Improving Nitrogen Fertilizer Management and Fate of Nitrogen in Sprinkler-Irrigated Cotton.

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Background:

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 center-pivot or linear-move overhead sprinkler irrigation systems. However, N management research and recommendations in the far western US are lacking for sprinkler irrigation. 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 vegetation index (NDVI, a common remote sensing vegetation 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 sprinkler-irrigated cotton.

Enhanced-efficiency N fertilizers like Agrotain Plus have been shown to reduce N_2O emissions in corn (Halvorson et al., 2014), but have not been widely tested in cotton (Watts et al., 2014).

We propose and improved and updated N fertilizer management recommendation for 4-bale/acre cotton based on a 36-inch NO_3-N soil test. We will also compare UAN with UAN plus the N loss inhibitor Agrotain Plus. Additionally, we will compare reflectance-based N fertilizer management with soil test-based management. The study we be conducted in Maricopa, AZ on a Trix sandy clay loam.

Objectives:

1. Compare soil test-based N fertilizer management with two canopy reflectance-based UAN-N management approaches in sprinkler-irrigated cotton.
2. Compare urea ammonium nitrate (UAN) and UAN with Agrotain Plus in sprinkler-irrigated cotton.
3. Construct N balances for sprinkler-irrigated cotton, i.e. quantify total N uptake, recovery N use efficiency, NO_3 leaching, and denitrification losses.

Results and Discussion

The amber NDVI in the two reflectance-based treatments never fell below their respective references during the growing season (Fig. 1). Therefore the two NDVI-based N treatments were not adjusted upwards. In fact, amber NDVI did not drop significantly below the N-fertilized treatments until the 210th day of the year (28 July) or peak bloom. This was three weeks after the third split of N fertilizer. In contrast to NDVI, the NDRE index showed zero-N plot deficiency on DOY 196 (mid bloom) (Fig. 2). NDRE has consistently reflected N deficiency much early than amber NDVI. Therefore, in future work, we will use NDRE for reflectance-based N management. Petiole NO_3 samples showed N deficiency in zero-N plots very early, on 165th DOY, or only one week after the first application of N fertilizer (early squaring) (Fig. 3).

First open boll biomass averaged 8916 lb/ac in N-fertilized plots, and was 7658 lb/ac in zero-N plots ($P < 0.05$, Table 2). Nitrogen uptake (leaves, burrs, and stems) at first open boll ranged from 89 to 131 lb N/ac in N fertilized plots, and was 67 lb N/ac in zero-N plots ($P < 0.05$, Table 2). The N uptake data is incomplete, as seed N has not been analyzed yet. Recovery efficiency (RE) of added N fertilizer was apparently much greater than in 2014 sprinkler irrigation study. It must be pointed out that the 2014 study had lower N fertilizer application rates than in 2015, i.e higher RE would be expected. The greatest RE this year in 2015 was with the low N rate of 59 lb N/ac where RE was 81% (Table2). The lowest RE of 35 % was with the 1.3 x Soil test rate (152 lb N/ac).

Final lint yields showed significantly lower lint yields for zero-N plots (1571 lb lint/ac) vs. the average of the N-fertilized plots (1816 lb lint/ac, or 3.8 bale/ac, Table 3, $P < 0.05$). These yield levels were slightly less than the 4 bale/ac yield goals. The lint yield of soil test-based N level with Agrotain Plus yielded 1950 lb/ac or 4 bale/ac, but there were no statistical differences among the N-fertilized plots ($P > 0.05$). There was no effect of Agrotain Plus in biomass, N uptake, RE, AE or lint yields (Table 2 and 3).

Nitrous oxide emissions did increase with N rate, for eight of the fourteen measurement dates (Table 2, Fig. 4),). However, Agrotain Plus did not significantly effect N_2O emissions ($P > 0.05$). Nitrous oxide emissions were greatest in the middle of the season between the second and third N supplication (Fig. 4). Emission factors (EF) , or percent of N fertilizer rate added emitted as N_2O-N (adjusted for zero-N), ranged from 0.2 to 0.65 % (Table 2). It is notable that these are well below the IPCC tier 1 EF of 1 % (Reay et al., 2012).

Table 4 shows the water balance for 0- 170 cm during the season, estimated from ET, irrigation, and rain inputs, and changes in soil water as measured by neutron probes. Deep percolation for sprinkler irrigation in this study was estimated to be negligible, similar to 2014. This compares to 14 to 23 % for the previous two years study with surface irrigation.

