EVALUATION OF NITROGEN MANAGEMENT WITH ESN-UREA-UAN COMBINATIONS FOR OPTIMUM IRRIGATED CONTINUOUS COTTON

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Abstract

Nitrogen (N) management (N rates X N sources) were evaluated over five years at the Delta Research and Extension Center near Stoneville, Mississippi. Nitrogen sources included combinations of Environmental Smart Nitrogen (ESN), urea (U) and urea-ammonium nitrate solution (UAN) applied as either 1) 100% ESN, 2) ESN [50%] + U [50%], 3) ESN [50%] + UAN [50%], 4) 100% U, or 5) 100% UAN. The sources were applied at rates of 60, 90, 120, and 150 lb N/acre shortly after seedling emergence. The dry material was broadcast-applied and incorporated with a cultivator and the solution was band-applied with a coulter applicator to both sides of the bedded row. Yields data was collected over the 5-year duration of the study with lint yields determined from grad samples taken during the spindle picking of the center two rows. Lint yields were analyzed with an analysis of variance (SAS) with mean separation determine from Fisher's protected LSD. In most years, N source had no significant effect on lint yield while N rates did result in significant yield responses. The rates of 90-120 lb N/acre were found to be optimum which agreed with other research from the region. There were no significant year interactions so main effects were determined across years. The ESN yields were found to be lower when averaged across years, replications, and N rates. Adding 50% of the total N as either U or UAN solution to ESN did improve yields in most years. Results did vary some from year to year and were good compared to the state average. Scientists conclude that economics should be used to make the final decision on N source and N rate.

Introduction

Continuous cotton is an item from the past and is rarely observed in the Mississippi Delta. However, as grain prices decreased, the profitability of cotton has remained the same and some producers are venturing back into cotton production, even with the high cost of equipment. Soil fertility has been limiting many producers, especially those that have moved into grain production, as these crops ultimately removed nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) compared to cotton. While producers have gradually recognized the importance of N, P, K, and S, they have been reluctant to spend money on new technologies or loss prevention products. Nitrogen has been the nutrient of greatest concern for most growers, as it rarely makes it from one season to the next, if not utilized by the growing plants due to climate (rainfall and warm temperatures) leading to volatilization, nitrification, and denitrification.

Nitrogen (N) management studies have been underway in the Mississippi Delta since the experiment station was established in 1904. Various aspects of research have evaluated and based primarily on the 4R's of fertilization management and nutrient management stewardship. This axiom says "the **R**ights source (or product), applied at the **R**ight rate, at the **R**ight time, and in the **R**ight place." This framework insures the Fertilizer Best Management Practices (FBMP's) are developed with sound science and prove economical for row crops. Nitrogen sources have changed over the decades as some sources disappeared and others appeared. Organic sources are rarely used while others such as anhydrous ammonia (NH_3) and ammonium nitrate (NH_4NO_3) are not being used for various reasons. Anhydrous ammonia (applied as a gas) is still common in other regions of the country and applied in the fall after harvest. Ammonium nitrate was a common N source for wheat and other crops, but faded when misused as an oxidizer for explosives. With time, new products have been developed, such as sulfur coated urea (SCU) and polymer coated urea (PCU). The SCU was useful but far too expensive in commercial row crop production. Polymer coated products such as ESN (Environmentally Smart Nitrogen) are being evaluated all over North America for potential use in crops such as rice and cotton. This research project was designed to evaluate ESN, Urea (U), and Urea-Ammonium nitrate (UAN) solution, either alone or in combinations for optimum cotton production in the Mississippi Delta. For this study cotton has been grown continuously without a cover crop or crop rotation. The study was initiated in 2015 and continued through 2019. The objectives were to 1) evaluate nitrogen management strategies utilizing both N sources and N rates in continuous irrigated cotton; 2) determine the economic implications of N management strategies for optimum cotton production; and 3) develop recommendations for alternative N sources.

