NITROGEN MANAGEMENT FOR COTTON GROWN IN A HIGH-RESIDUE COVER CROP CONSERVATION TILLAGE SYSTEM

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ABSTRACT

Over 70% of the cotton (*Gossypium hirsutum* L.) in the Tennessee Valley of northern Alabama is currently raised using conservation tillage techniques. High-residue small grain cover crops are becoming a common tool in these systems, but N immobilization may occur causing previous N recommendations to be obsolete. A replicated 3-year field study was initiated in 1999 in the Tennessee Valley of Alabama on a Decatur silt loam (clayey, kaolinitic, thermic Rhodic Paleudult) to test a factorial arrangement of N source (ammonium nitrate and urea-ammonium nitrate), N rates (0, 40, 80, 120, 160 lbs N acre^{-1}), N application timing (all at planting and 50-50 split between at planting and first square), and N application method (banded or broadcast) for cotton grown in a high-residue rye (*Secale cereale* L.) conservation system. Preliminary results suggest that 120 lbs N acre^{-1} may be needed to optimize yields (781 lbs lint acre^{-1} in 2000 and 1026 lbs lint acre^{-1} in 2001). Generally, highest yields were obtained when N was applied at planting (803 lbs lint acre^{-1} in 2000 and 957 lbs lint acre^{-1} in 2001). Ammonium nitrate applications resulted in greater yields when broadcast at planting while UAN applications resulted in greater yields when banded, regardless of application timing. At current prices for AN and UAN, the preliminary data suggest the most efficient and economical practice for cotton grown in high-residue conservation systems would be to apply 120 lbs N acre^{-1} as UAN in a banded application at planting.

KEYWORDS

Conservation tillage, cover crop, N source, N application, UAN, ammonium nitrate, N application method

INTRODUCTION

Nitrogen recommendations for cotton were developed for conventional tillage systems. For the most part, these recommendations were based upon N and C degraded soils as a result of tillage for extensive periods of time (Martens, 2001). The recommended rate of N for cotton in the Tennessee River Limestone Valley soils of northern Alabama ranges from 30 to 90 pounds N per acre (lbs N acre^{-1}), with 60 lbs N acre^{-1} used as an average (Mitchell *et al*, 1991; Monks and Patterson, 1996). Continuous cotton production, which has little crop residue, has caused soil degradation, erosion, and loss of organic matter in these soils (Schwab *et al*, 2002). Studies show that soil erosion from Alabama crop lands with conventional tillage can be as much as 10 tons per acre per year, which results in a soil loss of 0.10 inches per year. Alabama data suggests that soybean yield [*Glycine max* (L.) Merr.] could drop 35% within 20 to 30 years with this rate of soil loss (Monks and Patterson, 1996). A corresponding decrease in cotton production could seriously jeopardize the profitability of cotton production in Alabama.

Approximately 70% of the farmers in the Tennessee Valley region of Alabama currently use conservation tillage in cotton (Patterson, personal communication, 2002). The main two methods they use are planting into the old cotton stubble, or planting into a cereal cover crop. Planting into the cotton stalks is easier for plant establishment, but may increase compaction problems and reduces lint yield (Burmester *et al*, 1993; Raper *et al*, 2000; Schwab *et al*, 2002). Producers in the Tennessee Valley are increasingly using more high-residue cereal cover crops (>4,000 lbs residue acre^{-1}).

Bauer and Bradow (1993) state that rye offers many benefits as a cover, as it is easy to kill with herbicides, easy to establish, and provides intensive ground cover, even if planted late (Brown *et al*, 1985). Raper *et al* (2000) also found that a rye cover crop was the most critical factor in increasing yields of conservation tillage cotton on this soil type.

