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NITROGEN MANAGEMENT FOR SUBSURFACE DRIP IRRIGATED COTTON

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Summary

In subsurface drip irrigation (SDI) systems water constraints to cotton production are greatly minimized, and nitrogen management becomes the main priority. Injecting N fertilizer into SDI systems should in theory be as efficient as the irrigation delivery system itself is. However, previous research by the Texas A&M University – Texas Agric. Exp., Stn. Soil Fertility Program at Lubbock, TX has indicated that plant uptake of N fertilizer in SDI cotton is < 50 % of injected N. This research aims to improve N fertilizer management in SDI cotton. We tested two fluid N fertilizer sources: urea ammonium nitrate (UAN) vis a vis UAN plus ammonium thiosulfate (ATS). The ATS source theoretically acts as an N stabilizer against nitrification and denitrification losses. We also tested ways to fine-tune the timing of N fertigation by comparing UAN injection from 20 June to 22 July with UAN injection from 20 June to 12 August. Finally, we tested spectral reflectance-based timing of N fertigation from 20 June to 12 August. Our results showed that lint yields with UAN plus ATS did not differ from UAN alone. Timing of N fertilizer injection also did not affect lint yields. Lint yield with the reflectance-based treatment was not significantly different from yields with the other N-fertilized treatments. The most encouraging result of this study was the savings of 25 lb N/ac that was realized with the reflectance-based treatment (N rate was 65 lb N/ac) relative to the other N-fertilized treatments, which received 90 lb N/ac.

Introduction

Water and nitrogen are the first and second constraints to cotton production in the arid southwestern U.S, respectively (Morrow and Krieg, 1990). Subsurface drip irrigation (SDI) area in cottonland is relatively small at present in West Texas (250,000 ac., Jim Bordovsky, personal communication) but is expanding at a rapid rate. Efficiency of water application to cotton in SDI systems > 90 % (Bordovsky and Lyle, 1998). However, N management research for cotton in SDI has not kept up with the water management research. The main problem we address in this research is low N use efficiency in SDI cotton systems. Chua et al. (2003) reported that less than 50 % of the N fertilizer injected into a SDI cotton system in Lubbock, TX was recovered in the plant. Denitrification was cited as the main mechanism for this loss. Improving N fertilizer use efficiency would allow lower rates of N fertilizer to be used by producers without hurting lint yields. The reduced costs of improving efficiency of inputs such as fertilizer would help keep cotton farmers competitive in the world market place. The fate of fertilizer not taken up by cotton plants include emission of nitrous oxide, a greenhouse gas. Additionally, residual nitrate (NO_3) can be leached to groundwater and impact water quality. The environment of the West Texas Region is thereby protected when N fertilizer use efficiency is improved.

Previous research conducted in this area has indicated that improving the timing of N fertilizer injections in SDI cotton systems can save up to 60 lb N/ac, without hurting yields (Bronson et al., 2003; Chua et al., 2003). Assuming $0.30/lb N fertilizer and 250,000 ac of SDI cotton in West Texas; this represents potential savings of $4.5 million dollars for the cotton producers of our region.

Timing of N application is an important management tool that can result in improved N use efficiency in cotton. Norton and Silvertooth (1998) reported reduction in N fertilizer needed and increased N use efficiency if pre-plant N was avoided in irrigated cotton in Arizona. Based on that research, the Cooperative Extension of the University of Arizona states that the main window for N applications to cotton is centered at peak bloom or about 2200 heat units (base 60^{o}F). The rate of N uptake at peak bloom is apparently maximum in cotton (Silvertooth, 2001). In our previous work, we observed that modifying the timing of in-season N applications by applying N when chlorophyll meter readings were low, resulted in reduced N fertilizer applications and reduced residual soil NO_3^--N (Chua et al., 2003). However, more research is needed on improving the timing of N fertilizer injections to SDI cotton. The main researchable issue on timing is not when to commence N injections (this should be at the same time irrigation starts, at first square in mid-late June), but when to terminate the injections for the season. The window for this is probably some-where between first bloom and peak bloom. At this point, the plant has taken up all the N it requires and it will remobilize N into the developing cotton seed.

