NITROGEN FERTILIZER FOR CONSERVATION TILLAGE COTTON: SOURCE, RATES, AND TIMING

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Abstract

The expected benefits associated with any type of conservation system in the Southeast require the use of a winter annual cover crop, usually a winter cereal. Rye (*Secale cereale* L.) is a popular choice for experienced growers that utilize conservation systems due to its wide adaptability to soil fertility levels, climate zones, and biomass production. However, in order to maximize the benefits of a conservation system, supplemental N should be applied to enhance biomass production. An alternative to commercial N applied to the cover crop is poultry litter. No information exists on the optimal rates or time of application to maximize cover crop biomass production and how the potential residual effect of poultry litter affects cotton (*Gossypium hirsutum* L.) N requirements in a high residue conservation tillage system. Initial results indicate that if growers choose to maximize biomass production by utilizing a form of N fertilizer, regardless of the rate, that fall application would be more beneficial to the cover crop. In 2006, poultry litter applied to the rye cover crop increased cotton lint yields with no additional fertilizer compared to commercial fertilizer. The addition of 90 lb N ac^{-1} benefited the cotton crop, which was evident by the substantial increase in lint yields observed, regardless of the cover crop N rate. In 2007, regardless of N source, lint yields increased as cover crop N rate increased, but poultry litter improved lint yields compared to commercial fertilizer. At the recommended 90 lb N ac^{-1} sidedress rate, the difference between sources was not as great, but lint yields following poultry litter were higher. Future work in this area should focus on comparing poultry litter supplied to the cover crop and lower cotton N sidedress rates to current cotton conservation tillage systems that utilize approximately 30 lb N ac^{-1} to the cover crop and maintain recommended sidedress N rates.

Introduction

In the Southeast, conservation systems require winter annual cover crops to supplement previous crop residues and maximize the amount of residue left on the soil surface, which protects the soil from erosion during the winter and early spring months. Cover crops can also increase water infiltration because soil crust formation is reduced. Decomposing cover crop roots create channels allowing water to infiltrate the soil profile as opposed to running off the field (Williams and Weil, 2004). This decomposing biomass contributes to soil organic matter, which improves the overall soil quality of typically degraded soils in the region.

Rye is a popular choice for growers with multiple years of experience with conservation systems due to its wide adaptability to soil fertility levels, climate zones, and biomass production. However, in order to maximize the benefits of a conservation system, the biomass produced from the winter cover crop should also be maximized (Balkcom et al., 2007). In addition to timely planting of the cover crop, supplemental N should be applied to enhance biomass production. Conventional wisdom states that this additional commercial N only contributes to the cover crop and may actually increase N requirements of the subsequent cotton crop. As a result of current high N prices and narrow profit margins, growers must decide whether to enhance biomass production and subsequent benefits of the cover crop while increasing commercial N applications or sacrifice the benefits of a high residue cover crop by reducing total N production costs.

An alternative to commercial N sources applied to the cover crop is poultry litter. Poultry litter is available to many growers as a N source and can be obtained at a lower price than commercial N. The organic N fraction of poultry litter is not readily available, but will supply N over a longer time-frame as the litter is decomposed by soil microorganisms. As a result, more residual N may be available to the subsequent cotton crop, thereby potentially reducing N requirements.

No information exists on the optimal rates or time of application to maximize cover crop biomass production and how the potential residual effect of poultry litter affects cotton N requirements in a high residue conservation tillage system. Therefore, our objectives were to (i) compare N fertilizer sources, rates, and time of application for a rye winter cover crop to determine optimal biomass production for conservation tillage production, (ii) compare recommended and no additional N fertilizer rates across different biomass levels for cotton, and (iii) determine the effect of residual N applied to the cover crop across two N fertilizer rates for cotton.

Materials and Methods

This experiment was initiated in the fall of 2005 at the Wiregrass Research and Extension Center near Headland, AL on a Fuquay sand (loamy, kaolinitic, thermic Arenic Plinthic Kandiudults). The experiment has remained in the same location with no re-randomization of the treatments. The experimental area could be irrigated and received 8.0 and 7.75 inches during the 2006 and 2007 growing seasons.