Integration of cover crop residue into production systems increases microbial activity and alters the amount and

IN E. van Santen (ed.) 2002. Making Conservation Tillage Conventional: Building a Future on 25 Years of Research. Proc. of 25th Annual Southern Conservation Tillage Conference for Sustainable Agriculture. Auburn, AL 24-26 June 2002. Special Report no. 1. Alabama Agric. Expt. Stn. and Auburn University, AL 36849. USA.

seasonality of available inorganic N, affecting N use efficiency (Jackson, 2000). Two common N sources, urea-ammonium nitrate liquid 32% N (UAN) and ammonium nitrate 34% N (AN) are used in cotton cropping systems. Urea-ammonium nitrate liquid 32% N is generally cheaper at $120 per ton ($0.188 per lb N) (Limestone Farmers Cooperative, personal communication, 2002), easy to handle and apply, does not require special equipment, and herbicides can be mixed with it during application. It has a few disadvantages as it can scorch plant foliage, salt out at low temperatures, and may become bulky to store (Alabama Certified Crop Advisor Program, 2002). Ammonium nitrate works well as a top-dressing but is more expensive at $195 per ton ($0.287 per lb N) (Limestone Farmers Cooperative, personal communication, 2002) and very hygroscopic so it may cause caking problems or present an explosion hazard. Research by Touchton and Hargrove (1982) showed that AN is more efficient than UAN in conservation tillage systems, as UAN may be more susceptible to the urease enzyme concentrated in crop residue, causing more N loss as ammonia to the atmosphere (Bovis and Touchton, 1998).

Nitrogen application method also influences crop N use efficiency. Touchton and Hargrove (1982) showed that banding UAN resulted in higher yields and N uptake in no-till corn (*Zea mays* L.), when compared to broadcast treatments. Another study by Johnston and Fowler (1991) found that dribble banded UAN showed higher responses to yield than broadcast UAN in no-till wheat (*Triticum aestivum* L.). However, a study by Bell *et al* (1998) showed that banded and broadcast N-P-K fertilizer resulted in similar cotton yields.

Nitrogen application timing also affects cotton N use efficiency. The peak time that N is needed is mid-bloom through boll set (Monks and Patterson, 1996). Mullins and Burmester (1990) found that most nutrient accumulation occurs 63 to 98 days after planting, with leaf N concentrations decreasing as the season progresses. Monks and Patterson (1996) stated that only half of N should be applied at planting, with the remainder prior to first bloom. A study by Ebelhar *et al* (1996) showed a significant increase in cotton yield when N was 50-50 split at planting and pinhead square formation. However, research by Howard *et al* (2001) showed that splitting UAN, 50% at planting and 50% six weeks later, resulted in higher yields in only one of eight years.

It is likely that high-residue conservation tillage techniques will initially require higher N rates due to immobilization of N and loss from ammonia (NH_3) volatilization. Monks and Patterson (1996) expect total fertilizer N rates to be increased from 60 lbs acre^{-1} to 90 lbs acre^{-1} in the Tennessee Valley, but no research has been conducted to verify this rate. The objective of this research is to determine the most efficient combination of N rate, method, application timing, and source for high-residue conservation tillage cotton systems in the Tennessee Valley in northern Alabama.

METHODS AND MATERIALS

This experiment was initiated in November of 1999 at the Tennessee Valley Research and Extension Center of the Alabama Agricultural Experiment Station, in Belle Mina, AL with the planting of a rye cover crop. The soil type is a Decatur silt loam (clayey, kaolinitic, thermic Rhodic Paleudult), the major type in the region. The experiment design is a factorial arrangement of two N sources (UAN and AN), two N application times (at planting and 50% at planting/50% at first square), two N application methods (broadcast and banded), and four N rates (40, 80, 120, and 160 lbs N acre^{-1}) in a randomized complete block of 4 replications. A 0-N control is also included. The varieties used are 'Elbon' Rye and 'SureGrow 125 BG/RR' cotton.

Phosphorous, potassium, and lime are applied prior to planting the fall crop based on Auburn University test recommendations. Compaction can become a problem for this soil (Schwab *et al.*, 2002), thus, each year plots are deep tilled to the 18-inch depth using a Paratill® bent-leg subsoiler (Bigham Brothers Inc., Lubbock, TX 79452) immediately following the planting of the rye cover crop, in early November. Equipment used in this experiment is guided using a Trimble AgGPS Autopilot® automatic steering system (Trimble, Sunnyvale, CA 94088), with centimeter level precision. This insures that the equipment compaction is kept off the cotton row. This guidance system allows the banded application of N to be placed in the same location each time it is applied. The rye is terminated in mid-April using glyphosate at the labeled rate. A roller/crimper is then used to roll down the cover crop (Ashford *et al*, 2000). Cotton is planted in early May using a 4-row unit vacuum planter set on 40-inch rows at a rate of 5 seed per foot. All cotton production practices are followed as outlined by the Alabama Cooperative Extension Service.

