PRECIPITATION IMPACTS ON REDISUDAL NITROGEN AND FERTILIZER-N EFFECTS ON DRYLAND CROP PRODUCTION

Jena L. Schwartze[1], Augustine K. Obour[2], Dorivar A. Ruiz Diaz[1], John D. Holman[3], Brian Olson[2], Mark Reiman[4], and Alexandre Tonon Rosa[5]
[1]Kansas State University, Department of Agronomy, Manhattan, KS; [2]Kansas State University, Agricultural Research Center-Hays, Hays, KS; [3]Kansas State University, Southwest Research and Extension Center, Garden City, KS; [4]Bayer Crop Science, Gothenburg, NE; [5]Bayer Crop Science, Sacramento, CA

ABSTRACT

Understanding how precipitation affects residual soil nitrogen (N) is essential for improving crop productivity and N use efficiency in dryland system. Accordingly, our objective was to evaluate how residual soil N and in season N fertilizer applications affected corn and soybean productivity under contrasting precipitation patterns. The current results quantified the effects of residual soil N and in-season N applications on gain yield, crude protein, and soil N balance in corn (*Zea mays L.*) and soybean (*Glycine max L.*) during the 2024 and 2025 growing seasons.

N application did not significantly affect corn or soybean grain yield in either year because of drought and higher soil residual N. Crude protein in corn was also not significantly influenced by N rate in 2024 or 2025. Soybean crude protein responded to N treatments in 2024, with the normal N application (0 lbs/ac) producing higher crude protein than the enhanced rate (60 lbs/ac), but no significant differences were observed in 2025. Enhanced N applications (120 lbs/ac in corn; 60 lbs/ac in soybean) led to a surplus of soil N after the dry 2024 season, largely due to reduced crop uptake under limited precipitation. Despite this N surplus, soil N balance did not significantly influence 2025 yields. However, a negative correlation between soil N balance and corn yield was revealed, suggesting a reduced crop response to additional fertilizer-N when residual N is high. There was no relationship between residual soil N and soybeans grain yield in 2025. Findings from the study supports soil sampling and adjusting fertilizer-N rates based on residual N in dryland corn production systems where productivity is dependent on in-season precipitation and available soil water.

INTRODUCTION

While management practices influence crop performance, precipitation ultimately governs productivity in dryland cropping systems. In the semi-arid Great Plains, precipitation is a primary concern for producers and often dictates which management practices to implement on the operation. Since yield is the ultimate driver of success, recent precipitation variability has contributed to more fluctuations in dryland crop yields (Obour et al., 2015). The timing of rainfall and distribution are also critical for dryland crop production. Water stress during grain fill reduces yield more severely than stress that occurs earlier in the growing season (Dietzel et al., 2016). Understanding how management practices, such as N applications, can buffer crops against precipitation variability is essential for improving productivity in dryland systems.

The addition of N to a cropping system can improve overall crop productivity, but the fate of that N applied depends on precipitation and plant available water at planting.

Under typical growing conditions, crops can remove roughly 50-60% of applied N, leaving a portion in the soil that can support the following crops (Sainju, 2017). However, N uptake is strongly influenced by precipitation. In a study by Sainju et al. (2018), soil N levels were higher following a dry growing season because of reduced crop growth, which limited N uptake, resulting in greater residual N at the end of the growing season. This surplus N becomes vulnerable to losses through volatilization, denitrification, leaching, or runoff. However, in water-limited systems, most of the N could remain in the soil and become available for the next crop reducing the amount of N required for the next crop. Therefore, evaluating soil N balance can help producers make management decisions that minimize N accumulation, reduce environmental losses, and improve the cropping system efficiency.

This study aimed to identify how residual soil N and in-season N fertilizer applications affected crop productivity in corn and soybeans under contrasting precipitation patterns observed in 2024 and 2025 growing seasons.