The experimental design for the cover crop contained a split-split plot treatment restriction in a randomized complete block design with four replications. Main plots consisted of time of application (fall vs spring), subplots were N source (commercial fertilizer, and poultry litter), and sub-subplots were N rate (0 30, 60, and 90 lb N ac^{-1} as commercial fertilizer and 0, 1, 2, and 3 tons ac^{-1} as poultry litter on an as-sampled basis). Fall poultry litter treatments were applied on the same day the cover crop was planted, which corresponded to Nov. 19, 2005 and Nov. 9, 2006. Commercial fertilizer was applied on Dec. 12, 2005 and Dec. 4, 2006 after stand establishment. Based on soil test recommendations, 40 lb K_2O ac^{-1} was applied as KCl to all plots not receiving poultry litter at the initiation of the experiment. Spring applications of commercial fertilizer and poultry litter were applied on Feb. 8, 2006 and Feb. 7, 2007. Poultry litter application rates were designed to approximate commercial fertilizer rates based on total and estimated available N supplied in the litter (Table 1). Sub-subplot size was 24 ft. (8-36 inch rows) wide and 40 ft. long.

Table 1. Total and estimated available N applied in the fall and spring from poultry litter on a dry weight basis at the Wiregrass Research and Extension Center in Headland, AL during the 2005-2006 and 2006-2007 growing seasons.

		Rate (tons ac^{-1})							
	Time of	0	1	2	3	0	1	2	3
Crop year	application	Total N				Available N†			
		lb ac^{-1}							
2005-2006	Fall	0	76	152	229	0	38	76	115
	Spring	0	73	146	219	0	37	73	110
2006-2007	Fall	0	53	106	159	0	27	53	80
	Spring	0	69	138	207	0	35	69	104

† Available N based on an estimate of 50% total N available during the first year of application.

A rye cover crop was drilled across the experimental area each fall at 90 lb ac^{-1}. Biomass samples were collected from two 2.7 ft^2 areas within each plot approximately 3 weeks before anticipated planting date and immediately preceding chemical termination of the cover crop. After chemical termination, all plots were rolled to form a cover crop mat on the surface by laying the cover crop residue down parallel to the direction of planting. All plots were in-row subsoiled with a KMC Ripper Stripper®, equipped with rubber pneumatic tires to minimize surface soil disruption, approximately 1 wk before planting. DP 555® BG/RR Cruiser® treated seed were planted on 36-inch centers at approximately 58,000 seed ac^{-1} on May 15, 2006 and May 2, 2007. The corresponding eight row cotton plots were split with four rows receiving a sidedress N rate of 90 lb N ac^{-1}, while the other four rows were not fertilized, in order to estimate any residual effects from the commercial fertilizer and poultry litter supplied to the cover crop. Sidedress N, as urea-ammonium nitrate (UAN) was applied at early square on June 22, 2006 and June 20, 2007. Nitrogen uptake at mid-bloom was determined by collecting whole plant biomass from the aboveground portion of all plants within a 3.28 ft. section of a non-harvest row from each plot. The plant material collected was dried at 55 degrees Celsius for 72 hours and weighed to estimate plant biomass of each plot. A subsample from each plot was analyzed for total N by dry combustion on a LECO CHN-600 analyzer (LecoCorp.; St. Joseph, MI). Corresponding N contents and biomass were used to calculate N uptake at mid-bloom.

The plot area was defoliated with 1.5 pt/ac. of Finish® on Oct. 10, 2006 and Sept. 26, 2007. In 2007, Ginstar® was also applied at 5 oz/ac. All plots were harvested with a spindle picker equipped with a bagging attachment on Oct. 19, 2006 and Oct. 3, 2007. A sub-sample of seed cotton from each plot was ginned in a 20-saw tabletop micro-gin to determine ginning percentage. Lint yields were determined by weighing lint and seed collected from each plot and multiplying corresponding seed cotton by the ginning percentage of each plot. No fiber properties will be reported at this time.