Methods and Materials

The study was conducted at the Delta Research and Extension Center located at Stoneville, Mississippi from 2015 through 2019. The soils in the research area consisted of a Bosket VF sandy loam (Mollic hapludalfs) and Commerce silty clay loam (Fluvaquentic Endoaquepts). The twenty treatments were arranged in a randomized complete block design with four replications. Plots consisted of four rows on 40-in centers, 85 feet in length. Lint yields were determined from the harvest of the two center rows of each plot with a sample collected at harvest and ginned through a 10-saw micro-gin to determine the lint percentage. The N management treatments were arranged in a 5x4 factorial of N source and N rate. The N sources were: 1) 100% Environmental Smart Nitrogen [ESN]; 2) 50% ESN + 50% Urea (U); 3) 50% ESN + 50% Urea-ammonium nitrate solution [UAN]; 4) 100% U; and 5) 100% UAN. The N rates were set up as 60, 90, 120, or 150 lb N/acre. All N fertilizer was applied shortly after seedling emergence with the dry materials broadcast-applied and incorporated with a cultivator between the rows and the solution was band-applied to both sides of the row with a coutler applicator. All plots across the study were uniformly maintained through the growing season to minimize the impact of, weeds, insects, and water. The area was defoliated and harvested with a commercial cotton spindle picker adapted to plat harvest with the ability to weigh at the end of each plot. Grad samples were collected at the time of harvest, weighed, dried, then re-weighed and ginned through a 10-saw micro-gin with no seedcotton or lint cleaning. Lint yields were calculated based on harvested seedcotton weight and lint percentage. Only lint yields are discussed as N rate often impacts the lint percentage and only lint is sold. The collected data was subjected to an analysis of variance (with alpha = 0.05) for each year and then a combined analysis across years.

Results and Discussion

Lint yields have been illustrated in Tables 1A through 1E for the twenty treatments in the study and for each year. The values in the Tables are means averaged across four replications each year. In 2015, the first year of the study, there was no significant treatment effect from any of the 20 treatments (Prob. > F = 0.1298 and calculated $LSD_{(0.05)}$ = 220.8 lb lint/acre). The lint yield ranged from 1094.0 lb/acre (ESN, 60 lb N/acre) to 1437.0 lb/acre (ESN+UAN, 150 lb N/acre. However, by definition with Fisher's protected LSD, LAD is only used if Prob. > F is less than 0.05.

Table 1A. Cotton lint yield as influenced by N rates and N sources for irrigated continuous cotton. DREC, Stoneville, Mississippi. (2015)

N Source	60 lb N/A	90 lb N/A	120 lb N/A	150 lb N/A
2015	------------------------ Lint Yield, lb/acre ------------------------			
ESN	1094.0	1263.5	1329.9	1302.3
ESN + Urea	1107.7	1323.3	1331.3	1260.9
ESN + UAN	1378.8	1125.1	1298.5	1437.0
Urea	1243.9	1196.0	1325.1	1341.8
UAN	1185.8	1391.1	1343.1	1297.2
Prob. > F	0.1298 ns			
$LSD_{(0.05)}$	220.8			

In 2016, the second year of continuous irrigated cotton, lint yields were similar to those measured in 2015. The values shown in Table 1B are again the mean of four replications of 85-ft, 4-row plots. Unlike 2015, there was a significant treatment effect (Prob. > F = 0.0333 and calculated $LSD_{(0.05)}$ = 291.7 lb lint/acre). The range in lint yields was from 774.1 (100% UAN, 60 lb N/acre) to 1394.4 lb lint/acre (ESN+UAN, 150 lb N/acre). The lowest yields in 2016 were the lowest of any year of the study. The lower yields are likely due to a heavy rainfall event that led to significant denitrification loss from the UAN plot. Having ESN or U out at the same time could have offset the detrimental effects of unexpected heavy rainfall and N losses. Main effects will be discussed later in the Results section but there was no significant difference between N sources in 2016.