MATERIALS AND METHODS

Experimental Design

This study was initiated in 2024 at the Kansas State University Harold and Olympia Lonsinger Sustainability Farm in Osborne County, Kansas. Treatments consisted of complete factorial combination of tillage practices (NT and CT), cover crops (with and without) and crop rotations (corn, corn-soybean, and wheat-corn-soybean) and N fertility management (normal and enhanced N) for a total of 48 treatment combinations. Treatments were arranged in a randomized complete block design with three replications totaling 144 experimental units. Each individual plot was 80 ft long by 40 feet wide.

Grain Crop Management and Collection

Corn and soybeans were planted at the beginning of June, while winter wheat was planted in November. Corn and soybeans were both harvested in early November, while winter wheat was harvested in July. Grain yields were determined by collecting a single 5 ft x 80 ft pass Massey Ferguson 8XP plot combine. All soybean and wheat grain yields were adjusted to 13.5% moisture, and corn was adjusted to 15.5% moisture.

Grain samples were ground through a Wiley Mill and analyzed for N concentrations using a UNICUBE CN Analyzer (Elementar Americas, Inc., Ronkonkoma, NY). All N concentrations were converted to crude protein content by multiplying the N concentration by 6.25.

Soil Sampling

In May 2024, initial soil sampling for nutrients was collected using a hand soil probe from 0-5 cm and 5-15 cm soil depths. In January 2025, soil samples were collected using a Giddings probe from 0-30 cm and 30-60 cm. Each sampling was sent to the soil testing lab separately for nutrient analyses. Soil residual N amounts were calculated by combining total nitrate (NO_3^-) and ammonium (NH_4^+) levels from each sampling time and depth.

Nitrogen Balance

Nitrogen (N) balance was calculated using the following equation from Sainju, (2017):

$$Nitrogen\ balance = N\ inputs - N\ outputs - changes\ in\ soil\ total\ N$$

The N inputs for this research included a broadcasted urea fertilizer at two different application rates, normal and enhanced. In corn, the normal N rate was 60 lbs/ac and the enhanced N rate was an additional 60 lbs of N per acre to the normal rate, which was 120 lbs of N per acre for both corn and wheat. In soybeans, producers normally do not apply any N during the growing season. Therefore, the enhanced N application for soybeans would be 60 lbs of N per acre.

The N outputs were determined by how much N was removed from the 2024 harvest using the grain yield and N concentration from the grain.

$$N\ outputs = grain\ yield\ \left(\frac{lbs}{ac}\right) \times N\ concentration\ (\%)$$

The changes in soil total N was determined by subtracting the 2025 N content in a 0-60 cm profile from the initial soil analysis in a 0-15 cm profile in 2024.

$$Change\ in\ Total\ Soil\ N = 2025\ Total\ Soil\ N\ (0-60cm) - 2024\ Total\ Soil\ N\ (0-15cm)$$

Seasonal Precipitation Collection

Precipitation data was collected using the Kansas Mesonet system located in Osborne County, Kansas, which is about 20 miles southeast of the research site. Data was collected from March 1 – November 30 for both 2024 and 2025 growing seasons. The normal precipitation amount was based on the “Normal Annual Precipitation” map generated in 2020 by the Kansas State Climatologist's Office.

Statistical Analyses

All statistical analyses were completed using SAS version 9.4 (SAS Institute, 2012, Cary, NC). PROC GLIMMEX was used to analyze grain yields and crude protein content. N treatments were considered to be fixed effects, while replication was considered to be a random effect. PROC MIXED was used to analyze the N balance data, using N treatments as the fixed effect and replication as the random effect. PROC REG was used to determine if the N balance influenced 2025 grain yield. All analyses were considered significant at $P \leq 0.1$.