Table 1. Extractable soil NH_4 and NO_3, (0-12 inches), at pinhead early squaring, as affected by N management in sprinkler-irrigated cotton, Maricopa, AZ 2015

Nitrogen treatment	Fertilizer source	Fertilizer rate	NH_4	NO_3
		lb N/ac	------ ppm N ------	
Zero-N		0	3.2 a	32 b
Soil test-based N†	UAN	117	6.2 a	83 a
1.3*Soil test-based N†	UAN	152	8.1 a	87 a
Soil test-based N†	UAN + Agrotain Plus	117	23 a	77 a
Reflectance-based N-1‡	UAN	59	6.0 a	61 a
Reflectance-based N-2§	UAN	76	8.3 a	73 a
Reflectance-based N-1‡	UAN + Agrotain	59	7.1 a	61 a
Reflectance-based N-2§	UAN + Agrotain Plus	76	12 a	66 a

Table 2. First open boll biomass, N uptake and recovery efficiency, as affected by N management in sprinkler-irrigated "DP 1044 B2RF" cotton, Maricopa, AZ 2015

Nitrogen treatment	Fertilizer source	Fertilizer rate	Biomass	N uptake[a]	Recovery efficiency[a]	Seasonal N_2O flux	N_2O Emission Factor
		lb N/ac	lb/ac	lb N/ac	%	g N_2O-N/ac/113d	%
Zero-N		0	7658 b	67 b	-	111 b	-
Soil test-based N†	UAN	117	9394 a	131 a	54 b	648 a	0.46
1.3*Soil test-based N†	UAN	152	8618 ab	121 a	35 c	1104 a	0.65
Soil test-based N†	UAN + Agrotain Plus	117	8406 ab	112 a	39 c	346 ab	0.20
Reflectance-based N-1‡	UAN	59	9200 a	115 a	81 a	316 b	0.35
Reflectance-based N-2§	UAN	76	9107 a	116 a	64 ab	437 ab	0.43
Reflectance-based N-1‡	UAN + Agrotain Plus	59	8361 ab	89 a	38 cab	305 b	0.33
Reflectance-based N-2§	UAN + Agrotain Plus	76	9324 a	126 a	77 a	359 b	0.33

[a]Incomplete data. First open boll N uptake is for stems, leaves, and burrs, immature seed not yet delinted and analyzed for N,

Table 3. Lint yield, seed yield, agronomic and internal N use efficiency, as affected by N management in sprinkler-irrigated "DP 1044 B2RF" cotton, Maricopa, AZ 2015

Nitrogen treatment	Fertilizer source	Fertilizer rate	Lint yield	Agron. N use efficiency
		lb N/ac	lb/ac	lb lint/lb N fert.
Zero-N		0	1571 b	-
Soil test-based N†	UAN	117	1772 a	1.7 a
1.3*Soil test-based N†	UAN	152	1866 a	2.0 a
Soil test-based N†	UAN + Agrotain Plus	117	1950 a	3.2 a
Reflectance-based N-1‡	UAN	59	1778 a	3.5 a
Reflectance-based N-2§	UAN	76	1729 a	2.1 a
Reflectance-based N-1‡	UAN + Agrotain	59	1865 a	5.0 a
Reflectance-based N-2§	UAN + Agrotain Plus	76	1749 a	2.3 a

Table 4. Water balances for N management studies in surface and in sprinkler-irrigated "DP 1044 B2RF" cotton, Maricopa, AZ 2012-2015

Irrigation	Year	Root zone (cm)	ET	Rain	Irrigation	Change soil storage (0-1.7m)	Deep perc	Deep perc (% of irrigation)
			------------------------ cm -------------------------------					
Surface	2012	180	-82.3	9.5	83.4	-8.6	19.2	23
Surface	2013	180	-76.0	1.3	80.8	-5.0	11.1	13.7
Sprinkler	2014	180	-86.7	8.5	59.8	-19	0	0
Sprinkler	2015	180	-103	3.8	78.4	-21	0	0

Fig. 1. Amber NDVI as affected by N management in sprinkler-irrigated cotton, Maricopa, AZ, 2015.

