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Reflectance-based Nitrogen Fertilizer Management for Irrigated Cotton

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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 currently estimated at 300,000 ac, and is growing (Jim Bordovsky, personal communication). Efficiency of water application to cotton in SDI systems is about 90 % (Bordovsky and Lyle, 1998). However, N management research for cotton in SDI has not kept up with the water management research. 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. 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.

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). Previous research conducted in this area has indicated that improving the timing of N fertilizer injections in SDI cotton systems based on canopy reflectance assessments of in-season N status can save up to 90 lb N/ac, without hurting yields (Bronson et al., 2003; Chua et al., 2003). We also observed in earlier work 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 basing the timing and rates of N fertilizer injections to SDI cotton on spectral reflectance. In the previous work (Chua et al., 2003), our SDI system was not set up for fertigation treatments, but our existing, present SDI system is. In addition to reflectance treatments and their associate reference treatments (i.e. 1.5 * soil test treatment), we added a low, 0.5 * soil test treatment N rate to provide more information on a wide range of N fertilizer inputs.

The objectives of this study were:

1. To assess lint yields and N fertilizer use efficiency with two spectral reflectance based N management strategies compared to soil test-based N management in a SDI cotton system.
2. To assess lint yields and N fertilizer use efficiency of N fertilizer injected into a SDI cotton system at three fixed N rates between early square and mid bloom.

Materials and Methods

The 4-yr study was carried out at the Texas A&M AgriLife Research and Extension Center farm near Lubbock, TX on an Acuff sandy clay loam (fine-loamy, mixed, superactive, thermic, Aridic Paleustoll) (Bronson et al., 2011). Drip tape was in the center of every other furrow at a depth of 12 in. and water flowed at a rate of 1 qt min^{-1} at 15 psi. Irrigations of 0.20 inch were applied on 54 days between emergence and first open boll. All-Tex Apex

B2RF cotton in early June in 2007, and early May in 2008 and 2009. In 2009, FiberMax 9180 and Stoneville 5448 were planted in early May in a randomized block design. Harvest was in October each year. In 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:

N	N rate	Other details
1	0.5 X soil test	Soil test algor = 120 lb N/ac – 2 ft NO_3 – irrig. water
2	1.0 X soil test	Soil test algor = 120 lb N/ac – 2 ft NO_3 – irrig. water
3	1.5 X soil test	Soil test algor = 120 lb N/ac – 2 ft NO_3 – irrig. water
4	Reflectance based	Starts out at 0.5 X, referenced to 1.0X
5	Reflectance based	Starts out at 1.0 X, referenced to 1.5X
6	Zero-N	1 replicate/station only 2007-2009, two reps in 2010

In 2010, the N treatment plots were reduced to 1.0 X soil test, reflectance-1, and zero-N, each for the two cultivars. Each 8-row plot has its own irrigation and fertilizer injection station. Nitrogen fertilizer rate was based on an N requirement for a 2.5 bale/ac yield, which, according to Yabaji et al. (2007) is 125 lb N/ac. The amount of NO_3-N extracted in initial, spring 2007 0.1-acre grid soil samples from 0-24 inches (average 20 lb N/ac), and estimated 20 lb N/ac in irrigation water (12 inches of irrigation with 8 ppm NO_3-N water was anticipated) was subtracted from the 125 lb N/ac requirement to give a growing season N fertilizer requirement to be injected of 80 N/ac for 2007 (Table 1). Nitrogen fertilizer was injected into the SDI system five days a week, between early square and mid bloom. In the reflectance-based strategy 1 treatment, the N injection was initially set to the 0.5*soil test treatment, and in the reflectance-based strategy 2 treatment, the N injection was initially set equal to rate of the soil test treatment N-fertilizer. Every week canopy reflectance measurements were made with a CropCircle radiometer (Holland Scientific Inc., Lincoln, NE) at 40 inches above the canopy on one row per plot. Normalized difference vegetative index (NDVI) was calculated as:

(Reflectance at 880 nm-Reflectance at 590 nm)/(Reflectance at 880 nm+Reflectance at 590 nm)

When the NDVI in the reflectance-based strategy 1 treatments fell significantly below the NDVI in the soil test based management treatment, the N injection rate was increased to the soil test treatment N injection rate. When the NDVI in the reflectance-based strategy 2 treatments fell significantly below the NDVI in the 1.5 * soil test based management treatment, the N injection rate was increased to the 1.5 * soil test treatment N rate. 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 precipitation of calcium carbonate and clogging of emitters.

