NITROGEN MANAGEMENT AND BUDGETS FOR IRRIGATED COTTON IN THE WESTERN USA

Kevin Bronson, Jarai Mon, Eduardo Bautista and Doug Hunsaker
USDA-ARS, US Arid Land Agricultural Research Center, Maricopa, AZ

ABSTRACT

We present research on new and improved and updated N fertilizer management recommendations for 4-bale/acre cotton based on a 36-inch NO_3-N soil test for irrigated cotton from a 2-year study on surface/furrow irrigation study and a 1-year study under sprinkler irrigation. We also compared UAN with UAN plus the N loss inhibitor Agrotain Plus. Additionally, we compared reflectance-based N fertilizer management with soil test-based management. Nitrogen balances indicated that residual soil NO_3 was substantial, especially with N fertilizer rates > optimal. Recovery efficiency of N in plant ranged from 8 to 64 %. Recovery > 50 % were for the lower end of N rates (i.e. 53 to 84 lb N/ac). Net N mineralization estimated from zero-N plot N uptake ranged from 42 to 97 lb N/ac, with the high end being under sprinkler irrigation. Soil profile NO_3 between 36 and 72 inches was considered leached and made up the largest N loss pathway. Deep percolation below 6 feet was estimated with a water balance and ranged from 0.1 % under a sprinkler to 23 % in surface/furrow irrigation. Agrotain Plus shows promise for mitigating N_2O emissions and NO_3 leaching.

INTRODUCTION

Second to water, N fertilizer is the largest constraint to cotton production in the western USA (Morrow and Krieg, 1990). Canal infrastructure for irrigation water in Arizona means basin, flood, and furrow irrigation are still the pre-dominant irrigation methods. Nitrogen fertilizer recovery, however, is usually less than 50 % in surface-irrigated Western cotton (Navarro et al. 1997; Booker et al., 2007, and Bronson et al. 2007 and 2008). Declining water resources and competition from growing urban areas has led to renewed interested in center-pivot or linear-move overhead sprinkler irrigation systems. However, recent N management research and recommendations in the western US are lacking for surface and sprinkler irrigation, especially for newer cotton cultivars. In this region, 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 turn-around is an issue. 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). Active 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 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).

METHODS

In March, of 2012, 2013, and 2014, pre-plant soil sampling to 180 cm for NO_3 was done on four samples (two per plot in 2014) per plot. Cotton 'DP1044B2RF' was planted in late April to May 1 of each year. In 2012 and 2013 plots were 8, 40-inch rows wide by 550 feet. In 2014 plots were 6, 4-inch rows wide by 120 feet. At harvest, soil sampling to 180 cm for nitrate was repeated. Nitrogen treatments for surface irrigation in 2012 and 2013 (applied either by fertigating in the water run or knifing in the day before irrigation) were:

Nitrogen treatment	Fertilization mode	Fertilizer source	Notes
Zero-N			
Soil test-based N	Knife	Urea amm. Nitrate	In two splits, first square and first bloom†
Soil test-based N	Fertigate	Urea amm. Nitrate	In two irrigations, first square and first bloom
Soil test-based N	Fertigate	Ammonium sulfate[1]	In two irrigations, first square and first bloom
Reflectance-based N	Knife	Urea amm. Nitrate	In two splits, first square and first bloom
Reflectance-based N	Fertigate	Urea amm. Nitrate	In two irrigations, first square and first bloom

[1]Urea ammonium nitrate + Agrotain Plus in 2013

Nitrogen treatments for sprinkler irrigation in 2014 were:

Nitrogen treatment	Fertilizer source	Notes
Zero-N		
Soil test-based N	Urea amm. Nitrate	In three splits, first square and first bloom and mid bloom
1.3*Soil test-based N	Urea amm. Nitrate	In three splits, first square and first bloom and mid bloom
Soil test-based N	Urea amm. nitrate +	In three splits, first square and first bloom and mid bloom
Reflectance-based N-1	Urea amm. nitrate	In three splits, first square and first bloom and mid bloom
Reflectance-based N-2	Urea amm. nitrate	In three splits, first square and first bloom and mid bloom
Reflectance-based N-1	Urea amm. nitrate+Agrotain Plus	In three splits, first square and first bloom and mid bloom
Reflectance-based N-2	Urea amm. nitrate +	In three splits, first square and first bloom and mid bloom

Nitrogen fertilizer was applied in 2014 with a high clearance tractor by spraying into the furrow with fertilizer nozzles just prior to an irrigation. Irrigation was applied 2-4 times a week with FAO crop coefficients and 85 % ET replacement (Allen et al., 1998).

The experimental design is a completely randomized block, with four replicates.

Canopy reflectance was measured weekly from first square to first open boll using Crop Circle ACS-470 active sensor. Several vegetative indices were calculated including NDVI, CCCI, and NDRE. Amber NDVI 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. Soil moisture to 72 inches was determined every week with a neutron probe and the water balance was calculated with irrigation amounts, rain and ET (Maharjan et al., 2014). Biomass and total N uptake was determined plants on 1 m of row at first open boll. Nitrogen recovery efficiency, physiological N use efficiency and agronomic use efficiency was calculated. Lint and mature seed yields were machine harvested. Soil sampling for extractable NO_3-N from 0 to 72 inches was done after harvest to assess residual NO_3 and leached NO_3 (36 – 72 inches). Pre-plant and harvest soil profile NO_3, N_2O emission, NDVI, plant biomass, plant N uptake, lint, and seed yield was analyzed with a mixed model using SAS. Replicate was considered random, and N treatment was considered fixed.

RESULTS AND DISCUSSION

Cotton lint yields were similar in all three years (data not shown). Nitrogen fertilizer response was observed, i.e.. zero-N vs. N-fertilized plots was highly significant ($P<0.01$). However, among, N treatments, lint yields each year were similar. These similar-yielding N treatments included, N sources, N rates, knifing vs. fertigation. Recovery efficiency of added N varied from 8 to 55 %.

Nitrogen balances for the three site-years are shown in Table 1-3. Recovery > 50 % were for the lower end of N rates (i.e. 53 to 84 lb N/ac). Net N mineralization estimated from zero-N plot N uptake ranged from 42 to 97 lb N/ac, with the higher rates being under sprinkler irrigation. Soil profile NO_3 between 36 and 72 inches was treated as leached and made up the largest N loss pathway. Agrotain Plus showed effects for mitigating N_2O emissions and NO_3 leaching, but these treatments were not consistent.

The N balances in 2012 ranged from -2 to 56 lb N/ac (Table 1). Significant positive N balances should have been due to significant NO_3 leached, but this was not consistent (Tables 1-3). Leached N among N-fertilized treatments was greater than zero-N in 2013 and in 2014 (Table 2 and 3). The N balances in 2013 ranged was 4 to -16 lb N/ac (Tables 2). Under the sprinkler in 2014 the N balances ranged from 5 to 32 lb N/ac (Table 3).

Deep percolation below 3 feet was estimated with a water balance and ranged from 0.1 % under a sprinkler in 2014 and 15 to 23 % in surface irrigation (Table 4). Although the deep percolation was negligible inn 2014, NO_3 leached was fairly significant that site-year (Table 3).