Initial N applications are made immediately following planting of cotton using a drop spreader equipped for broadcast or banded applications for AN and a sprayer rig for UAN. The second application of the 50-50 split N is applied at first match head square formation. To account for the border effect of alleys, 2.5 feet are cut off each end of the plot using a rotary mower before harvest. The center two rows are harvested with a spindle picker equipped with a sacking unit.

Prior to termination, rye biomass is sampled by collecting two 0.25 m^2 per plot. The residue is dried at 131°F (55°C) until all moisture is removed and weighed to determine dry matter per acre. Approximately 30 g of subsample is ground through a 1 mm screen on a rotary mill. Total C and N by dry combustion using a Fisons 1500 NCS® nitrogen/carbon analyzer (Fisons Instruments, Beverly, MA 01915) is determined on subsamples. At first square, leaf chlorophyll from 25 of the upper most expanded leaves in each plot are read with a Minolta 502 SPAD® chlorophyll meter (Spectrum, Plainfield, IL 60544). Nitrogen concentrations from the leaf blade/petiole combination is then determined by dry combustion. Chlorophyll meter readings from 25 of the upper-most expanded leaves are taken again when the cotton is at 1st flower and mid-bloom. Petioles are separated from leaf blades and analyzed for NO_3-N using an ion selective electrode combination, while leaf blades are again analyzed for N using the combustion technique. The harvested cotton is subsampled and ginning percentage is determined before being sent to the USDA classing office (USDA, Pelham, AL 35124) for high volume instrumentation (HVI) analysis.

Analysis of variance (ANOVA) is conducted prior to determination of Fisher's protected least significant difference (LSD) values using the SAS statistical package® (SAS Institute, 2001). A significance level of $P = 0.10$ was established *a priori*. Only cotton yield and leaf N at 1st bloom data from the 2000 and 2001 seasons are presented in this paper.

RESULTS

2000 Season

In 2000, lint yield ranged from 547 lbs acre^{-1} (0-N check plots) to 1043 lbs acre^{-1}. A significant interaction occurred between N timing x N rate x N application method (Table 1). All N rates significantly increased yield over the 0 N check. When N was broadcast at planting, highest yield was obtained with the 160 lbs N acre^{-1} application (960 lbs acre^{-1}), and rates of 40-120 lbs N acre^{-1} were similar in yield. When N was banded at planting, highest yields (946 lbs acre^{-1}) were obtained with the 120 lbs N acre^{-1} rate, with a trend for reduced yields at the 160 lbs N acre^{-1} rate. Too much N will harm cotton as the plants grow excess vegetation, which reduces fruit load and lint yield (Gerik *et al*, 1994). When N was split applied, regardless of application method (broadcast or banded), there was no response to N application rate other than a yield increase over the 0 N control. However, yields were generally greater for broadcast applications than for banded applications when N was split applied.

At first flower, N source and N rate significantly affected leaf N concentration. Ammonium nitrate applications had higher leaf N (3.88%) than did UAN (3.78%). The 40 lbs N acre^{-1} rate had lower leaf N% (3.64%) than the other three rates (3.86%, 3.87%, and 3.96, for 80, 120, and 160 lbs N acre^{-1} respectively), as expected. Although significantly different, they were all within the sufficiency level of 3.50 to 4.50% N at first bloom (Jones *et al*, 1991). All treatments were in the sufficiency level except the 0 N check plots (3.16%) and UAN broadcast application of 40 lbs N acre^{-1} at planting (3.34%). These plots yielded 547 and 762 lbs lint acre^{-1}, respectively.

