Effect of Irrigation Scheduling Technique and Fertility Level on Corn Yield and Nitrogen Movement

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Abstract. *Florida has more first magnitude springs that anywhere in the world. Most of these are located in north Florida where agricultural production is the primary basis for the economy. Irrigated corn has become a popular part of the crop rotation in recent years. This project is a study of a corn and peanut rotation investigating Best Management Practices (BMPs) of nitrogen fertility level (336, 246, 157 kg/ha) and irrigation strategies as follows: (i) GROW, mimicking grower's practices, (ii) SWB, using a theoretical soil water balance, (iii) SMS, monitoring volumetric water content measured by soil moisture sensors and triggered using maximum allowable depletion (MAD) and field capacity (FC) as thresholds to refill the soil profile, (iv) Reduced: irrigation (60% of GROW) representing a low irrigation treatment and (v) NON: non-irrigated plots. The objectives were to determine the effect on yield of the various treatments as well as nitrogen movement through the profile based on bi-weekly soil samples. During 2015, yield was not significantly different across irrigated treatments; however, the non-irrigated treatment had significantly lower yield than all other treatments except SWB. Fertility rates 336 and 246 kg N/ha, or 246 and 157 kg N/ha were not significantly different; however, the 336 kg N/ha treatment was significantly higher than 157 kg N/ha. Irrigation and fertilizer were reduced without reducing yield by using BMPs compared to conventional practices during the first year of research. Movement of nitrogen through the vadose zone will be discussed.*

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Introduction

The Upper Floridan Aquifer (UFA) is the main aquifer in Florida and one of the most productive karst aquifers in the world (Katz and Raabe 2005). Most of the north-central Florida regions underneath the UFA are unconfined and characterized by a karst topography. Soils with coarse texture, low water holding capacities, low organic matter and high infiltration rates are characteristic in this region (NRCS 2016), hence, increasing the potential of nitrate leaching.

Nitrogen may originate from natural sources (e.g. precipitation, aquifer materials and organic debris leaching), as well as, from anthropogenic activities (e.g. fertilizer applications, wastewater, animal production) (DeSimone 2009). Nitrate from both sources is possibly the most widespread pollutant in groundwater that can persist for decades (Hallberg and Keeney 1993).

The north-central regions are estimated as the most pollutant vulnerable regions due to the potential groundwater degradation (Arthur et al. 2007). Excessive algal growth in aquatic systems, a reduction of the available dissolved oxygen, as well as, death to other organisms are some of the consequences of excess N in waterbodies (FDACS 2015). Thus, the implementation of agricultural Best Management Practices (BMPs) is imminent in areas susceptible to pollutants.

Corn is a high water and nutrient demanding crop and it has become a popular part of the crop rotation in recent years. Traditionally, growers use a calendar-based irrigation schedule, in which water is applied according to the crop stages using growers' general knowledge of the crop and local weather conditions. Nitrogen (N) fertilizers are commonly applied exceeding the N uptake by the plants allowing the excess N to potentially leach increasing the N load to groundwater sources.

The implementation of irrigation strategies such as a soil water balance method or soil moisture sensors (SMS) to monitor volumetric water content (VWC) continuously in the soil, provide information to growers about the status of the soil and the available water to the plants. Therefore, overirrigation or deep percolation could be avoided if irrigation is applied only when needed, while reducing potential N leaching. The objective of this paper is to compare conventional irrigation practices and common fertility rates with new irrigation scheduling techniques and lower N fertility levels which may increase irrigation efficiency and reduce N leaching from the root zone.

Materials and Methods

Experimental Field

This research study was conducted at the Suwannee Valley Agricultural and Education Center, near Live Oak, Florida (30.31353 N, -82.90122 W). In this paper, experimental data from the first year is presented. Predominant soils were identified as: Blanton-Foxworth-Alpin complex (48.7%), Chipley-Foxworth-Albany (31.6%) and Hurricane, Albany and Chipley soils (19.6%) (USDA 2013).

In Florida the corn growing season generally spans from April to August. Corn (Pioneer 1498 YHR/Bt) was planted on 3 April 2015 at 0.762 m row spacing, and 1.65 mm between plants for a total density of approximately 80,000 plants/ha. An on-site FAWN weather station located in Live Oak, FL was used to collect weather parameters (e.g. daily rainfall, maximum, minimum and average temperature and ET) (FAWN 2017).