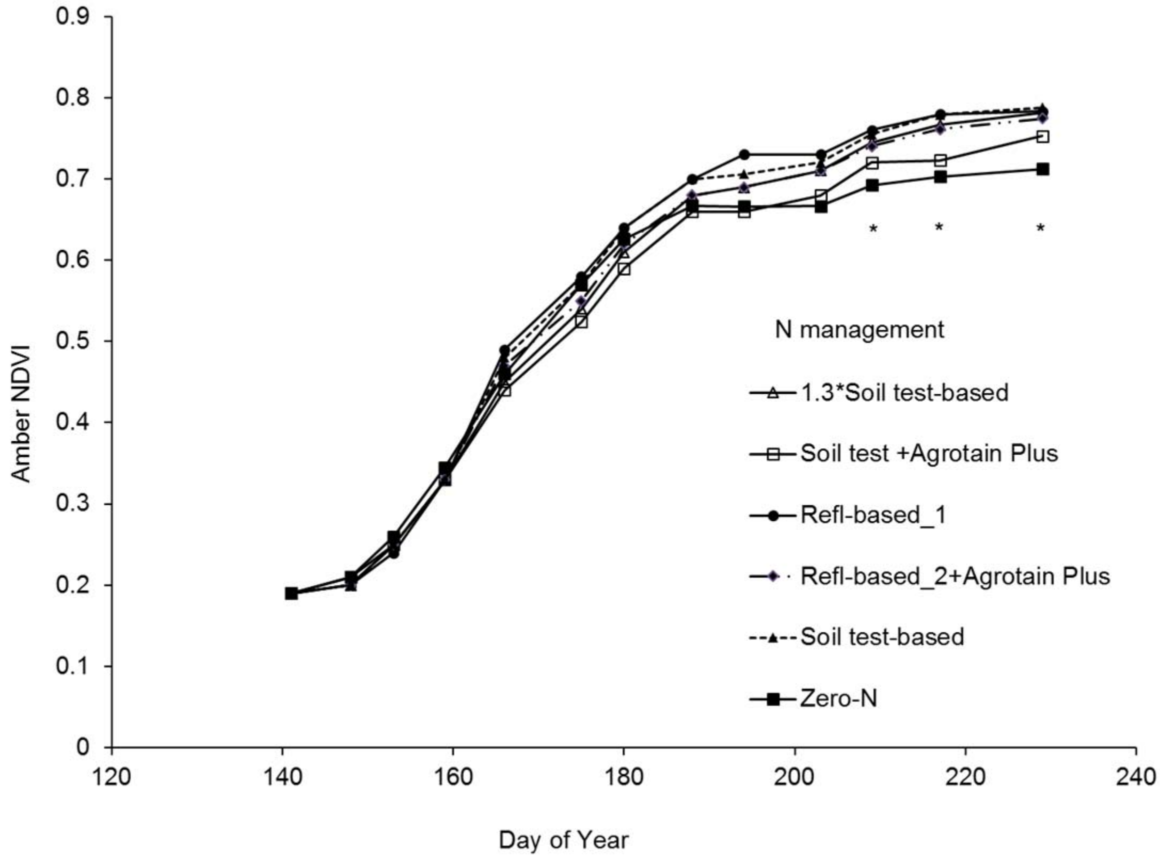

Fig. 2. NDRE as affected by N management in sprinkler-irrigated cotton, Maricopa, AZ, 2015.