All response variables were analyzed using the MIXED procedure (Littell et al., 2006) and the LSMEANS DIFF option to distinguish between treatment means (release 9.1; SAS Institute Inc.; Cary, NC). All data were analyzed by year. Cover crop data was analyzed with rep, timing, source, rate, and the interactions among timing, source, and rate as fixed effects in the model, while rep X timing X source were considered random. Depending on which factors were significant, another model was constructed for each year to measure cotton lint yields and N uptake. Any negative variance components were modeled with a compound symmetry model as described by Littell et al., (2006). Treatment differences were considered significant if $P \leq 0.05$.

Results and Discussion

Rye biomass production

Rye biomass results measured in spring 2006 indicate that N fertilizer source or time of application had no effect on measured biomass levels, however rate was highly significant (Table 2). Although there was no rate by source interaction, Fig. 1 illustrates corresponding biomass levels across N rates for each N source. Figure 1 clearly shows that corresponding N rates between N sources produced very similar biomass levels and that source was not a factor during the first year. Biomass levels measured in 2007 produced a timing X rate interaction ($Pr > F = 0.0440$) (Table 2), which indicates that biomass levels increased with fall application of N (Fig. 2). Timing of N fertilizer had no effect on measured biomass levels in 2006, but biomass levels following fall applied N averaged over sources and rates for both crop years indicate 25% higher biomass levels compared to spring applied N. This indicates that if growers choose to maximize biomass production by utilizing a form of N fertilizer that fall application would be more beneficial to the cover crop.

Table 2. F-values and significance values for fixed effects and their interactions

	2005-2006 growing season		2006-2007 growing season	
Effect	F Value	Pr>F	F Value	Pr>F
Timing	2.627	0.1395	8.789	0.0158
Source	0.006	0.9401	1.510	0.2503
Timing x Source	0.162	0.6968	1.032	0.3363
Rate	9.060	0.0001	59.774	<0.0001
Timing x Rate	2.117	0.1152	2.982	0.0440
Source x Rate	0.347	0.7912	1.366	0.2688
Timing x Source x Rate	0.188	0.9040	1.876	0.1510

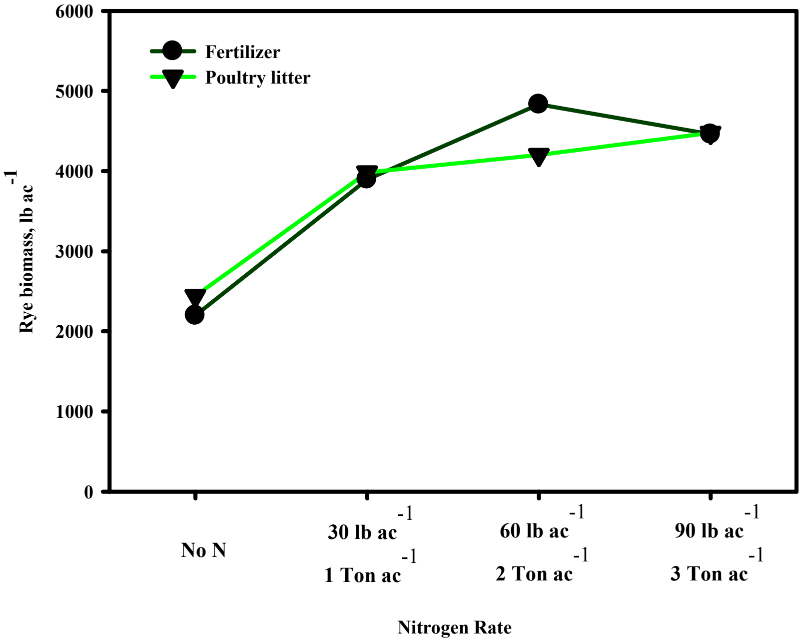

Figure 1. Rye biomass production attributed to source and rate of application during the 2005-2006 winter growing season at the Wiregrass Research and Extension Center in Headland, AL.

