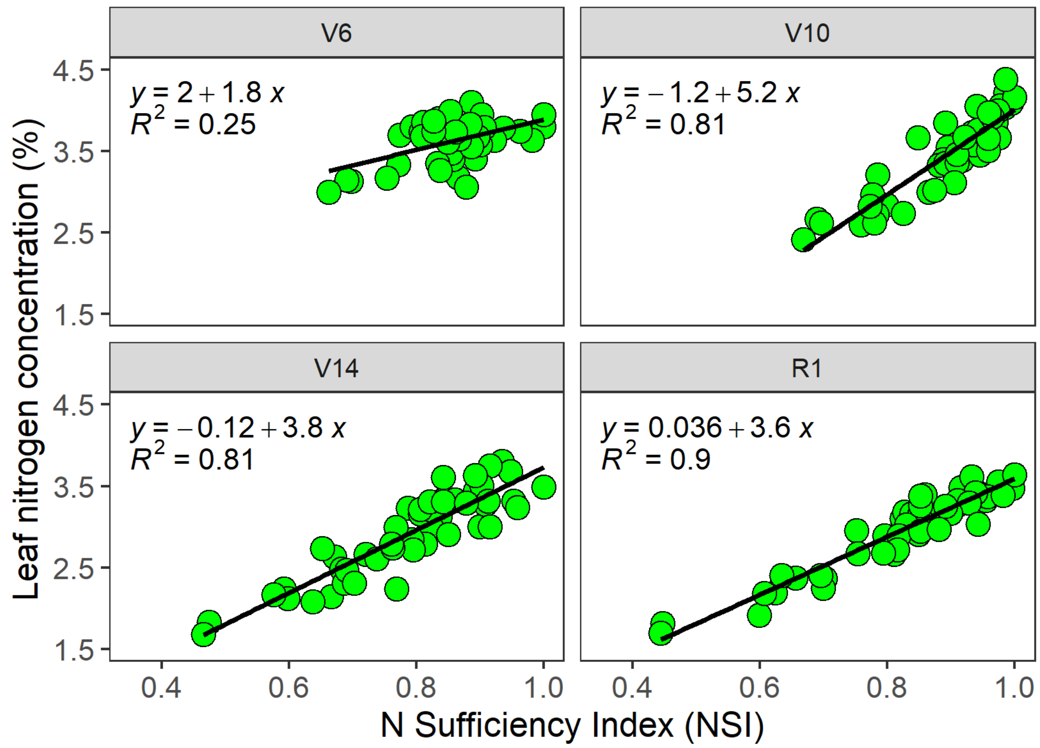

Figure 2. Relationship between leaf N concentration and N Sufficiency Index (NSI) for V6, V10, V14, and R1 crop growth stages (n = 48).