Experimental Design and Analysis

A randomized complete block design arranged in a split plot with four replicates per treatment was set up for the field experiment. Irrigation treatments as main plots and N fertility rates as sub-plots. Plots were 12.2 m long and 6.1 m wide separated by 6.1 m alleys. Alleys of 12.2 m were included between the blocks to let the irrigation system achieve adequate pressure to switch irrigation rates between treatments.

Irrigation treatments

The irrigation treatments evaluated consisted of the following:

I1-GROW: mimics grower's irrigation practices in which irrigation rates vary based on growth stages. The first 30 days after planting (DAP) zero irrigation was applied (unless severe windy conditions occurred). A target of 30 mm/wk was established for 31-39 DAP unless rainfall events equal or greater to 6.35 mm occurred. Target irrigation was 40 mm/wk with irrigation events of 11 mm for 40-59 DAP. One irrigation event was skipped if rainfall events were equal or greater than 13-19 mm, and two events were skipped if greater than 19 mm of rain occurred. Then, the irrigation target increased to 60 mm/wk unless 13-25 mm of rain occurred the day prior to a scheduled irrigation. Two irrigations were skipped if 25 mm of rain occurred. Finally, at full dent stage (105 DAP), weekly irrigation targets were reduced to 40 mm/wk for one week and 20 mm/wk for another week until finally irrigation was terminated at 115 DAP.

I2-SWB: soil water balance treatment. A theoretical SWB equation was used to schedule irrigation. It simulates soil water storage in corn root zone due to changes in effective rainfall (R), effective irrigation (I), run-off (RO), crop evapotranspiration (ETc), and drainage (D). It assumes negligible rates for RO due to sandy soils, and D occurs if water exceeds water holding capacity in the rootzone. Maximum allowable depletion (MAD) values of 50% and 33% were used during vegetative and reproductive stages, respectively. Weather data (i.e. rainfall, ET, temperature) was collected from the on-site FAWN weather station (FAWN 2017). Crop evapotranspiration (ETc) was calculated using phenologically based crop coefficients (Kc) (K-State Research & Extension Mobile Irrigation Lab 2014) and reference evapotranspiration (ETo) as follows:

$$ETc = Kc\ ETo$$

I3-SMS: soil moisture sensor (SMS)-based irrigation. Sentek SMS probes (Sentek Pty Ltd 2003) (i.e nine sensors from 5 cm to 85 cm) were used to schedule irrigation. According to guidelines proposed by Zotarelli et al. (2013), irrigation was determined using the MAD and field capacity (FC) points to refill the soil profile with irrigation.

A total of 10 mm per irrigation event was applied. Theoretical values for Chipley-Foxworth-Albany soil were used in this study (FC= 9.1%, 50% MAD= 6.3%, AWHC= 5% and PWP= 3.5%)(NRCS 2016). SMS irrigation was triggered when VWC in any of the probes for this treatment showed values below the 50% MAD threshold.

I4-Reduced: Using the same frequency as GROW, it applies only a 60% of GROW treatment with application rates of 10 mm.

I5-NON: Non-irrigated/rainfed plots.

A two span Valley Linear End feed 8000 (Valmont Industries 2015), Valley, NE) with a Variable Rate (VRI) package was used to irrigate different application rates to the crop based on the corresponding treatments. Senninger (Senninger Irrigation, Inc., Clermont, FL) LDN-UP3 Flat Medium Grove 20 mm M NPT nozzles were attached to drops at a 3 m sprinkler spacing. Valley 69 kPa pressure regulators (PSR-2 10 10(PSI) 3/4 F NPT) were installed on each drop to keep a constant flowrate. The NON treatment received irrigation only after granular fertilizer applications to provide adequate moisture conditions for nutrient uptake.

N fertility rates

Three N fertility rates were evaluated: F1=336 kg/ha; F2=246 kg/ha, and F3=157 kg/ha. The former represents a high N scenario commonly applied to corn in the region, F2 a medium rate representative of the UF/IFAS recommended N rate (Mylavarapu et al. 2015) and F3 a low scenario. The low and high N rates deviated ±36.4% from the UF/IFAS recommendation. The application of N fertilizer was accomplished at planting, two granular and four liquid sidedress applications during the vegetative crop stages.

A pre-plant soil sample analysis was performed to determine initial soil conditions. At planting an initial liquid application of 34 kg/ha of 16-16-0 was applied on the soil surface across all treatments. The N fertility rates started 14 DAP with the first granular application (at V3 corn growth stage). Total N applied on the low, medium and high rates were: 9, 25 and 34 kg N/ha, respectively using a 33-0-0 fertilizer (16.49% Ammoniacal N and 16.51% Nitrate-N). The second granular application (33-0-0) took place close to V6 corn growth stage. A total of 11, 27 and 45 kg N/ha were applied on F3, F2 and F1 rates, respectively. Afterwards, split liquid sidedress applications (28-0-0) were applied between V8 and VT- (tasseling) corn growth stages. At each liquid sidedress application a total of 26, 40 and 56 kg N/ha were applied on the F3, F2 and F1 rates, respectively.