RESULTS AND DISCUSSION

2024 and 2025 Grain Yields

Grain yield differed between 2024 and 2025 was mainly due to precipitation received during the growing seasons (**Figure 1a and 1b**). The summer portion of the growing season received about one inch more rainfall in 2025 than in 2024. The biggest differences occurred in August through September, when precipitation in 2025 was 6 inches more than in 2024. Rainfall during this part of the growing season helps support grain fill and ultimately affects yield the most. In comparison to the current Normal precipitation (1991-2020), 2024 was 8 inches below normal while 2025 was only 1 inch below normal. N treatment effects on corn yields were not significant in either 2024 (P = 0.54) or2025(P = 0.47). Similarly, soybean yields in 2024 (P = 0.11) and 2025 (P = 0.26) were not different (**Figure 1a**).

2024 and 2025 Grain Crude Protein Content

Precipitation had little effect on grain protein content compared to grain yield (**Figure 2a**). Corn crude protein increased from 2024 to 2025, reaching 9.3% in both N treatments, a 0.8% increase from 2024. N rate did not significantly affect protein in either year (2024 Corn (P = 0.6809); 2025 Corn (P = 0.77). In soybeans, crude protein increased by 2.0 - 3.0% from 2024-2025. N rate significantly affected soybean protein in 2024 (P = 0.004) but not in 2025 (P = 0.14).

Nitrogen Balance in soil after 2024 Harvest

Plots that received the enhanced N application (120 lbs N/ac in corn and 60 lbs N/ac in soybean) had a higher soil N balance after the 2024 harvest, indicating a significant treatment effect on residual N levels (Corn P = 0.001; Soybean P = <0.000) (**Figure 2b**). In 2024, corn yields and protein content were higher in enhanced N treatments due to the excess soil N within the soil. On the contrary, soybean yield and protein content was higher in normal N treatments in 2024. The N balance at the end of the season was negative, forcing the soybean to fix its own N due to low residual N at the beginning of the growing season and no additional N inputs. By the end of the growing season, normal N treatments in soybeans had a negative nutrient balance.

Nitrogen Balance Effect on 2025 Grain Yields

The first year of this study was not ideal due to drought conditions. Therefore, much of the N in the soil was not utilized and a portion remained in the soil for the following crop. This N balance in the soil did not have a significant effect overall on 2025 corn (P = 0.72) or soybean (P = 0.63) yields. However, regression analysis showed that in corn, there was a negative correlation between N balance and yield. Meaning that the more N present in the soil, the crops response to the N fertilizer will decrease, resulting in lower yields with higher N input (**Figure 3a**). In soybeans, there seems to be no correlation between N balance and yield (**Figure 3b**).