Table 1. Nitrogen balances of plant and soil as affected by N management in surface-irrigated cotton, Maricopa, AZ 2012

Nitrogen treatment	Fertilization mode	Fertilizer source	Fertilizer rate	Pre-plant soil NO_3 (0-36 in)	Irrigation N input	N minerali -zation	Plant N uptake	Post-plant soil NO_3 (0-36 in)	N Balance	Post-plant soil NO_3 (36-72 in)
			--- lb N/ac							---
Zero-N			0	29	15	72	116	51		34
Soil test-based N	Knife	Urea amm. Nitrate	132	15	15	72	149	74	11	112
Soil test-based N	Fertigate	Urea amm. Nitrate	132	42	15	72	147	58	56	61
Soil test-based N	Fertigate	Ammonium sulfate	132	20	15	72	155	45	39	59
Reflectance-based N	Knife	Urea amm. Nitrate	66	13	15	72	121	43	2	19
Reflectance-based N	Fertigate	Urea amm. Nitrate	66	14	15	72	126	43	-2	29

Table 2. Nitrogen balances of plant and soil as affected by N management in surface-irrigated cotton, Maricopa, AZ 2013

Nitrogen treatment	Fertilization mode	Fertilizer source	Fertilizer rate	Pre-plant soil NO_3 (0-36 in)	Irrigation N input	N minerali -zation	Plant N uptake	Post-plant soil NO_3 (0-36 in)	N Balance	Post-plant soil NO_3 (36-72 in)
			------------------------------	------------------------------	------------------------------	------------------------------	lb N/ac	------------------------------	------------------------------	------------------------------
Zero-N			0	51	15	42	108	30		8.5
Soil test-based N	Knife	Urea amm. Nitrate	106	74	15	42	156	73	8	63
Soil test-based N	Fertigate	Urea amm. Nitrate	106	58	15	42	142	82	-3	22
Soil test-based N	Fertigate	UAN+ Agrotain Plus	106	45	15	42	142	62	4	39
Reflectance-based N	Knife	Urea amm. Nitrate	53	43	15	42	143	26	-16	6.0
Reflectance-based N	Fertigate	Urea amm. Nitrate	53	43	15	42	131	34	-12	19

Table 3. Nitrogen balances of plant and soil as affected by N management in sprinkler-irrigated cotton, Maricopa, AZ 2014

Nitrogen treatment	Fertilization source	Fertilizer rate	Pre-plant soil NO_3 (0-36 in)	Irrigation N input	N minerali -zation	Plant N uptake	Post-plant soil NO_3 (0-36 in)	N Balance	Post-plant soil NO_3 (36-72 in)
		---------- lb N/ac ----------							
Zero-N		0	20	13	97	130	22		8.4
Soil test-based N	UAN	160	17	13	97	184	71	32	33
1.3*Soil test-based N	UAN	208	15	13	97	180	148	5	39
Soil test-based N	UAN + Agrotain Plus	160	17	13	97	169	95	23	33
Reflectance-based N-1	UAN	80	15	13	97	174	25	7	16
Reflectance-based N-2	UAN	104	20.5	13	97	172	49	14	28
Reflectance-based N-1	UAN + Agrotain Plus	80	20.5	13	97	170	31	10	16
Reflectance-based N-2	UAN + Agrotain Plus	104	17	13	97	163	34	34	21

Table 4. Water balances for N management studies in surface and in sprinkler-irrigated 'DP 1044 B2RF' cotton, Maricopa, AZ 2012-2014

Irrigation	Year	Root zone (cm)	ET	Rain	Irrigation	Change soil storage (0-1.7m)	Deep perc	Deep perc (% of irrigation)
			------------------------ cm -------------------------------					
Surface irrigation	2012	180	-82.3	9.5	83.4	-8.6	19.2	23
Surface irrigation	2013	180	-76.0	1.3	80.8	-5.7	11.9	15
Sprinkler	2014	180	-86.7	8.5	72.0	-6.3	0.1	0.1

SUMMARY

Nitrogen balances from N management studies of two site-years of surface irrigation and one year of sprinkler irrigation, summed up fairly well. Leaching was the main N loss pathway, and was apparently higher in surface irrigation than under a sprinker.

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Program Chair
David Tarkalson
USDA - ARS
3793 N 3600 E
Kimberly, ID 83341
(208) 423-6503
David.tarkalson@ars.usda.gov

Coordinator
Phyllis Pates
International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
ppates@ipni.net