Phosphorus and potassium applications were performed based on soil analysis results and equally applied across all fertility rates as required. In all years, 34 kg P/ha was applied at planting (16-16-0). In 2015, based on analysis results, 84 kg P/ha of 0-46-0 (Triple Superphosphate) was applied during the first granular application. In terms of potassium, 110 kg K/ha and 86 kg K/ha of 0-0-60 was applied during the first and second granular applications in 2015.

Soil sampling

Soil samples were taken at four depths (0-15, 15-30, 30-60 and 60-90 cm) biweekly during the crop season (April-August) until harvest. Subsequent soil sampling was performed on a monthly basis. Soil samples were performed in I1, I3 and I5 irrigation treatments only. Samples followed a field and processing protocol to finally be delivered at the Analytical Research Laboratory (UF/IFAS Anserv Labs 2011) for NO3-N and NH4-N analysis.

Results

The corn season spanned from March to August in which cumulative rainfall totaled 531 mm distributed in frequent and constant rainfall events reducing the need for irrigation. During the growing season, irrigation treatments GROW, SWB, SMS, Reduced and NON applied a total of 320, 185, 151, 211 and 15 mm respectively. Total water savings in comparison to the I1 treatment, which mimics conventional irrigation practices, resulted in 42%, 53%, 34% and 95% for the I2-I5 treatments, respectively (Fig. 1).

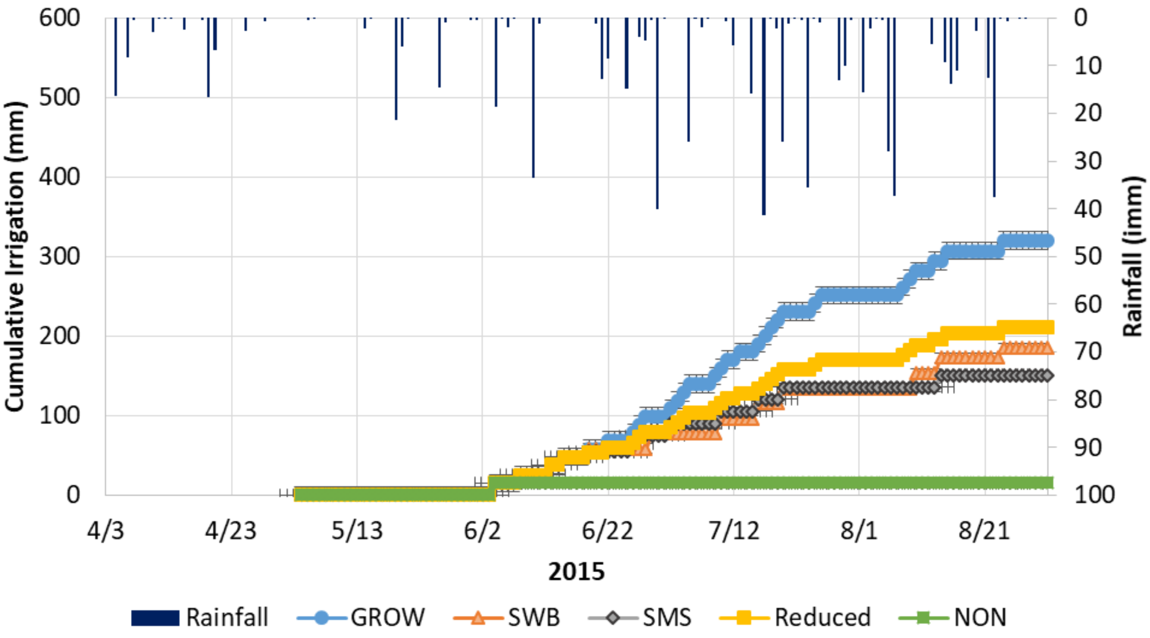


Fig. 1 Cumulative irrigation per treatment and daily rainfall during 2015 corn growing season.