FIGURES

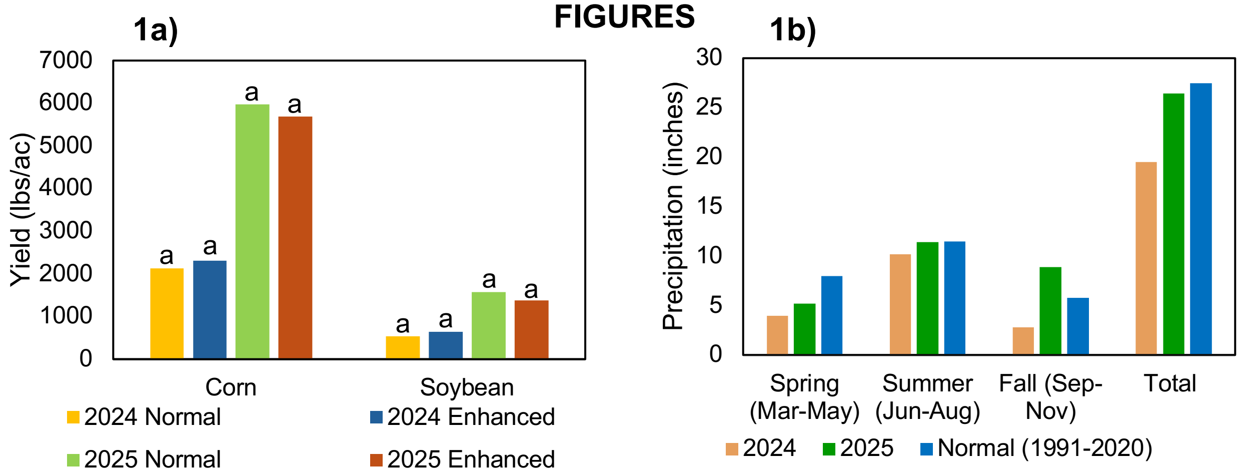

Figure 1: a) Enhanced N raised yields in 2024 and reduced them in 2025, though neither response was statistically significant. **b)** Cumulative precipitation by season and annual total for 2024 and 2025 compared with the 1991-2020 normal.

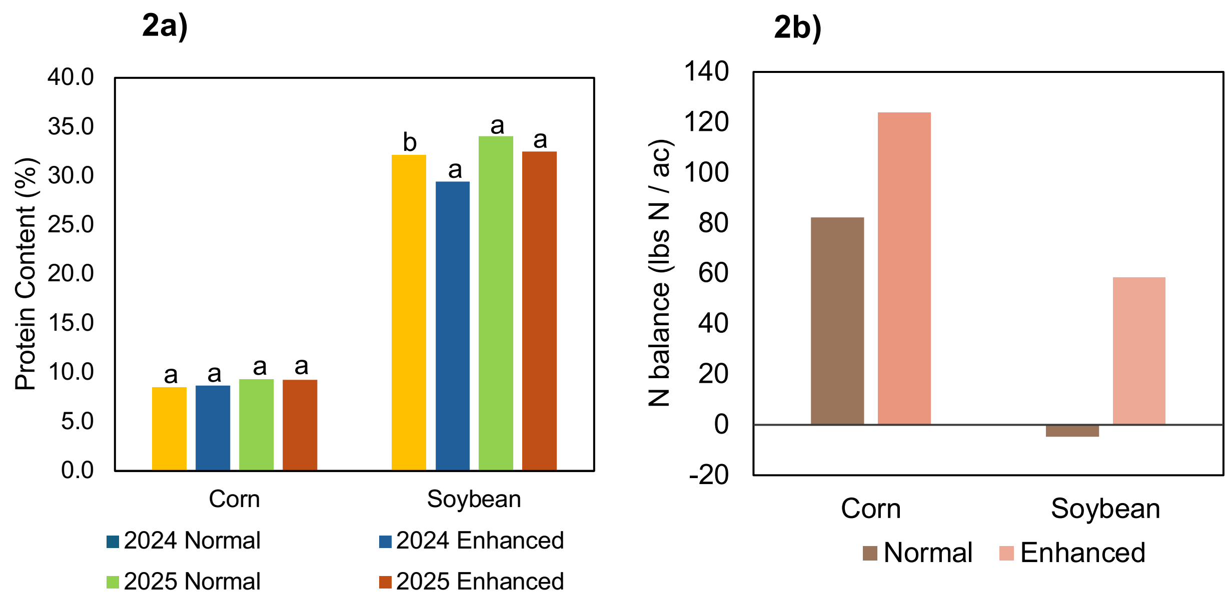

Figure 2: a) Corn protein was unaffected by N treatments either year, but soybean protein declined under enhanced N both years. **b)** N balance (lbs N per acre) for corn and soybean under Normal and Enhanced management. Positive values indicate a surplus of N left in the soil, and negative values indicate N loss after the 2024 growing season.

