NITROGEN FERTILITY MANAGEMENT FOR IRRIGATED AND RAIN-FED COTTON PRODUCTION IN THE MID-SOUTH

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Abstract

Much time and energy has been expended in determining economic fertility management for cotton in the Mid-South. Producers continue to look for ways to enhance production while decreasing the costs of inputs. In more recent years, research emphasis has been directed toward alternative strategies for managing fertilizer N and/or mechanisms for enhancing nutrient uptake. Coated materials have been developed that delay nitrogen (N) release or that can be used for carries of other nutrients along with N. Polymer coatings have been used in certain regions of the country to control N release but are still limited by interactions with the environment. Multi-year field studies have been underway for several years at the Delta Research and Extension Center (irrigated) and at the Tribbett Satellite Farm (rain-fed) to investigate cotton production as influenced by N rates and alternative N management strategies. The studies are replicated field trials with 4-5 replications of treatments arranged in randomized complete block designs. Seedcotton and lint yields have been calculated based on machine-picked data and sub-samples to determine lint percent and lint yield. In the most recent studies at each location, N rates have been reduced and the research with ESN (Environmentally Smart Nitrogen, polymer-coated product) has been expanded to look at combinations of readily available N and delayed-released material. Lint yields are more variable, as expected, under rain-fed conditions but can often be profitable where grain crops would not be without supplemental irrigation.

Introduction

Managing nitrogen (N) for cotton continues to be a key focal topic for many research programs across the country and particularly in the Mid-south. Because cotton is a perennial crop grown as an annual, it offers unique challenges to growers. While most crops respond to increasing nitrogen (N), they are not usually adversely affected by too much N. However, cotton yields can be decreased with too much N or other factors that shift the plant from reproductive growth back to vegetative growth. This shifts the energy sink from lint and seed to stalks, stems, and leaves. Nitrogen, along with planting seed and technology fees, continue as the more costly inputs for cotton production. For the perennial, cotton, N management has been complicated. Perennial plants often adjust growth and development based on the environment and micro-climate and may or may not produce fruit. Environmental stresses during reproductive growth can and often does result in fruit shed. The sudden loss of fruit causes the plant to shift back to vegetative growth. Annual plants shift from vegetative growth to reproductive growth and exert all energy to producing the next generation. Most of the recent work with respect to N has dealt with fertilizer use efficiency. Efforts continue to gain the most economical yield with the least cost of inputs. Nitrogen management can be quite varied, especially with respect to N applications. Application systems often spread the applications from prior to planting through blooming and even beyond. The most desirable timing of application allows for maximum uptake with the least loss to the environment or to other non-target species such as weeds. Phosphorus (P) and potassium (K) application timing is not as critical as these nutrients are not as mobile. Fall applications are often the desired timing and allows the nutrients to stabilize in the soil solution.

Many input factors are specific for varying soils, climate, crop, and management systems and can now even be varied on the move (variable rate technology). All have a significant impact on fertilizer management and should always be considered when selecting fertilizer Best Management Practices (BMP's). Getting nutrients into plants as close to the time they are needed leads to the most efficient use of nutrients whether coming from organic or inorganic sources. The plants themselves do not distinguish between nutrient sources. However, some crops can preferentially take up certain forms while others, through a symbiotic relationship with bacteria, get most of their N from the atmosphere. Many products continue to be developed and brought to the marketplace with claims of increased nutrient use efficiency, reduced nutrient loss, nutrient stabilizers, or various other mechanisms to reduce nutrient loss or enhanced nutrient uptake. Not always are the mechanisms of activity evident from the literature provided by the manufacturer marketer. In recent years products have been introduced to reduce ammonia volatilization, nitrification, denitrification or even some combinations that involve more than one mechanism. One of the newer materials on the market is a polymer-coated product, ESN® (Environmentally Smart Nitrogen) developed by Agrium Advanced Technologies, Inc. This product has being evaluated along with other N sources, urea (U, 46% N) and urea-ammonium nitrate (UAN) solution (32% N) under dryland (rain-fed) and irrigated conditions and on different soil types. The product ESN® is a urea granule within a micro-thin polymer coating. The coating allows water within the soil to move into the granule and dissolve the urea inside. The urea solution then moves out through the coating into the soil where it becomes available to the growing crop. Another product included in the original studies has been Agrotain® (N-*(n-Butyl*) thiophosphoric triamide (NBPT) from Koch Agronomic Services. This NBPT product has been touted as the world's leading urease inhibitor and is meant to reduce ammonia volatilization when coated on urea granules. Other companies have similar materials but generally the same active ingredient. NutriSphere-N® (Specialty Fertilizer Products, Leawood, KS, now owned by Verdesian Life Sciences) has also been included. The product is spray-coated onto granular urea or mixed with UAN solution to enhance nutrient uptake. The objectives of the research studies was to examine these products at varying N rates under both irrigated and rain-fed conditions in the Mississippi Delta.