Using ammonium thiosulfate (ATS) with urea ammonium nitrate solution (28-0-0-5) as the N source instead of urea ammonium nitrate (32-0-0) alone may reduce the denitrification losses cited above and improve N fertilizer use-efficiency. This is because ATS is a nitrification inhibitor (Goos and Johnson, 1992; Goos and Johnson, 1999) and can prevent nitrification (an oxidation reaction) of NH_4, the first product of urea hydrolysis. Ammonium would theoretically be the dominant source of N that the cotton would take up. If little inorganic N is in the NO_3 form, then denitrification should be minimized.

The objectives of this study were:

1. To assess lint yields and N fertilizer use efficiency of N fertilizer urea ammonium nitrate (UAN) (32-0-0) injected into a SDI cotton system between: first square and early bloom, and first square and peak bloom.
2. To assess lint yields and N fertilizer use efficiency of the two N fertilizer sources: UAN (32-0-0) and UAN plus ammonium thiosulfate (28-0-0-5)
3. To assess lint yields and N fertilizer use efficiency of canopy reflectance-based N management of UAN (32-0-0) compared to soil test-based UAN, both injected up to peak bloom.

Materials and Methods

The study was conducted at the Texas A&M Research and Extension Center farm near Lubbock, TX on an Acuff sandy clay loam (fine-loamy, mixed, superactive, thermic, Aridic Paleustoll). Water flowed daily after first square at a rate of 1 L min^{-1} at 0.08 MPa. Drip tape was in the center of every other furrow at a depth of 12 in. Fiber Max '989' was planted on 13 May and harvested 2 November.

The experimental design was a randomized complete block design, one-way factorial with three replications or blocks. Blocks consisted of 40, 40-in. rows that were 600 feet long. Each block was divided into five, 8-row plots that were randomly assigned to the five N-fertilized treatments:
-28-0-05 injected up to early bloom
-28-0-05 injected up to peak bloom
-32-0-0 injected up to early bloom
-32-0-0 injected up to peak bloom
-32-0-0 injected up to peak bloom, spectral-reflectance based
-An un-replicated, zero-N plot was in block two.

Each 8-row plot has its own irrigation and fertilizer injection station. Nitrogen fertilizer rate was based on a N requirement for a 2 .5 bale/ac yield, which, according to Zhang et al. (1998) is 150 lb N/ac. The amount of NO_3-N extracted in initial, spring 2005 0.1-acre grid soil samples from 0-24 inches (average 8 lb N/ac), 22 lb starter-N (ammonium polyphosphate), and estimated 30 lb N/ac in irrigation water (14 inches of irrigation with 8 ppm NO3-N water was anticipated) was subtracted from the 150 lb N/ac requirement to give a growing season N fertilizer requirement to be injected of 90 N/ac (Table 1). Nitrogen fertilizer was injected into the SDI system daily, between 20 June and terminated at either 22 July (early bloom) or 12 August (peak bloom). In the reflectance-based treatments, the N injection was set at 50 % of the rate of the N-fertilizer treatments that received 90 lb N/ac. Every week canopy reflectance measurements were made with a CropScan MSR16 spectroradiometer at 48 inches above the canopy. Green vegetative index (GVI) was calculated as reflectance at 820 nm/reflectance at 550 nm. When the GVI in the reflectance-based treatments fell significantly below the GVI in the 32-0-0 to peak bloom treatment, the

N injection rate was to be increased. Plant samples were taken on 14 July and on 4 August for biomass and leaf and stem N analysis. Soil samples were also taken at these times from 0-9 inches above the drip tape and analyzed for NH_4 and NO_3. Total irrigation applied in the growing season of 2005 was 10.4 inches, which provided 23 lb N/ac. Therefore, our total N supply on the timing and N-source plots was 142-143 lb N/ac (Table 1). Sulfuric acid (25 % H_2SO_4) was injected continuously to lower the pH of the well water from pH 7.7 to pH 6.8, and prevent precipitate formation and clogging of emitters.

Results and Discussion

Early squaring biomass and lint yields were very high in 2005 (Table 2). Lint yields averaged 1846 lb/ac for the four N source and timing treatments (Table 3). This 3.8 bale/ac yield greatly exceeded our 2.5 bale/ac yield goal. This was due to the above average rainfall and cool temperatures in the 2005 growing season and the lack of damaging insect pressure. The N supply was slightly less than our target, but we did not consider N mineralization from soil organic matter, which could have contributed another 50 lb N/ac (Chua et al., 2003).