The 2017 lint yields were lower than those from 2016 while overall average seedcotton yields were not lower. The average lint percentage in 2017 was 40.23 when averaged across 80 observations and 44.23 in 2016 averaged across a similar 80 observations. This again points to the need of using lint yields for comparisons rather than seedcotton

Table 1B. Cotton lint yield as influenced by N rates and N sources for irrigated continuous cotton. DREC, Stoneville, Mississippi. (2016)

N Source	60 lb N/A		90 lb N/A		120 lb N/A		150 lb N/A	
2016	----------------------- Lint Yield, lb/acre -----------------------							
ESN	1050.9	cd	1173.5	abc	1267.4	abc	1250.0	abc
ESN + Urea	1091.5	bc	1297.5	abc	1289.4	abc	1368.5	ab
ESN + UAN	1183.6	abc	1202.5	abc	1290.0	abc	1394.4	a
Urea	1248.4	abc	1197.6	abc	1274.7	abc	1352.7	ab
UAN	774.1	d	1420.5	a	1245.0	abc	1194.7	abc
Prob. > F	0.0333 *							
LSD (0.05)	291.7							

yields. The values shown in Table 1C are the mean of four replications of 85-ft, 4-row plots. There was a significant treatment effect (Prob. > F = 0.0018 and calculated LSD(0.05) = 137.8 lb lint/acre). The range in lint yields was from 898.8 (100% ESN, 60 lb N/acre) to 1247.1 lb lint/acre (100% U, 150 lb N/acre). The LSD was much lower in 2017 compared to the two previous years indicating less overall variability in the field compared to the previous two years. Overall lint yield for the field was down about 9% (100 lb lint/acre) compared to 2016. As mentioned earlier, seedcotton yields were up slightly in 2017, but overall lint yields were lower.

Table 1C. Cotton lint yield as influenced by N rates and N sources for irrigated continuous cotton. DREC, Stoneville, Mississippi. (2017)

N Source	60 lb N/A		90 lb N/A		120 lb N/A		150 lb N/A	
2017	----------------------- Lint Yield, lb/acre -----------------------							
ESN	898.8	f	1065.2	cde	1142.5	a-e	1173.6	a-d
ESN + Urea	1033.2	ef	1167.4	a-e	1206.4	ab	1079.5	b-e
ESN + UAN	1037.1	de	1207.7	ab	1190.4	abc	1188.3	abc
Urea	1145.2	a-e	1145.8	a-e	1142.4	a-e	1247.1	a
UAN	1048.5	de	1154.5	a-e	1153.0	a-e	1134.9	a-e
Prob. > F	0.0018 **							
LSD (0.05)	137.8							

The 2018 average lint yields were up by 21.4% (1369.3 compared to 1128.1 lb lint/acre), however, there was no significant difference between treatments. Lint yields ranged from 1251.1 lb/acre (ESN, 60 lb N/acre) to 1418.5 lb/acre (ESN+UAN, 150 lb N/acre) (Table 1D). There was no significant treatment effect from any of the 20 treatments (Prob. > F = 0.6452 and calculated LSD(0.05) = 132.3 lb lint/acre) and this occurred in a year with the lowest calculated LSD.

The 2019 growing season completed five years of research to evaluate ESN and both ESN+UAN and ESN+U for consideration in a cotton production system in Mississippi. The 2019 overall lint yield was intermediate to the previous four years with an overall lint yield of 1274.0 lb lint/acre. The lint range when averaged across four replications was 952.2 lb lint/acre to 1459.8 lb lint/acre. As in previous years, the lowest yield is with 100% ESN at 60 lb N/acre and the highest yields are with ESN+UAN at 150 lb N/acre. The analysis of variance showed a highly significant difference between treatments (Prob. > F = <0.0001 with a calculated LSD(0.05) = 222.3 lb lint/acre.

Table 1D. Cotton lint yield as influenced by N rates and N sources for irrigated continuous cotton. DREC, Stoneville, Mississippi. (2018)

N Source	60 lb N/A		90 lb N/A		120 lb N/A		150 lb N/A	
2018	----------------------Lint Yield, lb/acre ------------------------							
ESN	1251.1		1354.2		1402.7		1386.5	
ESN + Urea	1324.8		1381.3		1428.0		1386.2	
ESN + UAN	1362.1		1406.2		1362.9		1418.5	
Urea	1309.6		1376.2		1400.5		1373.2	
UAN	1305.8		1401.2		1375.5		1378.7	
Prob. > F	0.6452 ns							
LSD (0.05)	132.3							