Methods and Materials

Multi-year field studies were initiated at the Delta Research and Extension Center (DREC, irrigated) and Tribbett Satellite Farm (TSF, rain-fed) to evaluate nitrogen management for cotton in the Mid-South. The DREC location has been maintained as a corn/cotton rotation while TSF has been maintained as continuous cotton. Initial studies were designed to evaluate multiple N rates and different N sources or amendments. Nitrogen rates were 90, 120, and 150 lb N/acre applied as a split application of urea (U) and urea-ammonium nitrate solution (UAN) and a single application of ESN. After the first year, Agrotain-treated urea was included in the evaluation. In 2013, the NutriSphere-N treatments were discontinued and replaced with an ESN+UAN or ESN+U combination with these system applied just after planting. The high rate (150 lb N/acre) was removed in 2014 and a 60 lb N/acre low rate was included. For the split applications, 60 lb N/acre was applied just after emergence with the remaining N applied as a sidedress application (to establish rates) at the pin-head square growth stage (PHS). For the ESN+UAN and ESN+U systems, a uniform rate of either UAN or U (30 lb N/acre) was applied along with the remainder of each rate applied as ESN. All cultural practices were maintained uniformly through the season. The rain-fed (non-irrigated) study was located at the Tribbett Satellite Farm (TSF) on a Dundee-Forestdale silty clay loam with some Dowling soil intermingled. The experimental design was a factorial arrangement of treatment in a randomized complete block (RCB) design with five replications and grown as a continuous cotton system. The first study was initiated in 2010 and continued through 2013. The irrigated site was established in 2011 at the Delta Research and Extension Center (DREC) on a Dubbs silt loam. Since the irrigated study is rotated with corn, the study location varies from year to year and was located on a Newellton silty clay in 2012, 2014 and 2016 and back to the Dubbs in 2013 and 2015. Treatments were arranged in an RCB design with four replications. All granular treatments at each location were hand-applied, pre-weighed and broadcast applied after emergence. Each plot was harvested with a commercial spindle picker adapted for individual plot harvest. Grab-samples were taken at the time of harvest and ginned through a 10-saw micro-gin to determine the lint percent and subsequent lint yields. All data were then analyzed with the Statistical Analysis System (SAS Institute, Cary, NC) utilizing Analysis of Variance (ANOVA) with mean separation by Fisher's Protected Least Significant Difference. Previous research has shown a decrease in lint percentage as N rates increase so only lint yields will be discussed in the results section.

Results and Discussion

Tribbett Satellite Farm (2010-2013)

The first study at TSF was initiated in 2010 under rain-fed (non-irrigated) growing condition. Lint yields were not significantly increased with increasing N rates and had no significant effect due to the varying N source or combination of N source and/or enhancer (Table 1). Lint yields ranged from 1170 to 1218 lb/acre across the different sources. In 2011, lint yields ranged from 592 to 643 lb/acre and again no significant difference. A new system, urea+Agrotain, was added in 2011 but showed no differences. As with the previous year, there was no N rate response. In 2012, lint yields were more than two times what they had been in 2011 and ranged from 1350 to 1398 lb lint/acre. Again there was no significant difference among the different sources when averaged across N rates. In 2013, the U+NutriSphere-N (U+NS) and UAN+NutriSphere-N (UAN+NS) systems were replaced with ESN+UAN and ESN+U systems and continued in 2014, 2015, and 2016 only at lower N rates for the non-irrigated soil. The 2013 lint yields were even higher than the previous year ranging from 1396 to 1549 lb lint/acre. For both systems, 45 lb N/acre was applied to each plot as either U or UAN and the remaining N (45, 75, and 105 lb N/acre) was applied as ESN. The UAN was "knifed-in" while the U and ESN were surface-applied as a broadcast. Cultivation was then used to help with incorporation of the dry materials. Cotton lint yields in 2013 were much higher than those measured in 2012. Lint yields ranged from 1400 to 1605 lb/acre. The lower yields were associated with the UAN+ESN system with no explanation why this system was significantly lower than all others. There was a significant response to N in 2013 with the greatest lint yield measured with 150 lb N/acre. In previous years, with lower lint yields there had been no response to increasing N rates indicating that sufficient N was available at the lowest N rates. Following the 2013 growing season, a 60 lb N/acre N rate was included and the component of ESN reduced to 30 lb N/acre.