2001 Season

In 2001, cotton lint yield ranged from 572 lbs acre^{-1} (0-N check) to 1135 lbs acre^{-1}. There were several significant interactions in this crop season. There was a N source x N method interaction (Table 2). Ammonium nitrate application resulted in greater yield (1014 lbs acre^{-1}) when broadcast, but UAN application yielded higher when banded (1006 lbs acre^{-1}). Rain may affect urea efficiency (Bovis and Touchton, 1998). No rain fell after fertilization in 2000, but within 12 hours of application in 2001, 0.38 inches fell

Table 1. Effect of N application timing, method, and N rate (lbs acre^{-1}) on cotton lint yield for a high-residue conservation system in the Tennessee Valley of Alabama in 2000.The no N check yielded 572 lbs acre^{-1}.

	Broadcast N-rate				Banded N-rate			
Application timing	40	80	120	160	40	80	120	160
	lbs acre^{-1}							
At planting	767	733	725	960	717	739	946	839
Split†	700	812	790	791	663	742	663	750
$LSD_{0.10}$	132							

† Split = 50% N at planting, 50% N at 1st square.

Table 2. Effect of N source and N method on cotton lint yield for a high-residue conservation system located in the Tennessee Valley of Alabama in 2001. The no N check yielded 572 lbs acre^{-1}.

N Source	Banded	Broadcast
	------------ lbs acre^{-1} ------------	
AN	877	1014
UAN	1006	944
$LSD_{0.10}$	56	

after the at-planting and 0.92 inches after first square applications. It is expected that the banded UAN performed better than when broadcast as the N was more concentrated near the cotton root system (Touchton and Hargrove, 1982).

There was an application timing x N rate x application method interaction in 2001 (Table 3) . Nitrogen rate did not affect yield when broadcast at planting, except when compared to 0 N check plots (572 lbs acre^{-1}). Broadcast split applications at 80 lbs N acre^{-1} and greater yielded higher than the 40 lbs N acre^{-1} rate. Banded at planting N increased yields with 120 lbs N acre^{-1} (1029 lbs acre^{-1}) over 80 lbs N acre^{-1} (839 lbs acre^{-1}).

There was also a N source x N method x N application timing interaction (Table 4). Urea-ammonium nitrate liquid banded at planting (1053 lbs acre^{-1}) out performed AN banded at planting (840 lbs acre^{-1}), but AN broadcast at planting (1035 lbs acre^{-1}) out performed the UAN broadcast at planting (913 lbs acre^{-1}). When N was split, there was no yield response; yields were equivalent regardless of N source and method.

Table 3. Effect of N application timing, method, and N rate (lbs acre^{-1}) on cotton lint yield for a high-residue conservation system in the Tennessee Valley of Alabama in 2001.The no N check yielded 572 lbs acre^{-1}.

	Broadcast N-rate				Banded N-rate			
Application timing	40	80	120	160	40	80	120	160
	------------------lbs acre^{-1} ------------------							
At planting	912	985	1006	980	819	839	1029	1129
Split†	896	1004	1026	1020	838	958	1042	913
$LSD_{0.10}$				112				

† Split = 50% N at planting, 50% N at 1st square.

Table 4. Effect of N application time, N-method, and N-source on cotton lint yield for a high-residue conservation system located in the Tennessee Valley of Alabama in 2001. The no N check yielded 572 lbs acre^{-1}.

	Broadcast N-source		Banded N-source	
Application timing	AN	UAN	AN	UAN
	---------------lbs acre^{-1} ---------------			
At planting	1035	913	840	1053
Split†	995	976	912	964
$LSD_{0.10}$		80		

† Split = 50% N at planting, 50% N at 1st square.

The N source x N method interaction revealed broadcast AN (3.43%) increased leaf N compared to banded AN (3.33%). Ammonium nitrate broadcast also resulted in greater leaf N concentrations (3.43%) than when UAN was broadcast (3.26%). There was a linear response to N rate when N was applied at planting (Table 5). Split applications resulted in an increase in leaf N from the 40 lbs N acre^{-1} (2.92%) to the 80 lbs N acre^{-1} (3.54%), but no increase after that. There was also a N application timing x N source x N rate interaction (Table 6). At planting, AN rates of 120 (3.60%) and 160 lbs N acre^{-1} (3.81%) had greater leaf N than lower rates. Urea-ammonium nitrate source resulted in a linear response to N rate when applied at planting. The highest N rates (120 and 160 lbs N acre^{-1}) were generally the only plots without a N deficiency, regardless of source. There was also a N source x N method x N rate interaction (Table 7). Broadcast AN resulted in a linear response to N rate, while banded AN resulted in increased leaf N only with N rates greater than 80 lbs acre^{-1}. The reason for the greater leaf N concentrations for UAN applications of 40 lbs N acre^{-1} is unclear, but may be related to reduced plant size and a concentration effect.

