Improving Nitrogen Fertilizer Management in Subsurface Drip-Irrigated Cotton.

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Background:

Declining water availability in the lower Colorado River basin has been a fact of life in the American Southwest since 2000 (Scanlon, 2016). Following water, N fertilizer is the main constraint to cotton production in the western USA (Morrow and Krieg, 1990). Canal infrastructure of irrigation water in Arizona means basin, flood, and furrow irrigation are still the pre-dominant choices of irrigation methods. Navarro et al. (1997) in Arizona, and Booker et al. (2007) and Bronson et al. (2007; 2008) in Texas reported that recovery efficiency ground-based N applications in furrow-irrigated cotton ranged from only 15 to 34 %. With declining water resources and competition from growing urban areas there is renewed interested in subsurface drip irrigation (SDI) systems. However, N management research and recommendations in the far western US are lacking for SDI cotton. In the western US, weekly petiole NO_3 sampling and analysis is the recommended approach to monitor in-season cotton plant N status. However, petiole sampling is laborious and laboratory turn-around is time-consuming. Additionally, petiole NO_3 analysis can be highly variable (Bronson et al. 2001). Canopy reflectance, on the other hand is a rapid, non-destructive method to assess in-season cotton N status (Chua et al., 2003; Bronson et al, 2003). Canopy reflectance-based N management in subsurface drip systems in Texas resulted in reduced N fertilizer use, without hurting lint yields (Yabaji et al., 2009). In that research, N fertilizer was initially applied at half the rate of a regional soil test based recommendation. When normalized difference vegetative index (NDVI, a common remote sensing vegetative index) in the reflectance treatment fell below NDVI of the soil test/adequately fertilized plot, N fertigation was increased. This simple "sufficiency index" approach has not been tested in the western US in SDI cotton.

We propose an improved and updated N fertilizer management recommendation for 4-bale/acre cotton based on a 36-inch NO_3-N soil test. Additionally, we will compare soil test-based N management for full and deficit irrigation. The study was conducted in Maricopa, AZ on a Casa Grande sandy loam.

Objectives:

1. Compare lint yields and NUE with soil test-based N fertilizer management with canopy reflectance-based UAN-N management approach in subsurface drip irrigated cotton.
2. Compare lint yields and NUE for full and deficit irrigation in subsurface drip irrigated cotton.
3. Construct N balances for subsurface drip irrigated cotton, i.e. quantify total N uptake, recovery N use efficiency, NO_3 leaching, and denitrification losses.

Methods:

In March, 2016, pre-plant soil sampling to 180 cm (70-inch) for NO_3 was done on four samples per plot. Total number of DGPS-referenced soil sampling points was 60. Cotton cultivar 'DP1549 B2XF' was planted on 12 April, 2016 in plots that were 8, 1-m (40 inch) rows wide by 330 feet. Harvest was in October. Nitrogen and irrigation treatments included:

Nitrogen treatment	Irrigation level (% ET)
1. Soil test-based N†	100
2. Reflectance-based N‡	100
3. Zero-N	100
4. Soil test-based N†	75
5. Zero-N	75

† Based on lint yield goal of 4.0 bale/ac, and a 200 lb N/ac N requirement, minus 0 - 36 in. soil NO_3-N and estimated irrigation input of 20 lb N/ac (estimated 40 inch irrigation of 2 ppm NO_3-N water).
‡ Applications start out at 50 % treatment no. 1, subsequent applications based on NDRE relative to treatment no. 1.

Nitrogen fertilizer as UAN was fertigated in 24 doses between first square and mid bloom. The experimental design was a completely randomized block, with three replicates. Canopy reflectance was measured weekly from first square to first open boll using two Crop Circle ACS-470 active sensors. Several vegetative indices were calculated including NDVI, CCCI, and NDRE. NDRE was used for reflectance-based N treatments. Surface flux of N_2O was measured weekly for 10 weeks during the season using vented chambers and gas chromatography. Biomass and total N uptake were determined for plant sampled from 1 m (36 inches) of row at first open boll. Nitrogen recovery efficiency, physiological N use efficiency and agronomic use efficiency were calculated. Lint and mature seed yields were measured by two-row picker harvesters for both yield mapped-entire plot and 20-foot long sections centered on the DGPD points. Mature cotton seed N was determined from grab samples at the four DGPS points per plot and the percentage of seed N to total N uptake calculated. Micronaire and other fiber quality attributes will be determined on lint and the relationships of these to N fertilizer rate estimated (data not available at report time). Soil sampling for extractable NO_3-N from 0 to 180 cm was done after harvest to assess residual NO_3 on four samples per plot to assess the spatial variation of residual NO_3 across the plot, and effect of treatments (data not available at time of this report).