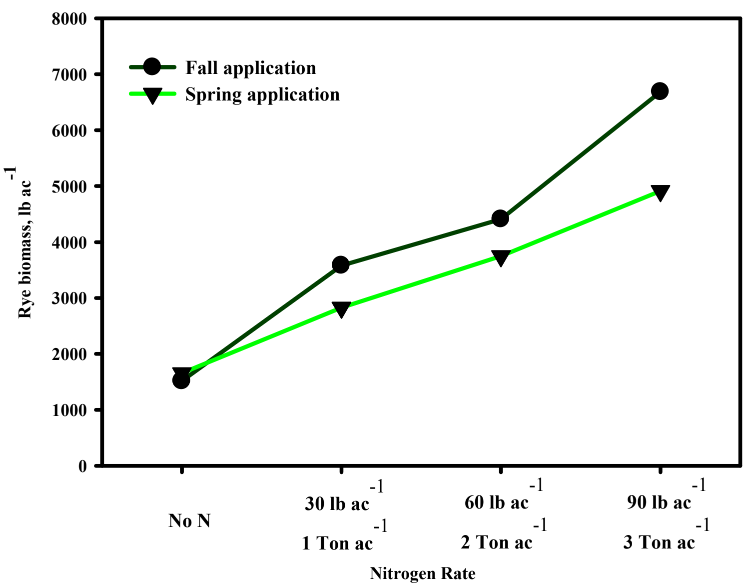

Figure 2. Rye biomass production measured between N rates, regardless of source and time of application during the 2006-2007 winter growing season at the Wiregrass Research and Extension Center in Headland, AL.

Lint Yields

Time of application or source of fertilizer had no effect on biomass levels in 2006 (Table 2); therefore, these variables were not accounted for in the analysis pertaining to 2006 cotton lint yields. Cover crop N rate was the only variable significant in the biomass analysis. Based on this information and an effort to simplify the analysis, cover crop N rate served as the main plot, while the two sidedress N rates applied to the subsequent cotton crop were used as subplots for the analysis of lint yields. In 2006, cover crop N rate and cotton sidedress N rate influenced yields, but no interaction was observed between these factors (Table 3). Lint yields measured in 2006 indicate that a significant amount of residual N may have been present when the experiment was initiated, based on the high lint yields measured with no N supplied to the cover crop or cotton crop (Table 3). On the other hand, if significant soil N were present, one would hypothesize that rye, an excellent scavenger of N (Brandi-Dohrn et al., 1997), would not have responded to the additional N supplied. The poultry litter applied to the rye cover crop increased cotton lint yields with no additional fertilizer compared to commercial fertilizer (Table 3). The addition of 90 lb N ac^{-1} benefited the cotton crop, which was evident by the substantial increase in lint yields observed, regardless of the cover crop N rate (Table 3). Notably, 3 tons of poultry litter ac^{-1} applied to the cover crop resulted in comparable cotton lint yields to 90 lb N ac^{-1} at sidedress.

In 2007, time of application and cover crop N rate influenced measured biomass levels (Table 2). This required a slightly more complicated analysis of cotton lint yield for 2007 with timing of cover crop N application as the main plot, cover crop N rate as the subplots, and the two sidedress N rates as the sub-subplots. Significant interactions between time of application and sidedress N rates, as well as, cover crop N rates and sidedress N rates were observed in 2007 (Table 4). As expected, regardless of cover crop N timing, lint yields were increased with 90 lb N ac^{-1} compared to 0 lb N ac^{-1}. However, spring applied N to the cover crop produced superior yields compared to fall applied N at the 0 lb N ac^{-1} sidedress rate (Fig. 3). Nitrogen applied in the spring to the cover crop would be less susceptible to loss, prior to cotton uptake, which could explain this difference. Depending on how quickly the poultry litter is mineralized, spring applications could also synchronize better with cotton uptake.

Figure 4 illustrates the interaction between cover crop N rate and sidedress N rate observed during the 2007 growing season. By examining only N applied to the cover crop (0 lb N ac^{-1} sidedress), the residual effects of the poultry litter are apparent. Regardless of N source, lint yields increased as cover crop N rate increased, but poultry litter improved lint yields compared to commercial fertilizer (Fig. 4). At the recommended 90 lb N ac^{-1} sidedress rate, the difference between sources was not as great, but lint yields following poultry litter were higher (Fig. 4). This data

Table 3. Cotton lint yields and N uptake measured at mid-bloom across cover crop fertilizer timing, cover crop N rates and sidedress cotton N rates during the 2006 cotton growing seasons at the Wiregrass Research and Extension Center in Headland, AL.