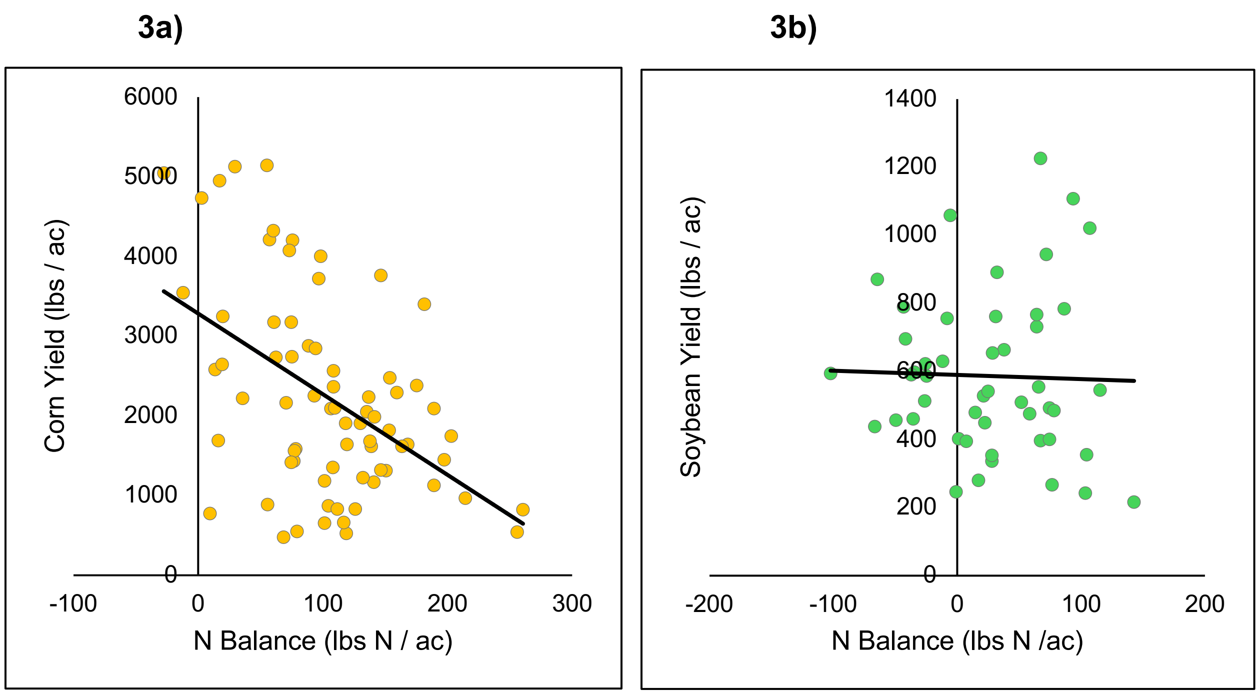

Figure 3: a) N balance did not significantly affect corn yield, but the negative correlation indicates reduced fertilizer responsiveness at higher residual N levels. **b)** Soybean yield showed no significant response to N balance, though a slight negative trend suggests lower yields at higher residual N levels.

REFERENCES

Dietzel, R., Liebman, M., Ewing, R., Helmers, M., Horton, R., Jarchow, M., & Archontoulis, S. (2016). How efficiently do corn- and soybean-based cropping systems use water? A systems modeling analysis. *Global Change Biology*, *22*(2), 666–681. https://doi.org/10.1111/gcb.13101

Kansas Mesonet · Historical Weather. (n.d.). https://mesonet.k-state.edu/weather/historical/

Kansas Office of the State Climatologist · Kansas Climate. (n.d.). https://mesonet.k-state.edu/climate/basics/

Obour, A. K., Stahlman, P. W., & Thompson, C. A. (2015). Wheat and Grain Sorghum Yields as Influenced by Long-term Tillage and Nitrogen Fertilizer Application. *International Journal of Plant & Soil Science*, 19–28. https://doi.org/10.9734/IJPSS/2015/17295

Sainju, U. M. (2017). Determination of nitrogen balance in agroecosystems. *MethodsX*, *4*, 199–208. https://doi.org/10.1016/j.mex.2017.06.001

Sainju, U. M., Lenssen, A. W., Allen, B. L., Stevens, W. B., & Jabro, J. D. (2018). Nitrogen balance in dryland agroecosystem in response to tillage, crop rotation, and cultural practice. *Nutrient Cycling in Agroecosystems*, *110*(3), 467–483. https://doi.org/10.1007/s10705-018-9909-7