Protecting Suwannee Valley Springs: Advanced Nitrogen Strategies for Water Quality and Sustainable Farming

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INTRODUCTION

PROBLEM IDENTIFICATION

Florida faces significant challenges with **water quality** due to agricultural fertilizer nitrate leaching. **Sandy** soils, characterized by high **infiltration** rates and low cation exchange capacity, combined with substantial **precipitation**, create favorable conditions for nitrate leaching and negatively impact corn yield and water quality (Rath et al., 2021).

IMPACT on Water Quality and Yield

- The Florida Department of Environmental Protection (FDEP) identifies nitrate as a major concern in the Suwannee River Basin, with approximately **70%** of nitrate contamination stemming from agricultural fertilizers (FL: FDEP). High nitrate leaching leads to nutrient loss, reducing corn yield and efficiency.

A SOLUTION: The Best Management Practices (BMPs)

Precision Irrigation | 4R's Approach (Right Source, Rate, Time and Placement**) | Crop Rotation**

INNOVATION in Fertilizer Source: A Controlled Release Fertilizers (CRFs)

Advantage: Gradual nutrient release, matching plant demand, optimizing nutrient uptake, and minimizing losses; single application at planting Vs Multiple application of Conventional Fertilizer

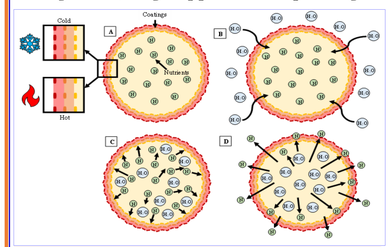


Fig. Illustration of the mechanism of release for a semi-permeable coated CRF (Figure credit: Morgan Morrow and Vivek Sharma)

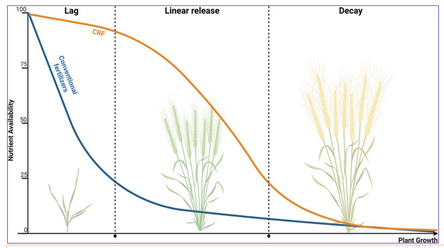


Fig. Schematic representation of the temporal development of soil nutrient availability, as supplied by CRF and Conventional Fertilizers. Source: *Mansouri et al 2023*

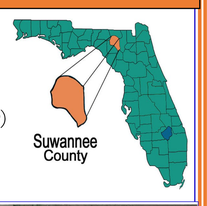
OBJECTIVE: To evaluate the effectiveness of **strategic nitrogen (N) fertilizer application** and **placement** in enhancing corn **yield**, improving **water quality**, and reducing **nitrate leaching**. The goal is to optimize corn production **sustainability** in Florida, improving both water quality and agricultural productivity by enhancing crop growth, yield, and reducing nitrate leaching.

Materials and Methods

Research Location: UF/IFAS North Florida Research and Education Center-Suwannee Valley in Live Oak, FL, (planned for three years: **2023-25**).

Experimental Design: Randomized Complete Block Design (RCBD) to effectively control variability within the field.

Equipped with: Soil Moisture Sensors and G3 Drainage Lysimeters



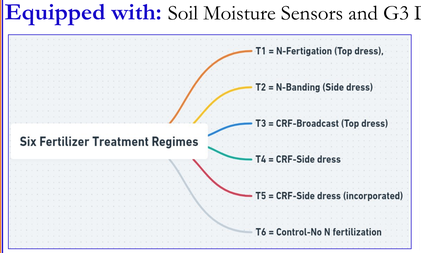


Fig. Illustration of the six distinct treatment adopted to be evaluated in order to find the best 4R combination: Right Rate, Place, Source, and Time.

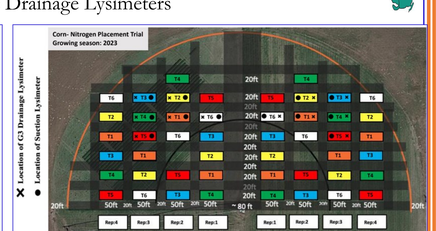


Fig. Illustration of a Randomized Complete Block Design Experiment setup to evaluate six treatments, equipped with the soil moisture sensors & G3 Drainage Lysimeter

DATA COLLECTION:

Plant Height:
- Measures the growth status of maize.
- Indicators of N deficiencies.