Pre-plant and harvest soil profile NO_3, N_2O emission, NDVI, plant biomass, plant N uptake, lint, and seed yield were analyzed with a mixed model using SAS. Replicate was considered random, and N treatment was considered fixed.

Results and Discussion

Pre-plant soil profile (0-36 inch) soil NO_3-N was a low 24 lb N/ac, due to removal by a large barley winter cover crop. Our soil test based N rate was therefore 156 lb N/ac (200 target -24 – 20 estimated from irrigation water). We used the same soil test N rate for both the 100 and 75 % ET irrigation level, in order to make these treatment comparisons strictly for water level.

Nitrogen deficiency in this study appeared rapidly in all vegetation indices as significant differences in N-fertilized plots vs. zero-N, on day 153, one week after the start of fertigation. This must have been a result of low initial soil profile NO_3. All vegetation indices for the reflectance-based N treatment fell significantly below soil test N plots, two weeks after fertigation commenced (N rates for reflectance were initially 50 % of soil test target of 156 lb N/ac). Amber NDVI during the growing season is shown in Fig. 1. The last four weeks of the fertigation period, UAN injection rates were the same between the two treatments (Fig. 2). Final reflectance-based N rate was 141 lb N/ac, 15 lb N/ac less than the soil test treatment.

Petiole-NO_3-N levels dropped immediately in zero-N plots for both irrigation levels and remained low (Fig. 3). Initial values for all plots at first square were far less than previous years' studies with larger and fewer N fertilizer applications, and markedly below the critical petiole-NO_3-N value of 15,000 ppm (Silvertooth et al., 2011). Reflectance-based N petiole-NO_3 was initially significantly lower than soil test, and then caught up by day 166. At first bloom (day 166), the N-fertilized plots were fairly close to the critical of 12,000, and the previous years' studied indicated a petiole NO_3-N value of 10,000 at first bloom is adequate.

In early August, first open boll biomass samples were taken. Biomass was high at 13,300 lb/ac for soil test N and 100% irrigation, and 8,900 lb/ac for soil test N, 70 % water. Nitrogen and water effects on canopy height related very well to NDVI (Fig. 4). We find that the Honeywell height sensor was very rapid response and is accurate.

Lint yields are shown in Table 1. There was no yield reduction with reflectance-based management compared to soil test N, although biomass was less in the former. A modest savings of 15 lb N/ac less N fertilizer was achieved with reflectance-based N management (Table 1). However, the lint yields of 1400 lb/ac were lower than the target of 2000 lb/ac (Table 1). Fruits from nodes 6- 9 apparently dropped on some of the 45 ^{o}C hot days we experienced when these fruits were at small green boll stage. However, canopy temperature data shows that only the zero-N plots exhibited plant leaf temperatures above air (Fig. 5). Interestingly, the soil test N rate at 75 % irrigation had canopy temperatures less than air, similar to the soil test and reflectance-based N at 100 % water. The relatively high "canopy" temperatures observed at day 152 were due to the high, hot exposed soil background 42 days after emergence.

The high recovery efficiency of added/fertigated N of 81 % in the soil test, 100 % irrigation was not unexpected, but is a significant result that solidifies the hypothesis that NUE is high in fertigated drip systems

Deep percolation estimates as high as 6 % of rain and irrigation were higher than expected, although they were increased by surprise rains (Table 2). There was no deep percolation in the zero-N plots. We did notice that the beds in zero-N plots were often wet as the smaller, N-deficient plants took up less water than the N-fertilized plots.