The results for NO_3-N soil samples down to 90 cm are shown in this paper. NO_3-N average concentrations increased in all fertility treatments as fertilizations were applied during the crop season. During the soil sampling performed in 1 June F1 showed the highest NO_3-N average concentrations in all soil layers (i.e. 19.5, 18.1, 10.3 and 6.2 mg/kg at 0-15, 15-30, 30-60 and 60-90 cm) after the last two liquid side dress applications performed on May 22nd and May 29th. The first two soil layers showed the greatest response. F2 and F3 followed a similar pattern having smaller spikes after the first granular and the last two side-dress fertilizations (Fig. 2).

After the pronounced NO_3-N spikes obtained as a response of the fertilizations on the top layer, average nitrate-N decreased in all soil layers and N fertility rates. Overall nitrate-N concentrations averaged 1.2 mg/kg on the soil samplings performed from 1st July 2015 to October 2015 (post 2015 fertilization events). However, during the samplings in November and December 2015 (after harvest-fallow period) nitrate-N concentrations increased about two fold (3.5, 3.6 and 2.4 mg/kg) on the top soil layer in F1- F3 rates, respectively (Fig. 2). This increase in nitrate-N concentrations after harvest are the result of crop biomass residue mineralization processes after harvest.

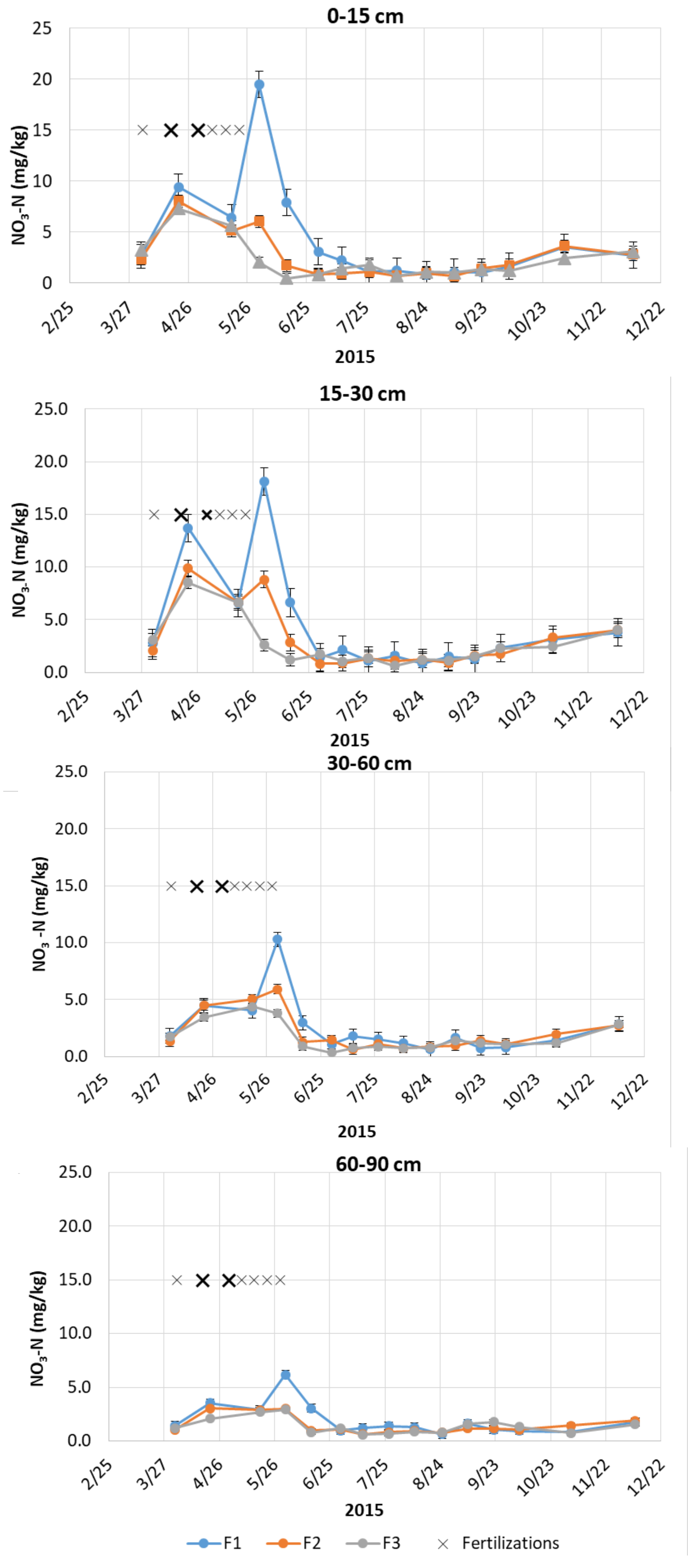
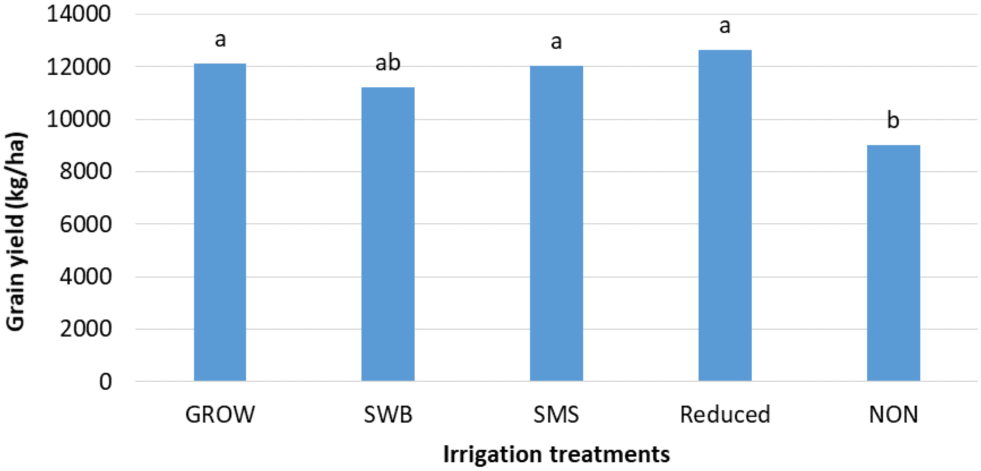