Leaf Area Index (LAI):
- Critical for photosynthesis and biomass conversion.
- Influences overall crop growth.

Aboveground Biomass:
- Linked directly to N availability.
- Crucial for plant development.

Lysimeter Water Quality Samples:
- Measures water flow and nitrate levels
- Estimate potential nitrate contaminating groundwater.

Soil Nitrate Levels at 0-12, 12-24, 24 -36, and 36-48 inches:
- Reflects potential nitrate leaching.
- Impact on water quality

Grain Yield:
- Measures the effectiveness of different placement strategies.

Fig. We are taking regular plant height measurements. In this picture, Mr. Rakesh Singh is using a 14 ft. pole to monitor and collect data on plant height.

Fig. Using Leaf Area Index meter to collect data on plant leaf canopy development

Fig. We are regularly pumping deep drainage water samples from the lysimeter to collect nitrate in the leached water content, evaluating water quality and N leaching

Importance of Nitrogen Monitoring and Data Collection at Key Growth Stages

V4 to V6 Stages:
- **Root Development**: Essential for effective N uptake.
- **Early Nitrogen Application**: Supports vegetative growth.

V10 to V13 Stages:
- **Peak Nitrogen Uptake**: Necessary for rapid leaf and stem growth.
- **Pre-Tasseling Assessment**: Ensures N sufficiency for reproductive stages.

R1 (Silking) Stage:
- Crucial for silk development and successful pollination.
- Key stage for determining kernel set and quality.

R3 (Milk Stage):
- **Kernel Nitrogen Needs**: Important for managing kernel development under stress.

R6 (Physiological Maturity):
- Evaluates N utilization throughout the season.
- Determines grain quality.

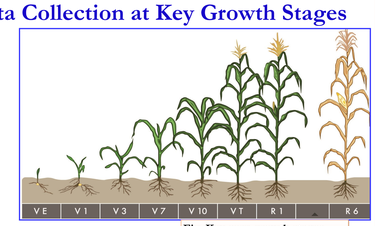
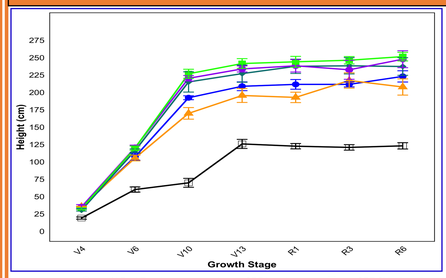


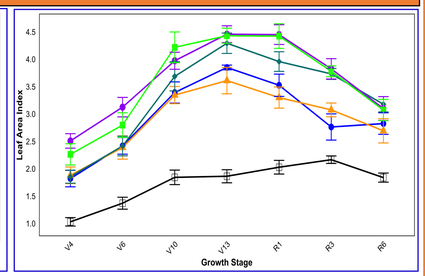
Fig. Key corn growth stages

STATISTICAL ANALYSIS

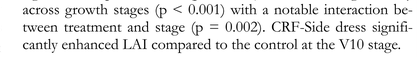
All statistical analyses and visualizations were conducted using R:
- **Modeling**: Mixed-effects models explored the relationship between response variables (plant height, LAI, biomass, tissue N, soil nitrate, and yield), treatment, and growth stage as predictors.
- **ANOVA**: Conducted to evaluate the significance of treatment and growth stage effects.
- **Assumption Checking**: Visual inspections of residuals and quantile-quantile plots; homogeneity of variances assessed using Levene's test.
- **Post Hoc Analysis**: Employed the emmeans package for pairwise treatment comparisons, with Tukey adjustment for multiple comparisons.
- **Visualization**: Results visualized using ggplot2 to facilitate clear interpretation and communication.