Table 1E. Cotton lint yield as influenced by N rates and N sources for irrigated continuous cotton. DREC, Stoneville, Mississippi. (2019)

N Source	60 lb N/A		90 lb N/A		120 lb N/A		150 lb N/A	
2019	----------------------Lint Yield, lb/acre ------------------------							
ESN	952.2	f	1232.0	b-e	1308.6	a-d	1354.4	abc
ESN + Urea	1031.6	ef	1321.0	a-d	1418.7	ab	1440.2	ab
ESN + UAN	1145.4	c-f	1349.7	abc	1362.1	abc	1459.8	a
Urea	1118.0	def	1164.1	c-f	1239.8	a-e	1436.6	ab
UAN	1068.9	ef	1419.9	ab	1327.4	a-d	1330.4	a-d
Prob. > F	<0.0001 ***							
LSD (0.05)	222.3							

A combined analysis for all treatments across five years has been shown in Table 1F. There was not a significant year effect so main effects are shown for treatments averaged across replications and years (n=20). When adding years and replications without a significant interaction between years, the LSD(0.05) is much lower than any individual year (Prob. > F = <0.0001, LSD(0.05) = 92.2 lb lint/acre). Average lint yields ranged from 1049.4 lb lint/acre to 1379.6 lb lint/acre. While ESN+UAN at 150 lb N/acre was the highest numerical yield, it was not significantly better than 100% UAN at 90 lb N/acre. For this particular field, the normal N recommendation would be 110-120 lb N/A. In almost every case 60 lb N/acre was not sufficient for maintaining optimum yields (Table 1F). Since years were not found to be significantly different in this study based on a combined analysis of variance and there was no significant interaction between N source and N rate, main effects were determined.

Table 1F. Average cotton lint yield as influenced by N rates and N sources for irrigated continuous cotton. DREC, Stoneville, Mississippi. Five-year average (2015-2019)

N Source	60 lb N/A		90 lb N/A		120 lb N/A		150 lb N/A	
2015-2019	----------------------Lint Yield, lb/acre ------------------------							
ESN	1049.4	f	1217.7	e	1290.2	a-e	1293.4	a-e
ESN + Urea	1117.8	f	1298.1	a-e	1334.8	abc	1313.1	a-d
ESN + UAN	1221.4	de	1258.2	cde	1300.8	a-e	1379.6	a
Urea	1213.0	e	1214.8	e	1276.5	b-e	1350.3	abc
UAN	1076.6	f	1357.4	ab	1288.8	a-e	1267.2	b-e
Prob. > F	<0.0001 ***							
LSD (0.05)	92.2							

Table 2 provides a summary of the nitrogen sources averaged across N rates and replications (n=16) for individual years. When averaged across N rates, the only year where the was a significant source effect was 2017 and that was only if rounding the alpha level. The Table does show some trends but in most years the Prob. > F was above the 20% level. The nitrogen rate main effect (averaged across N source and replications, n=20) is also shown in Table 2. The N rate response was significant in each of the five years with the optimum N rate at 90-120 lb N/acre. In none of the five years was there ever an advantage to the highest N rate (150 lb N/acre). This agrees with much of the research conducted at the Delta Research and Extension Center over the last 40 years. Only in rare years is there ever a response to the higher rates even with higher than average yields. This observation would indicate that something other than N rate was a yield limiting factor. Since so many factors can be yield limiting, this is not surprising.

Table 2. Main effects for cotton lint yield as influence by N rates and N sources for irrigated continuous cotton. DREC, Stoneville, Mississippi. (2015-2019)