Table 1. Spring soil NO_3 contents, N fertilizer amounts injected, and N supplied in irrigation water, Lubbock, TX, 2005

N source	N timing	Spring soil NO_3[1]	Starter N fertilizer	N fertilizer injected	Well water-NO_3	Total N supply
		-----------------	-----------------	lb N/ac	-----------------	-----------------
28-0-0-5	Early bloom[2]	8	22	90	23	143
28-0-0-5	Peak bloom[3]	7	22	90	23	142
32-0-0	Early bloom[2]	8	22	90	23	143
32-0-0	Peak bloom[3]	8	22	90	23	143
32-0-0	Reflectance-based[3]	7	22	65	23	117
Zero-N	N/A	7	22	0	23	52

[1] 0-24 inches
[2] Injected from 20 June to 22 July
[3] Injected from 20 June to 12 Aug

Table 2. Mid bloom biomass, leaf N, green vegetative index, chlorophyll meter readings as affected by nitrogen management, Lubbock, TX, 2005.

N source	N timing	N fertilizer injected	Green veg. index	Chlor. meter	Leaf N	Biomass
					%	lb/ac
28-0-0-5	Early bloom[1]	90	8.7 a	42.8 a	3.5 b	4548 a
28-0-0-5	Peak bloom[2]	90	8.5 a	41.5 ab	3.6 ab	5810 a
32-0-0	Early bloom[1]	90	8.5 a	42.6 a	3.5 b	6204 a

32-0-0	Peak bloom[2]	90	8.8 a	41.0 b	3.7 a	6609 a
32-0-0	Reflectance-based[2]	65	8.0 b	40.4 b	3.3 c	5695 a
Zero-N	N/A	0	6.4 c	38.9 c	2.9 d	5786 a

[1] Injected from 20 June to 22 July
[2] Injected from 20 June to 12 Aug

Table 3. First open boll biomass, N accumulation, N fertilizer recovery efficiency, seed and lint yields as affected by nitrogen management, Lubbock, TX, 2005.

N source	N timing	N fertilizer injected	Total N uptake	Recovery efficiency	Biomass	Seed yield	Lint yield
		--------- lb N/ac ------		%	--------------- lb/ac ------------------		
28-0-0-5	Early bloom[1]	90	-	-	-	2611 a	1865 a
28-0-0-5	Peak bloom[2]	90	-	-	-	2598 a	1829 a
32-0-0	Early bloom[1]	90	-	-	-	2629 a	1879 a
32-0-0	Peak bloom[2]	90	160 a	63 a	9647 a	2549 a	1812 a
32-0-0	Reflectance-based[2]	65	143 a	62 a	9164 a	2511 a	1817 a
Zero-N	N/A	0	103 b	-	8047 b	2072 b	1620 b

[1] Injected from 20 June to 22 July
[2] Injected from 20 June to 12 Aug

At mid bloom, biomass did not differ among the treatments (Table 2). Chlorophyll meter readings were lower with zero-N than with all N-fertilized plots (Table 2). Green vegetative index and leaf N in the reflectance-based treatment was lower than the other N-fertilized treatments. This prompted us to increase the rate of N fertilizer injection in the reflectance-based treatment between 3 and 12 August.

Recovery efficiency of injected fertilizer N was calculated by the difference method and was 62-63 % for the 32-0-0 to peak bloom and reflectance-based treatments (Table 3). This is greater than the < 50 % N recovery reported by Chua et al. 2003 for SDI cotton at this same site. Greater recovery of injected N in our current study was achieved with near daily N injections, in contrast to the infrequent, 30 lb N/ac injections into the SDI system of Chua et al. (2003).

Our results showed that lint yields with UAN plus ATS did not differ from UAN alone. Timing of N fertilizer injection also did not affect lint yields. Lint yield with the reflectance-based treatment was not significantly different from yields with the other N-fertilized treatments. A savings of 25 lb N/ac was realized with the reflectance-based treatment (N rate of 65 lb N/ac) relative to the other N-fertilized treatments, which received 90 lb N/ac.

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