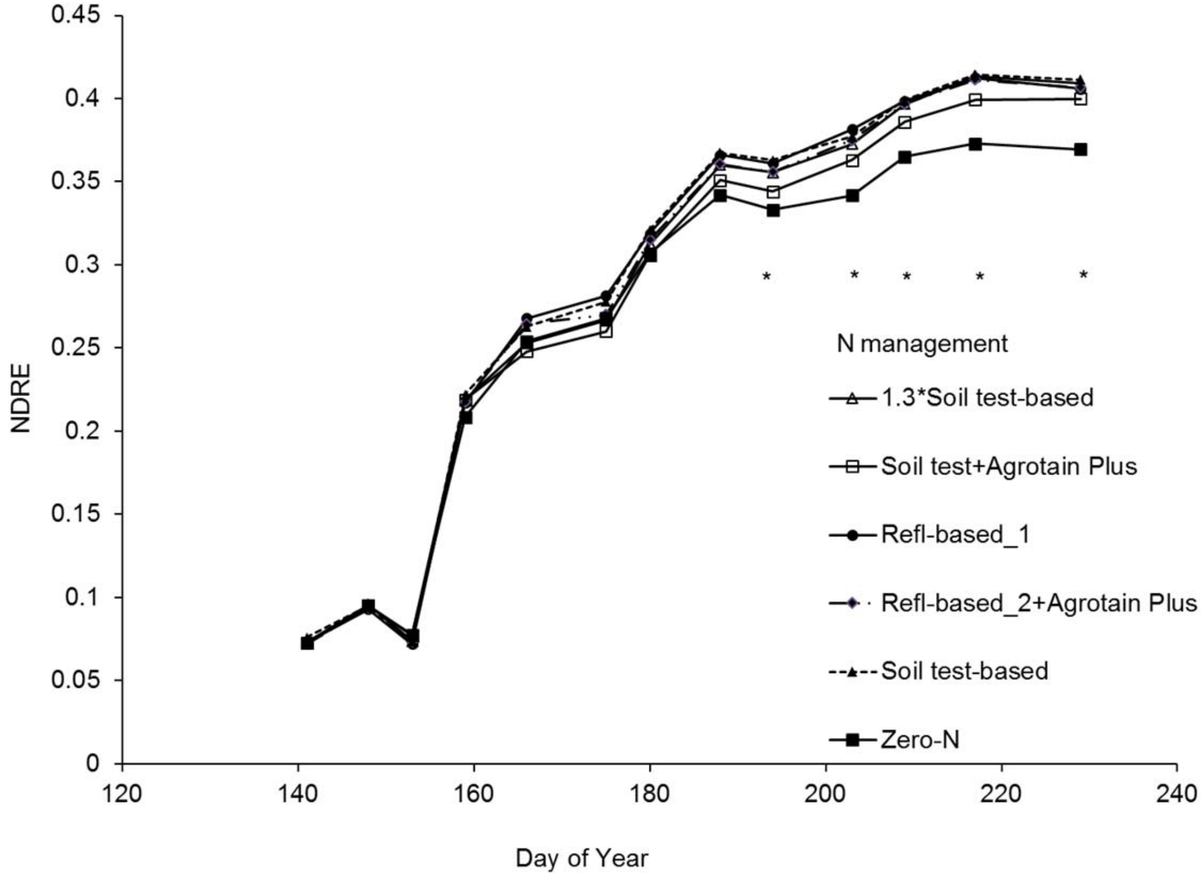

Fig. 3. Petiole NO_3–N as affected by N management in sprinkler-irrigated cotton, Maricopa, AZ, 2015 (arrows indicate N fertilizations).

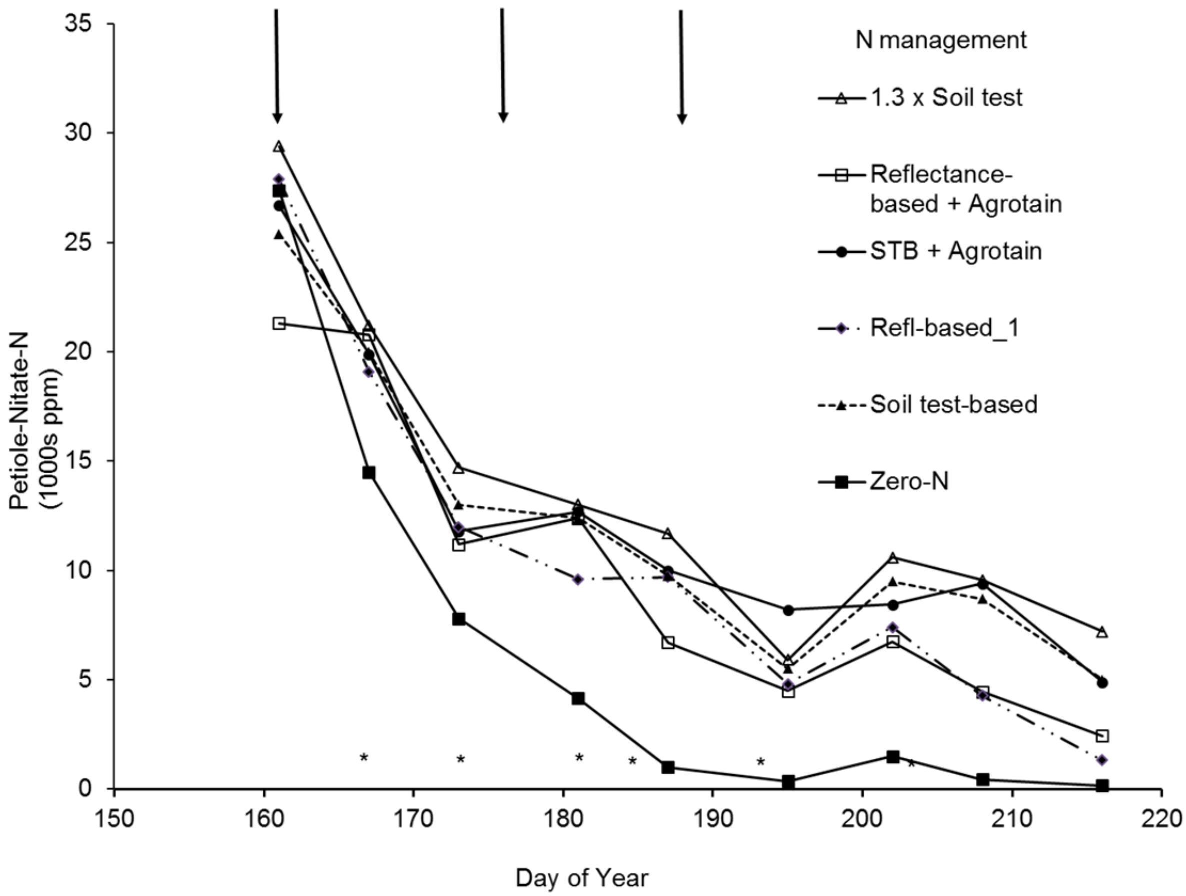

Fig. 4. Nitrous oxide emissions as affected by N management in sprinkler-irrigated cotton, Maricopa, AZ, 2015 (Arrows indicate N fertilizations).