Factor	2015		2016		2017		2018		2019	
	------ lb lint cotton/acre ------									
Fertilizer N Source										
ESN	1247.4		1185.4		1070.0	B	1348.7		1211.8	
ESN + Urea	1263.3		1261.8		1121.6	ab	1380.1		1302.9	
ESN + UAN	1309.9		1267.6		1155.9	a	1387.4		1329.3	
Urea	1276.7		1266.8		1170.1	a	1364.9		1239.4	
UAN	1304.3		1158.6		1155.9	ab	1365.3		1286.6	
LSD (0.05)	110.4		145.8		68.9		66.2		111.2	
Prob. > F	0.7605 ns		0.4037 ns		0.0507 *		0.7969 ns		0.2214 ns	
Nitrogen Rate, lb/A										
60	1202.0	b	1069.7	b	1032.5	b	1310.7	b	1063.2	c
90	1259.8	ab	1257.1	a	1148.1	a	1383.8	a	1297.4	b
120	1325.6	a	1273.3	a	1164.7	a	1393.6	a	1331.3	ab
150	1333.9	a	1312.1	a	1166.9	a	1388.6	a	1404.3	a
LSD (0.05)	98.8		130.4		61.6		59.2		99.4	
Prob. > F	0.0321 *		0.0022 **		< 0.0001 ***		0.0204 *		< 0.0001***	

A final look in this study showed the main effects for seedcotton, lint percentage, an lint yield when averaged across years, replications and the other main effect (Table 3). Interestingly, when average across N rates, there is no N source effect on lint percentage, but both seedcotton and lint yield are lower with ESN followed by UAN. However, these are not different from each other. With respect to N rate averaged across years, replications and, N source, the analysis of variance showed significant difference for seedcotton, lint percentage, and lint yield. The optimum N rate, with respect to both seedcotton and lint yield, was 90 to 120 lb N/acre. Even though numerically 150 lb N/acre saw higher seedcotton and lint, the differences were not significant. As observed with numerous other studies, as N rate increased, lint percentage decreased.

Summary and Conclusions

After five years of continuous cotton, lint yields have remained good for the location of the study. Other studies at the Delta Research and Extension Center have shown significant yield response to corn/cotton rotation with some years reaching in excess of 50% advantage to the rotation. In other years, long-term rotations have seen years where the response is negative and has been related to July-August rainfall that caused more boll rot in cotton behind corn compared to cotton following cotton. In the Centennial Rotations (founded 2004) the response to rotation has averaged more than 20% per acre per year. In that study, there has been no negative rotation years. In the study of record, nitrogen response was evident in each year, but was not related to any particular N source. The 90 and 120 lb N/acre N rate continued to be the optimum N rate for continuous cotton. When cotton follows corn or fallow, producers should favor the lower side of N rates. The old adage that a little extra never hurts is usually not true for cotton that is raised as an annual but is a perennial by growth habit. Adding too much without a higher boll load usually results in uncontrolled vegetative growth and additional costs in an effort to control plant size.

When averaged across years and N rates, ESN did show lower yields compared to ESN+UAN or ESN+U indicating that the release rate of the polymer coated urea (PCU) is probably not right for cotton. With the added cost of polymer coating, the product is questionable for a recommended production practice for the area. Split the ESN with either UAN or U did improve cotton yields but was no better than either U or UAN alone. In order to determine whether ESN is an option, producers need to look at the cost of the product as well as the cost of application. The ESN has proven acceptable in other parts of the country on both wheat and potatoes.

Table 3. Main effects for seedcotton, lint percentage, and lint yield as influence by N rates and N sources for irrigated continuous cotton. DREC, Stoneville, Mississippi. (2015-2019)

5-Year Average	Seedcotton		Lint Percent		Lint	
	(lb/A)		(%)		(lb/A)	
Fertilizer N Source						
ESN	2867	b	42.3		1212.7	b
ESN + Urea	3005	a	42.2		1265.9	a
ESN + UAN	3056	a	42.2		1290.0	a
Urea	2984	a	42.4		1263.6	a
UAN	2955	ab	42.3		1247.5	ab
LSD (0.05)	102		0.3		68.9	
Prob. > F	0.0067 **		0.7030 ns		0.0197 *	
Nitrogen Rate, lb/A						
60	2662	c	42.7	a	1135.6	c
90	2997	b	42.3	b	1269.2	b
120	3080	ab	42.1	b	1298.2	ab
150	3154	a	41.9	c	1320.7	a
LSD (0.05)	92		0.3		41.2	
Prob. > F	< 0.0001 ***		< 0.0001 ***		< 0.0001 ***	