Results and Discussion

Lint yields for the four years exceeded our 2.5 bal/ac yield goal (Tables 1-4). Reflectance strategy 1 resulted in 16 to 50 lb N/ac less N fertilizer injection rates than the soil test-based management. This represents 23 to 50 % savings in N fertilizer. Lint and seed yields did not differ between reflectance and soil test N management treatments. Reflectance strategy-2 resulted 10 lb N/ac more than the soil test treatment, in 2007 only, with no yield benefit. Therefore, after three years of testing reflectance-2 strategy, we abandoned, starting in 2010. 2010 was the first year in which we tested reflectance strategy-1 for two cultivars in one study. Averaged across N treatments, lint and seed yields were significantly higher with ST5458 vs. FM 9180. Never-the-less, the N-fertilizer saving strategy of reflectance-1 saved substantial N (50 lb N/ac) for both cultivars, without hurting yields (i.e. lint and seed yields were similar between soil test-based and reflectance-strategy-1). Recovery efficiency of injected N fertilizer was variable, but high, ranging from 47 to 101 %.

Table 1. First open boll biomass, N accumulation, N fertilizer recovery efficiency, seed and lint yields as affected by nitrogen management, Lubbock, TX, 2007 (adapted from Bronson et al. 2011).

N treatment	N fertilizer injected[1]	Total N uptake	Recovery efficiency	Biomass	Seed yield	Lint yield
	--------- lb N/ac -----		%	--------------- lb/ac ------------------		
1.5*Soil test-based	120	-	-	-	2379 a	1347 a
Reflectance strategy 2	90	131 a	62 a	7666 a	2253 a	1330 a
Soil test-based	80	128 a	65 a	7704 a	2241 a	1326 a
Reflectance strategy 1	62	120 a	72 a	7561 a	2350 a	1372 a
0.5*Soil test-based	40	-	-	-	2270 a	1365 a
Zero-N	0	76 b	-	5362 b	1692 b	1062 b

[1] Injected from 11 July to 11 August

Table 2. First open boll biomass, N accumulation, N fertilizer recovery efficiency, seed and lint yields as affected by nitrogen management, Lubbock, TX, 2008 (adapted from Bronson et al. 2011).

N treatment	N fertilizer injected[1]	Total N uptake	Recovery efficiency	Biomass	Seed yield	Lint yield
	--------- lb N/ac -----		%	--------------- lb/ac ------------------		
1.5*Soil test-based	94	138 a	75 a	7993 a	2553 a	1532 a
Reflectance strategy 2	62	-	-	-	2572 a	1586 a
Soil test-based	62	130 a	101 a	7546 a	2455 a	1495 a
Reflectance strategy 1	46	110 b	94 a	6587 b	2542 a	1538 a
0.5*Soil test-based	31	-	-	-	2129 b	1283 b
Zero-N	0	67	-	4968	1640	1006

[1] Injected from 26 June to 16 July and 5 to 8 August

Table 3. First open boll biomass, N accumulation, N fertilizer recovery efficiency, seed and lint yields as affected by nitrogen management, Lubbock, TX, 2009 (adapted from Bronson et al. 2011).

N treatment	N fertilizer injected[1]	Total N uptake	Recovery efficiency	Biomass	Seed yield	Lint yield
	--------- lb N/ac -----		%	--------------- lb/ac ------------------		
1.5*Soil test-based	72	124 a	47 a	7761 a	2526 a	1527 a
Reflectance strategy 2	48	-	-	-	2487 a	1509 a
Soil test-based	48	114 a	49 a	7670 a	2471 a	1522 a
Reflectance strategy 1	24	109 b	77 a	8058 a	2581 a	1610 a
0.5*Soil test-based	24	-	-	-	2326 b	1487 a
Zero-N	0	90	-	6962	2029	1336

[1] Injected from 26 June to 16 July and 5 to 8 August

Table 4. First open boll biomass, N accumulation, N fertilizer recovery efficiency, seed and lint yields as affected by cultivar and nitrogen management, Lubbock, TX, 2010.

Cultivar	N treatment	N fertilizer injected[1]	Total N uptake	Recovery efficiency	Biomass	Seed yield	Lint yield
		--------- lb N/ac -----		%	-------------- lb/ac ----------------		
FM9180	Soil test-based	89	107 a	60 a	7351 a	2507 a	1435 ab
ST5458	Soil test-based	89	95 a	48 a	7406 a	2426 a	1602 a
FM9180	Reflectance strategy 1	44	-	-	-	2306 a	1351 b
ST5458	Reflectance strategy 1	44	-	-	-	2296 a	1513 ab
FM9180	Zero-N	0	54 b	-	5212 b	1651 b	1001 c
ST5458	Zero-N	0	52 b	-	5345 b	1708 b	1165 bc

[1] Injected from 26 June to 16 July and 5 to 8 August

Conclusion

- Reflectance-based N management strategy1 saved 22, 26, 50, and 51 % N compared to soil test based management during 2007, 2008, 2009, and 2010 respectively.
- Recovery efficiency of daily injection of N between early square and mid bloom was 47 to 101 %.

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