Nitrous oxide emissions were low and not different between N-fertilized and zero-N plots (Table 3, Fig. 6). The zero emission factor (i.e. percent of added/fertigated N that was emitted as N_2O) combined with low overall seasonal N_2O emissions is a very significant result. This is especially true given the growing emphasis on low greenhouse gas production/footprint in cropping and industrial production today.
In summary, the 2016 field season with SDI cotton was successful. High biomass, N uptake and recovery efficiency of fertigated N were the highlights. Also notable was the relatively low deep percolation, and the very low N_2O emissions. Lower than expected lint yields due to heat stress were not expected in SDI cotton. The study will be repeated in 2017. We will do our 6-hr., base 11-mm daily irrigations starting at 8 am, instead of 11 am, as we observed this eliminated temporary mid-day wilting. We will also not wait 21 days between emergence irrigation and start of in-season irrigation and N fertigation, as the entire test may have been N-limited.

Table 1. Lint yield, seed yield, N uptake and N use efficiencies as affected by N management and irrigation level in subsurface drip-irrigated 'DP 1549 B2XF' cotton, Maricopa, AZ 2016

Nitrogen treatment	Irrigation level	Fertilizer rate	Biomass yield	Lint yield	Total N uptake	Recovery efficiency	Agron. N use efficiency	Internal N use efficiency
	mm	lb N/ac	lb/ac	lb/ac	lb N/ac	%	lb lint/lb N fert.	lb N/bale
Soil test-based N	896	156	13,307 a	1358 a	186 a	81 a	3.5 a	65 a
Reflectance-based N	896	141	11,726 b	1412 a	151 b	67 a	4.2 a	52 b
Zero-N	896	0	5635 d	816 d	59 c	-	-	32 c
Soil test-based N	674	156	8898 c	1136 b	140 b	59 a	3.2 a	58 ab
Zero-N	674	0	5207 d	640 c	49 c	-	-	34 c

Table 2. Water balances as affected by N management and irrigation level in subsurface drip-irrigated 'DP 1549 B2XF' cotton, Maricopa, AZ 2016.

N treat.	Irrigation level	Root zone (cm)	ET	Rain	Irrigation	Change soil storage (0-1.7m)	Deep perc	Deep perc (% of irrigation)
			------------------------ cm			------------------------------		
Soil test-based N	896	180	-84.9	3.1	80.1	-9.8	5.3	6.4
Reflectance-based N	896	180	-84.9	3.1	80.1	-8.2	3.8	4.6
Zero-N	896	180	-84.9	3.1	80.1	-0.8	-3.7	0
Soil test-based N	674	180	-69.1	3.1	57.9	-10.8	2.8	4.6
Zero-N	674	180	-69.1	3.1	57.9	-5.2	-2.8	0

Table 3. Seasonal nitrous oxide emissions as affected by N management and irrigation level in subsurface drip-irrigated ‘DP 1549 B2XF’ cotton, Maricopa, AZ 2016.

Nitrogen treatment	Irrigation level	Fertilizer rate	N_2O Emissions
	mm	lb N/ac	g N/ac
Soil test-based N	896	156	89 a
Reflectance-based N	896	141	39 a
Zero-N	896	0	90 a
Soil test-based N	674	156	62 a
Zero-N	674	0	45 a

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Fig. 1. Amber NDVI as affected by N management and irrigation level in SDI cotton, Maricopa, AZ, 2016.