Table 1. Summary of cotton yields averaged across N rates under rain-fed conditions for various N sources and amendments. Tribbett Satellite Farm, Tribbett, MS

Nitrogen Source	Cotton Lint Yield, lb/acre			
(+ Amendment)	2010	2011	2012	2013*
UAN Solution	1213.1	611.3	1382.8	1549.1 a
Urea	1191.0	623.7	1397.5	1535.2 a
UAN + NutriSphere-N®	1218.2	598.6	1350.5	1396.0 b
Urea + NutriSphere-N®	1169.5	643.3	1354.3	1487.0 ab
Urea + Agrotain®	----	609.3	1383.1	1522.4 a
ESN®	1183.9	592.3	1355.3	1508.2 a
LSD (0.05)	76.5 ns	61.1 ns	73.9 ns	101.9 *

Delta Research and Extension Station (2011-2013)
An irrigated study with the treatments previously describe was initiated in 2011 on the Delta Research and Extension Center. Lint yields under the irrigated conditions and sandy loam soil were twice those measured at TSF under rain-fed conditions the same year. The lint yields (Table 2) with ESN and U+Agrotain (averaged across N rates) were about 4% lower than the other systems but that difference was not significant. Yields at the150 lb N/acre were about 6% lower than the 120 lb N/acre rate, again not significant. The 2012 lint yields ranged from 1497 to 1568 with no significant difference between the N sources when averaged across the three N rates. The only system that tended lower was the ESN and was only 2.6 to 4.5% lower than the range of the other sources. In 2012, there was again no response to increasing N rates indicating that 90 lb N/acre was at least sufficient for the yields produced under rain-fed conditions.

The DREC yields in 2013 were much more variable than in any previous year of the study. Lint yields ranged from 1480 to 1716 lb/acre when averaged across N rates (Table 2), and significantly different at the 5% level as determined by the Analysis of Variance ($LSD_{(0.05)}$ = 160 lb lint/acre). The lower yields were with ESN alone and with urea alone. The higher yields were with UAN and UAN+ESN. There was no significant N rate response on the sandy loam site (DREC) even with yields over 1600 lb lint/acre. Lint yields at DREC were averaged across years with the summary included in Table 2. Over the three years, under irrigated conditions, lint yields with 100% ESN were significantly lower than any of the other systems. This is probably related to the efficiency of split applications of nitrogen under irrigated conditions. The system allows for more timely N application and uptake. With this in mind changes were proposed for following research in order to better utilize ESN in the southern states. At both the rain-fed location (TSF) and the irrigated location (DREC), there had been little response to increasing N rates in either continuous cotton (TSF) or irrigated cotton (DREC).

Table 2. Cotton lint yields for irrigated cotton at the Delta Research and Extension Center, averaged across N rates for varying nitrogen sources with and without amendments.

Nitrogen Source	Cotton Lint Yield, lb/acre			
(+ Amendment)	2011	2012	2013	AVE
UAN Solution	1285.1	1552.5	1692.8 a	1510.1 a
Urea	1272.6	1537.3	1585.2 ab	1465.0 ab
UAN + NutriSphere-N®	1272.6	1565.8	1715.5 a	1518.0 a
Urea + NutriSphere-N®	1263.8	1567.8	1655.5 a	1495.7 a
Urea + Agrotain®	1211.6	1550.0	1641.0 a	1463.9 ab
ESN®	1222.8	1496.9	1479.9 b	1399.9 b
LSD (0.05)	101.4 ns	83.9 ns	160.3*	68.5**

*NOTE**: NutriSphere-N replaced in 2013 with UAN+ESN and Urea+ESN

Tribbett Satellite Farm (2014-2016)

In 2014, the high N rate was replaced with a 60 lb N/acre rate in each study along with a continuation fo the evaluation of ESN in combinations with urea or UAN solution. At the TSF (rain-fed) location, there was a significant N rate effect with the 60 lb N/acre rate yielding significantly lower lint yields, 1319.6 lb/acre compared to 1418.5 and 1459.2 lb lint/acre for the 90 and 120 lb N/acre rates. At this location, 2014 was the only year where an N response was observed. Lower yields (381 lb lint/acre averaged across N rates and N sources) were observed in 2014 at TSF compared to the previous year. Lint yields ranged from 978.3 to 1062.8 lb/acre but no significant difference was determined. The trend found ESN and ESN plus urea or UAN to be lower (Table 3). The 2016 average yields were back up compared to 2015 with and overall average of 1340.8 lb lint/acre (range from 1293.3 to 1365.9 lb/acre). Again in 2016, there was no significant impact from N rates or N sources and amendment (Table 3).