Treatment		2006 Lint yields	2006 N uptake
Cover Crop N Rate			
Poultry litter (tons ac^{-1})	Commercial fertilizer (lb ac^{-1})	------------------lb ac^{-1}------------------	
0	0	1352	38.9
1	0	1511	44.0
2	0	1517	41.9
3	0	1604	49.5
0	30	1391	42.3
0	60	1442	39.7
0	90	1501	38.9
Sidedress Cotton N rate (lb ac^{-1})			
0		1328	31.6
90		1620	52.8
		Analysis of variance (P>F)	
Cover Crop N Rate		0.0020	0.2419
Sidedress Cotton N rate		<0.0001	<0.0001
Cover crop X Sidedress		0.1431	0.5893

Table 4. Cotton lint yields and N uptake measured at mid-bloom across cover crop fertilizer timing, cover crop N rates and sidedress cotton N rates during the 2007 cotton growing seasons at the Wiregrass Research and Extension Center in Headland, AL.

Treatment		2007 Lint yields	2007 N uptake
		------------------lb ac^{-1}------------------	
Timing Cover Crop Fertilizer			
Fall		1192	47.1
Spring		1233	48.9
Cover Crop N Rate			
Poultry litter (tons ac^{-1})	Commercial fertilizer (lb ac^{-1})		
0	0	1011	46.2
1	0	1267	48.7
2	0	1288	54.9
3	0	1393	57.4
0	30	1136	41.7
0	60	1182	45.7
0	90	1211	41.5
Sidedress Cotton N rate (lb ac^{-1})			
0		912	36.0
90		1513	60.0
		Analysis of variance (P>F)	
Timing		0.2408	0.6770
Cover N rate		0.0002	0.0184
Timing x Cover N rate		0.6085	0.3420
Sidedress N rate		<0.0001	<0.0001
Timing x Sidedress N rate		<0.0001	0.2745
Cover N rate x Sidedress N rate		0.0265	0.6366
Timing x Cover N rate x Sidedress N rate		0.9425	0.6539

indicates there is no advantage to cover crop N rates greater than 30 lb N ac^{-1} as commercial fertilizer or 1 ton ac^{-1} as poultry litter when 90 lb N ac^{-1} is supplied at sidedress to the cotton. However, due to the organic fraction of poultry litter, utilizing higher poultry litter rates to the cover crop with lower sidedress N rates could provide some cost saving to growers without sacrificing yields.

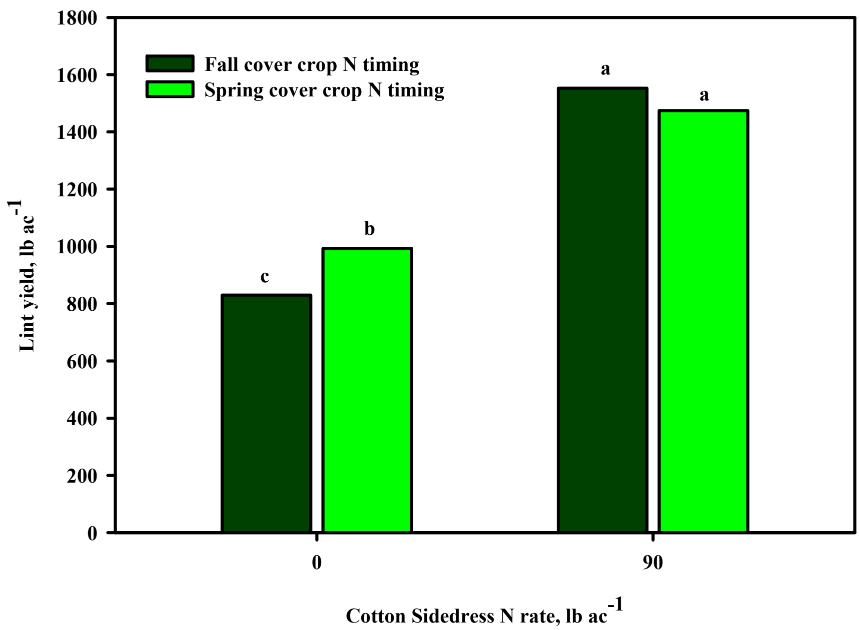

Figure 3. Cotton lint yields measured following fall and spring applied N to the cover crop and two cotton sidedress N rates (0 and 90 lb N ac^{-1}) during the 2007 growing season at the Wiregrass Research and Extension Center in Headland, AL.