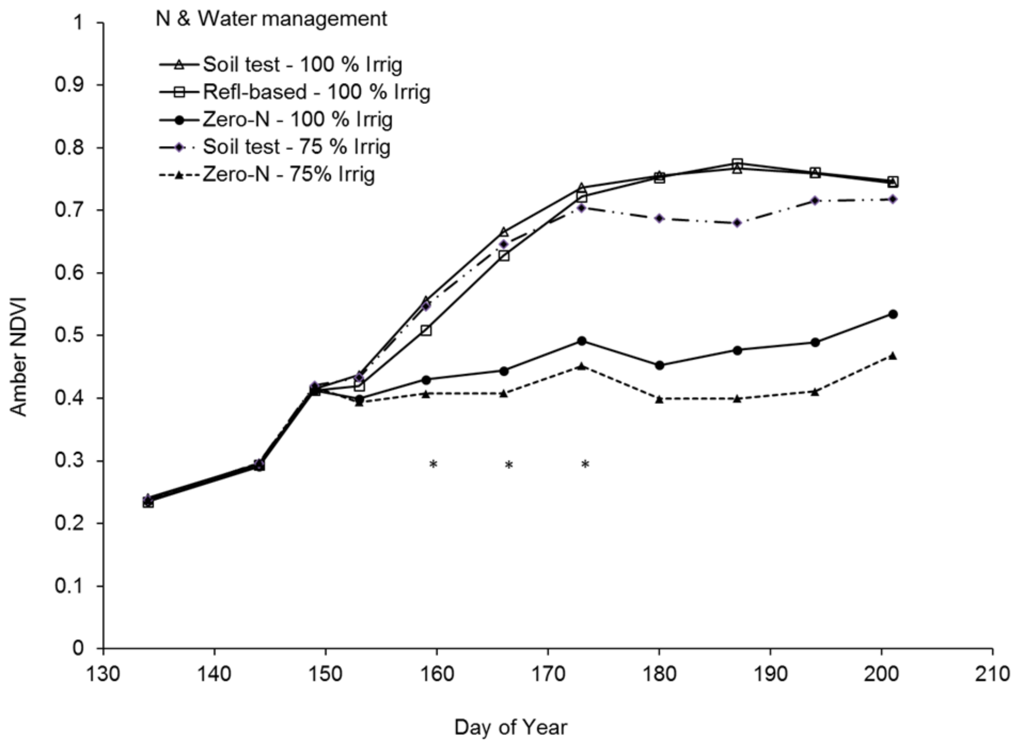

Fig. 2. Nitrogen (urea ammonium nitrate) fertigations as affected by N management in SDI cotton, Maricopa, AZ, 2016.

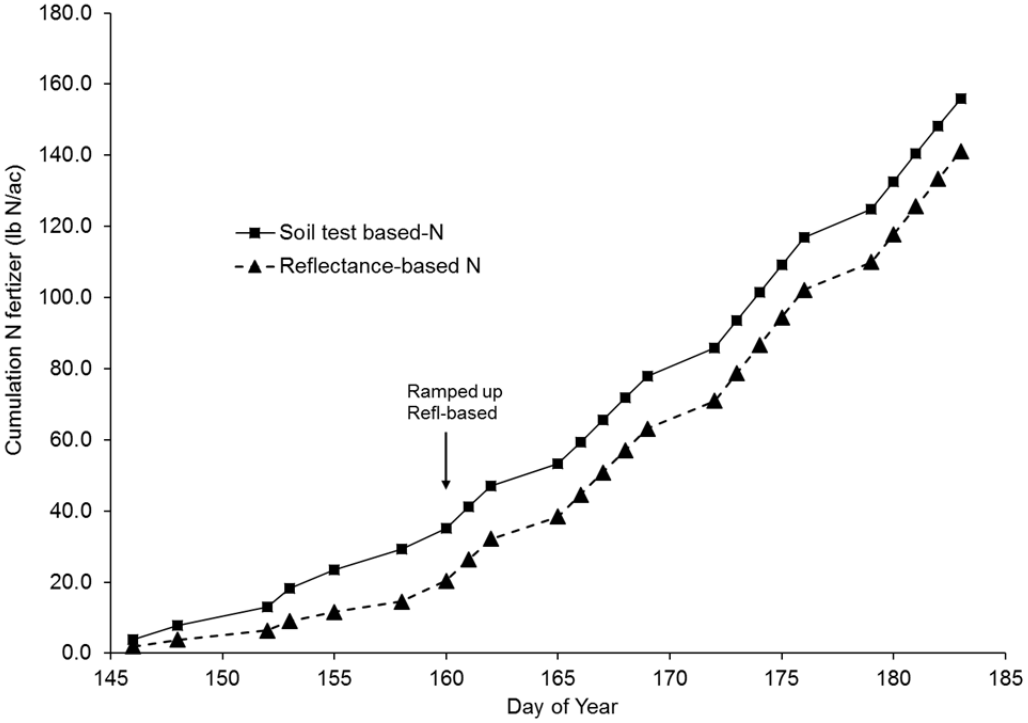

Fig. 3. Petiole-nitrate-N as affected by N management and irrigation level in SDI cotton, Maricopa, AZ, 2016.