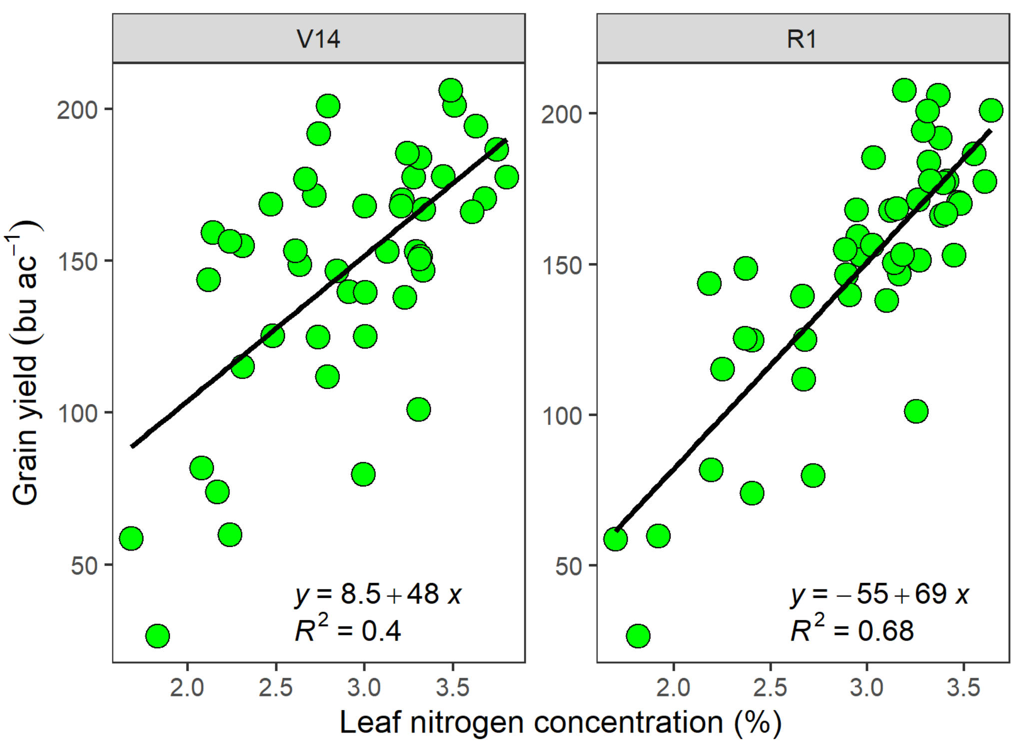

Figure 3. Relationship between grain yield and leaf N concentration at V14 and R1 growth stages (n = 48). Both relationships were significant ($P < 0.05$).

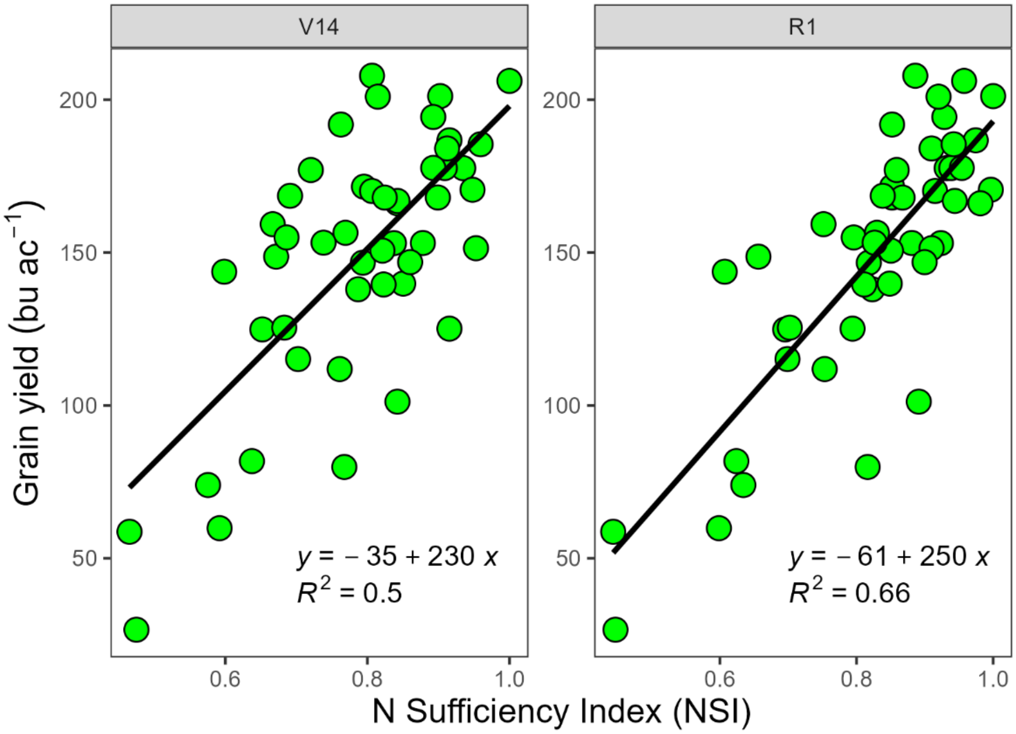

Figure 4. Relationship between grain yield and NSI at V14 and R1 growth stages (n = 48). Both relationships were significant ($P < 0.05$).