Fig. 2 Average soil nitrate-nitrogen (NO_3-N) per N fertility rates across irrigated treatments. The "x" symbols indicate fertilization events with the bold "x" indicating granular applications.

Yield was not significantly different across irrigated treatments; however, the non-irrigated treatment had significantly lower yield than all other treatments except SWB. In the 2015 season, mean grain yields resulted in 12,115, 11,173, 11,989, 12,616 and 8,976 kg/ha for I1-I5 irrigation treatments, respectively (Fig. 3, top). Significant differences in yield were not found between 336 and 247 kg N/ha rates, or between 247 and 157 kg N/ha rates; however, F1 mean yield (12,303 kg/ha) was significantly higher than F3 yield (10,545 kg/ha) (Fig. 3 bottom).



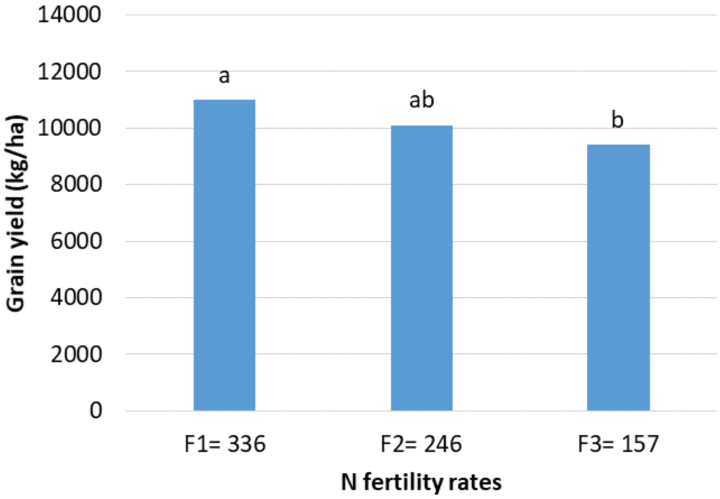


Fig. 3 Final grain yield across irrigated treatments (top) and across N fertility rates (bottom) obtained in the 2015corn growing season.

Conclusions

During the 2015 corn growing season, average yield obtained following the UF/IFAS N fertilization recommendations (F2=246 kg N/ha) were not statistically different than yields obtained with conventional N applications (F1=336 kg N/ha). Therefore, the same grain yield could be achieved with 246 kg N/ha while reducing the N applications by 26.6%. Furthermore, potential N leaching from the soil profile can be reduced following UF/IFAS recommendations.

Alternatives to schedule irrigation resulted in water savings without reductions in yield. Using a soil water balance (I2 treatment), or sensors that provide real-time data to monitor VWC (I3 treatment), or a reduced scenario (I4 treatment) to schedule irrigation resulted in 42%, 53% and 34% water savings compared to conventional irrigation practices (I1 treatment) in corn production during 2015. These three irrigation strategies can be potentially used as a water efficiency management tool for corn production in Florida while conserving water without negative impacts on yield.

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