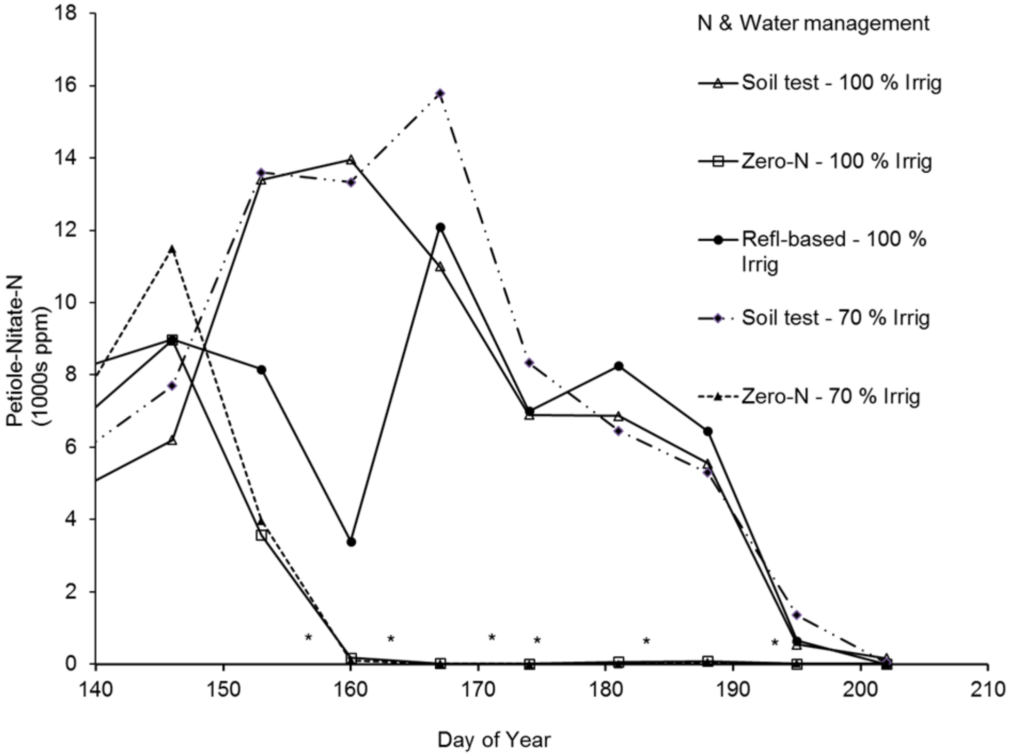

Fig. 4. Canopy height measured by ultrasonic sensor as affected by N management and irrigation level in SDI cotton, Maricopa, AZ, 2016.