CONCLUSIONS

Lint yield and leaf N at 1st bloom data suggest that 120 lbs N acre^{-1} may initially be needed for cotton grown in high-residue (>4,000 lbs residue acre^{-1}) conservation systems in the Tennessee Valley. We speculate that N requirements may not be as high for systems with less residue and that N requirements may be reduced over time in high residue systems as soil C and N pools reach new equilibriums. Nitrogen applied at planting generally resulted in greater lint yields (803 lbs lint acre^{-1} in 2000; 957 lbs lint acre^{-1} in 2001) for both sources (UAN and AN) compared to split applications (739 lbs lint acre^{-1} in 2000; 962 lbs lint acre^{-1} in 2001). Ammonium nitrate applications resulted in greater yields when broadcast compared to banding, while efficiency of UAN application was increased when banded. Using 120 lbs N acre^{-1}, at a cost of $0.19 per lb N for UAN ($22.80 per acre) and $0.28 per lb N for AN ($33.60 per acre), producers can save $10.80 per acre by using UAN rather than AN. Applying all N at planting saves trips across the field, reducing operating costs and compaction. Banding all UAN at planting may help producers maximize cotton yield and profit in high-residue conservation systems in the Tennessee Valley.

ACKNOWLEDGMENT AND DISCLAIMER

The authors wish to thank Mr. Bobby E. (Chet) Norris, Superintendent, Tennessee Valley Research and Extension Center of Alabama Agricultural Experiment Station for helping to maintain this experiment. We also wish to thank Mr. Jeffrey A. Walker for his assistance in data collection and managing this experiment. Reference to trade or company name is for specific information and does not imply approval or recommendation of the company by the USDA or Auburn University to the exclusion of others that may be suitable.

Table 5. Nitrogen leaf percentage at the first bloom cotton stage for application timing and N rate in a high-residue conservation system located in the Tennessee Valley of Alabama in 2001. The N-concentration of the no N check was 2.65% N.

Application	N rate			
timing	40	80	120	160
At planting	2.95†	3.06†	3.50	3.69
Split‡	2.92†	3.54	3.55	3.63
$LSD_{0.10}$	0.110			

† Insufficient leaf N at first bloom.

‡ Split = 50% N at planting, 50% N at 1st square.

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Table 6. Nitrogen leaf percentage at the first bloom cotton stage for application timing, N source, and N-rate (lbs acre^{-1}) in a high-residue conservation system located in the Tennessee Valley of Alabama in 2001. The N-concentration of the no N check was 2.65% N

	AN rate				UAN rate			
Application timing	40	80	120	160	40	80	120	160
	%							
At planting	3.02†	2.96†	3.60	3.81	2.88†	3.15†	3.39†	3.57
Split‡	2.93†	3.47†	3.53	3.72	2.91†	3.24†	3.57	3.54
$LSD_{0.10}$	0.155							

† Insufficient leaf N at first bloom.

‡ Split = 50% N at planting, 50% N at 1st square.

Table 7. Nitrogen leaf percentage at the first bloom cotton stage for N-source, N-application method, and N-rate (lbs acre^{-1}) in a high-residue conservation system located in the Tennessee Valley of Alabama in 2001. The N-concentration of the no N check was 2.65% N

	Broadcast N-rate				Banded N-rate			
Source	40	80	120	160	40	80	120	160
	lbs acre^{-1}							
AN	3.00†	3.37†	3.52	3.83	2.94†	3.06†	3.62	3.70
UAN	3.93	2.93†	3.50	3.42†	3.87	3.21†	3.46†	3.69
$LSD_{0.10}$	0.155							

† Insufficient leaf N at first bloom.

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