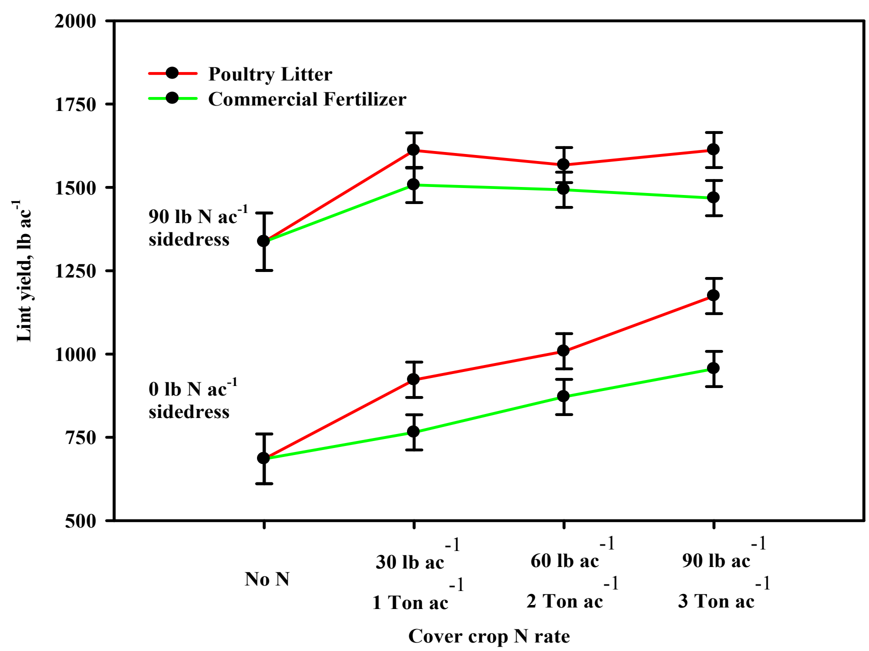

Figure 4. Cotton lint yields measured across two sources of N (commercial fertilizer and poultry litter) applied to the cover crop and two cotton sidedress N rates (0 and 90 lb N ac^{-1}) during the 2007 growing season at the Wiregrass Research and Extension Center in Headland, AL.

N uptake

Each analysis performed in 2006 and 2007 for lint yields was used to examine differences among plant N uptake at mid-bloom. In 2006, cover crop N rate had no effect on uptakes at mid-bloom, but sidedress cotton N rate did influence uptakes at mid-bloom (Table 3). There was no observed interaction between these variables (Table 3). Plots receiving the recommended 90 lb N ac^{-1} at sidedress had higher measured plant uptakes compared to plots receiving no N at sidedress (Table 3).

In 2007, only cover crop N rate and sidedress cotton N rate influenced uptakes at mid-bloom (Table 4). Measured uptakes at mid-bloom were lowest from plots receiving 90 lb N ac^{-1} to the cover crop, while the highest observed uptakes were measured from plots receiving 3 tons ac^{-1} of poultry litter (Table 4). Generally, higher measured uptakes were observed from plots receiving poultry litter compared to plots receiving commercial fertilizer (Table 4). As in 2006, measured uptakes at mid-bloom in 2007 were greater following plots that received the recommended 90 lb N ac^{-1} at sidedress compared to no additional N at sidedress (Table 4). Plant uptakes measured in 2007 were numerically higher than uptakes observed in 2006.

Conclusions

Poultry litter can be considered a slow release fertilizer and preliminary results indicate that poultry litter applied in the fall benefits both the cover crop and the cotton crop. Cover crop biomass is maximized and cotton N rates could be at least partially reduced by using poultry litter. Future work in this area should focus on comparing poultry litter supplied to the cover crop combined with lower cotton N sidedress rates to the current cotton conservation tillage systems that utilize approximately 30 lb N ac^{-1} to the cover crop and maintain recommended sidedress N rates may be warranted. These scenarios could maximize biomass, maintain yields, and decrease costly commercial N use.

Disclaimer

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