Results and Discussion

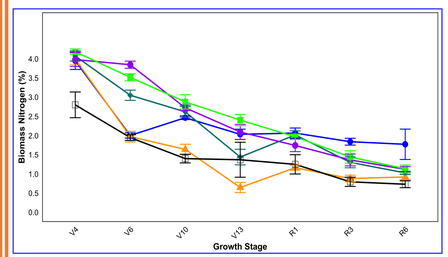


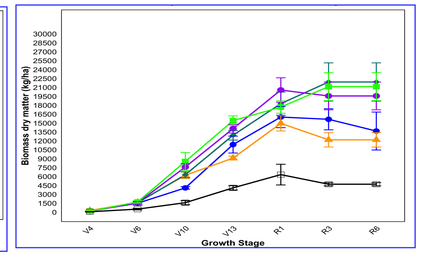


- **Effects on Plant Height**: Fertilizer placement treatments significantly influenced plant height ($p < 0.001$), with significant variations across growth stages ($p < 0.001$) and interaction between treatment and stage ($p < 0.001$). CRF treatments, especially CRF-Side dress, produced notably higher heights at V10, V13, and R1 stages.



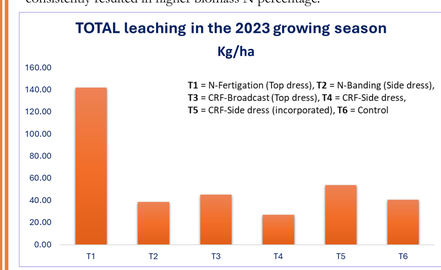
- **Effects on Leaf Area Index (LAI):** Fertilizer placement had a significant impact on LAI ($p < 0.001$). LAI varied significantly across growth stages ($p < 0.001$) with a notable interaction between treatment and stage ($p = 0.002$). CRF-Side dress significantly enhanced LAI compared to the control at the V10 stage.

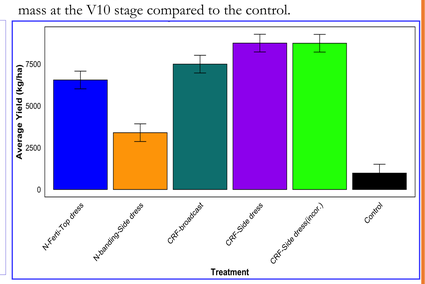




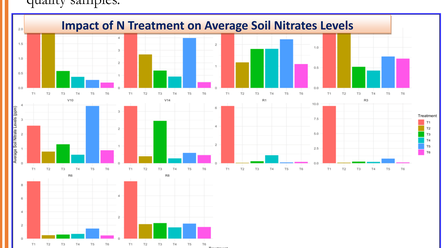
- **Effects on Biomass Nitrogen Content:** Nitrogen treatments significantly affected biomass nitrogen content ($p < 0.001$). Variations in N content were also significant across growth stages ($p < 0.001$), with a notable interaction between treatment and stage ($p < 0.001$). Specific treatments consistently resulted in higher biomass N percentage.

- **Effects on Biomass:** Nitrogen treatments significantly influenced biomass ($p < 0.0001$). Biomass was also significantly affected by growth stages ($p < 0.001$), with a notable interaction between treatment and stage ($p < 0.001$). CRF treatments notably enhanced biomass at the V10 stage compared to the control.





- **Conventional fertilizer (Top dress)** resulted with a highest nitrate levels in the water quality samples throughout the growing season.
- **Interestingly all CRFs** resulted in low nitrate in the water quality.
- **CRF-Side** resulted in significantly less nitrate contamination in water quality samples.



Impact of Fertilizer Treatment on Soil Nitrate Levels

Early Season: N-Fertigation and N-Banding were high
Late Season: N-Fertigation was higher
T4 (CRF-Side dress) had lower levels overall.

- **Effects on Corn Yield:** N-Fertigation (T1) significantly improved yield compared to N-banding (T2) ($p = 0.0059$) and control (T6) ($p < 0.0001$). All CRF treatments resulted in significantly higher yields than N-banding (T2) ($p < 0.0001$), with **CRF-Side dress and CRF -Side dress** incorporated achieving the highest yields (both $p < 0.0001$)

FUTURE WORK

- Integrate results from the 2024 to prepare for 2025 season.
- Integrate the DSSAT crop model and machine learning tools to improve application of findings and enhance predictability for precise management.

ACKNOWLEDGEMENT

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