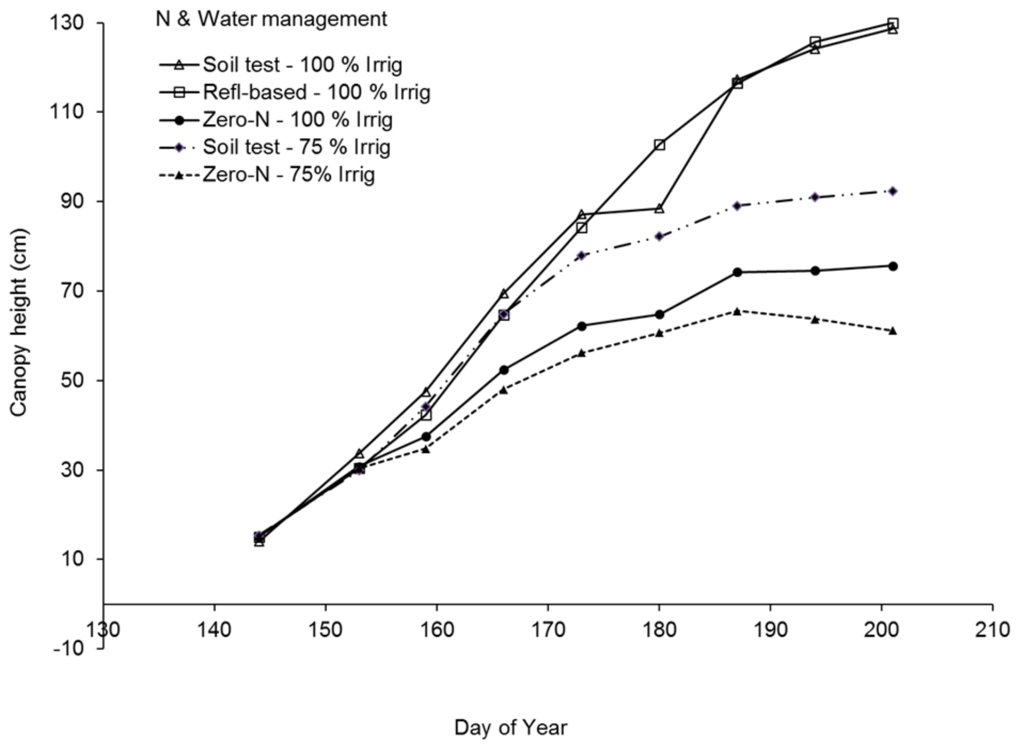

Fig. 5. Canopy temperature minus air temperature as affected by N management and irrigation level in SDI cotton, Maricopa, AZ, 2016.

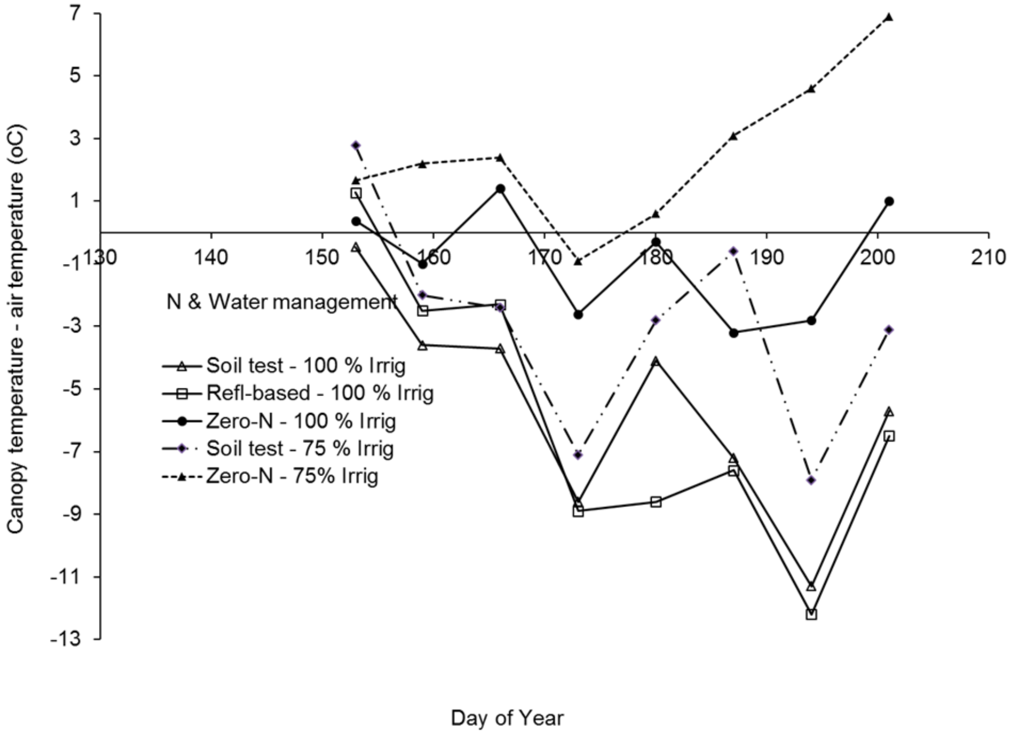

Fig. 6. Nitrous oxide emissions as affected by N management and irrigation level in SDI cotton, Maricopa, AZ, 2016.