Delta Research and Extension Center (2014-2016)

Cotton lint yields from an evaluation of N sources and N rates under irrigated conditions at the Delta research and Extension Center are summarized in Table 4 with yields average across N rates. When averaged across the different N sources there was a significant response to increasing N rates in both 2015 and 2016. In 2015, there was no increase between 60 lb N/acre (939.3 lb lint/acre) and 90 lb N/acre (933.2 lb lint/acre). Adding an additional 30 lb N/acre above the 90 lb N/acre rate resulted in a significant increase and a yield of 1025.9 lb lint/acre. For 2016, the significant response was from 60 to 90 lb N/acre (1279.6 to 1346.3 lb lint/acre) with no additional yield at 120 lb N/acre. Cotton lint yields were significantly different depending on the N source or combination of sources. The 2014 yields ranged from 1454.0 to 1532.0 lb lint/acre with no significant difference. However, significant differences were evident in 2015 and 2016. Lint yields in 2015 were more than a bale lower than the average yield in 2014. The 2015 lint yields ranged from 887.2 to 1042.5 lb/acre with an overall field average of 966.2 lb lint/acre while that same average in 2014 was 1491.1 lb lint/acre. In 2015 the better yields were obtained with a combination of ESN and urea or UAN solution while the lowest yield was with UAN and ESN alone (Table 4). Lint yields in 2015 when averaged across all treatments was 1340.8 lb lint/acre and an increase of 38% over the 2015 yields. They were still lower than yields in 2014. While the UAN alone yields were the lowest in 2015, they were the highest in 2016 at 1388.3 lb lint/acre. The ESN yields were again at the low end in 2016. The data suggest a strong influence from rainfall and weather-related influence.

Table 3. Cotton lint yields from an evaluation of nitrogen sources and amendments at varying N rates. Tribbett Satellite Farm. Tribbett MS. Averaged across N rates. 2014-2016

Nitrogen Source	Cotton Lint Yield, lb/acre					
(+ Amendment)	2014		2015		2016	
UAN Solution	1362.7	b	1037.4		1348.2	
Urea	1428.6	ab	1055.6		1365.9	
UAN + ESN	1353.0	b	984.5		1352.5	
Urea + ESN	1436.7	ab	990.9		1325.3	
Urea + Agrotain®	1471.1	b	1062.8		1359.3	
ESN®	1343.6	ab	978.3		1293.3	
LSD (0.05)	95.6		94.5 ns		77.5 ns	
Prob. > F	0.0421		0.2836		0.2730	

Table 4. Cotton lint yields from an evaluation of nitrogen sources and amendments at varying N rates. Delta Research and Extension Center, Stoneville, MS. Averaged across N rates. 2014-2016

Nitrogen Source	Cotton Lint Yield, lb/acre					
(+ Amendment)	2014		2015		2016	
UAN Solution	1491.0		887.2	a	1388.3	a
Urea	1471.7		988.0	ab	1344.9	ab
UAN + ESN	1480.7		1042.5	a	1351.8	ab
Urea + ESN	1532.0		1014.1	a	1311.9	bc
Urea + Agrotain®	1520.3		974.1	ab	1355.4	ab
ESN®	1454.0		891.0	b	1246.7	c
LSD (0.05)	107.2 ns		115.4		69.1	
Prob. > F	0.6885		0.0432		0.0037	

Conclusions

While one source is the best in one year it may not be the best for another. Unfortunately, a producer is not be the best for another situation. These types of results illustrate the need to make educated decisions as to the best way to manage fertilizer N on the farm. By understanding the potential sources of loss for each N source and what an amendment bring to the table, one can best hedge their investment. Some of these products, such as NBPT, offer a cheap insurance to reduce potential N loss prior to plant uptake. Some of the products available include urease inhibitors, nitrification inhibitors, or actual combinations of the two. These are chemical in nature while products that include coatings can affect the rate of release. Most of these products, with specific pathways that can be defined and examined, offer potential should environmental conditions arise that could lead to potential N loss. Unfortunately, one does not know it the desired benefit can be obtained in a timely manner. For example, a urease inhibitor may be of no economic benefit if an incorporating rain occurs very shortly after surface application. If conditions do not favor a particular loss pathway, then interrupting that pathway does not provide an economic benefit.