Nitrogen Fertilizer: Timing, Source, and Rate for a Winter Cereal Cover Crop

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Introduction

Conservation tillage is one component utilized throughout the United States to maintain a minimum of 30% residue on the soil surface. This residue, typically from previous crops, helps reduce soil erosion from water and wind, decrease labor and energy inputs, increase soil water availability for subsequent crops, and enhance soil quality (Kern and Johnson, 1993; Reeves, 1994). Growers in the Southeast also utilize conservation tillage, but soil quality benefits are enhanced by using a winter annual cover crop to supplement previous crop residues and maximize the amount of residue left on the soil surface. Decomposing cover crop roots also create channels that allows water to infiltrate the soil profile as opposed to running off the field (Williams and Weil, 2004). This combination of cash crop and cover crop residue contributes to soil organic matter, which improves the overall soil quality of the typically degraded soils in the region.

Rye (*Secale cereale* L.) 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). Supplemental N fertilization is one agronomic practice that can be used to increase biomass production, but the cost of N fertilizers tempts some growers to eliminate this expense to reduce total N production costs, despite the benefits of more biomass.

An alternative N source to increase cover crop biomass production is poultry litter. Poultry litter is available to many growers and can usually be obtained at a lower price than commercial N, depending on hauling costs. 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. The available N fraction of poultry litter could fertilize a cover crop, while the organic fraction that mineralizes over time could contribute to the N requirements of a subsequent summer crop. We will only focus on the cover crop in this proceeding.

Despite the benefits of increased biomass production, limited information exists on the optimal rates and times of application to maximize cover crop biomass production. Therefore, our objective was to compare N fertilizer sources, rates, and time of application for a rye winter cover crop to determine optimal biomass production for conservation tillage production.

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 remained in the same location each year with no re-randomization of the treatments.

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, Nov. 9, 2006, and Nov. 2, 2007. Commercial fertilizer was applied on Dec. 12, 2005, Dec. 4, 2006, and Nov. 19, 2007 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, Feb. 7, 2007, and Feb. 14, 2008. 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, 2006-2007, and 2007-2008 winter 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
2007-2008	Fall	0	64	127	191	0	32	64	96
	Spring	0	66	132	199	0	33	66	100

† 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 spring planting date and immediately preceding chemical termination of the cover crop in early April. The plant material collected was dried at 131 degrees Fahrenheit for 72 hours and weighed to estimate plant biomass of each plot.

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. Treatment differences were considered significant if $P \leq 0.05$.

Results and Discussion

Average rye biomass measured across all three years of the experiment indicates that, regardless of N source, rate was highly significant (Table 2). Figure 1 illustrates the average biomass produced for each rate across both sources and time of application for all three years of the experiment. The red line at 4000 lb ac^{-1} is a minimum biomass level proposed by Reiter et al. (2003) for a high residue cereal cover crop conservation tillage system in Alabama. Figure 1 shows that rye biomass production is enhanced with N fertilizer and in order to achieve the minimum biomass level, an application of at least 30 lb N ac^{-1} is required. Additional N fertilizer can increase biomass production, but the high cost of N prohibits the cost effectiveness of this practice.

Biomass levels measured in 2007 produced a timing X rate interaction (Pr > F = 0.044) (Table 2) that indicates biomass levels increased with fall application of N across sources (Fig. 2). A similar trend existed for the other two growing seasons (Table 2), however, the results varied across the remaining years. In 2006, biomass levels were increased with fall application of N, but higher biomass levels were measured following spring application of N across N rates, regardless of source in 2008. Two out of three years suggests that if growers choose to maximize biomass production by utilizing a form of N fertilizer; a fall application would produce more cover crop biomass.

Table 2. F-values and significance values for fixed effects and their interactions for nitrogen timing, source, and rates during three experimental years at the Wiregrass Research and Extension Center in Headland, AL.

	2005-2006 growing season		2006-2007 growing season		2007-2008 growing season	
Effect	F Value	Pr>F	F Value	Pr>F	F Value	Pr>F
Timing	2.63	0.14	8.79	0.02	1.98	0.19
Source	0.01	0.94	1.51	0.25	12.6	0.01
Timing x Source	0.16	0.70	1.03	0.34	0.08	0.781
Rate	9.06	<0.01	59.8	< 0.01	43.4	< 0.01
Timing x Rate	2.12	0.12	2.98	0.04	2.24	0.10
Source x Rate	0.35	0.79	1.37	0.27	3.44	0.03
Timing x Source x Rate	0.19	0.90	1.88	0.15	2.68	0.06

A source X rate interaction (Pr > F = 0.027) was observed for rye biomass levels during the 2008 growing season (Table 2). Commercial N fertilizer produced higher biomass levels following N application when averaged across application time (Fig. 3). Although poultry litter rates were applied to approximate commercial N rates, the available N fraction of poultry litter is only an estimate (Table 1). A 50% estimate of total N within poultry litter is actually a conservative estimate. Other results with poultry litter in the region indicate that much of the total N applied is available (Mitchell and Tu, 2005), however, these results were based on litter applications during spring and early summer for subsequent summer crops when temperatures are warmer. Surprisingly, poultry litter produced a lower biomass response in 2008 after two years of application, despite the residual effect of an organic N source like poultry litter.

Conclusions

Poultry litter appears comparable to fertilizer as a source of N for a rye cover crop. An application of 30 lb N ac^{-1} produced sufficient biomass to meet a minimum biomass threshold, and a fall application of N was more beneficial during two out of three years. These results represent only one location over a 3-year period; therefore, these findings can not be expected to represent the entire Southeast. However, these results can be expected to provide general information related to N fertilizer and biomass production in the Southeast.

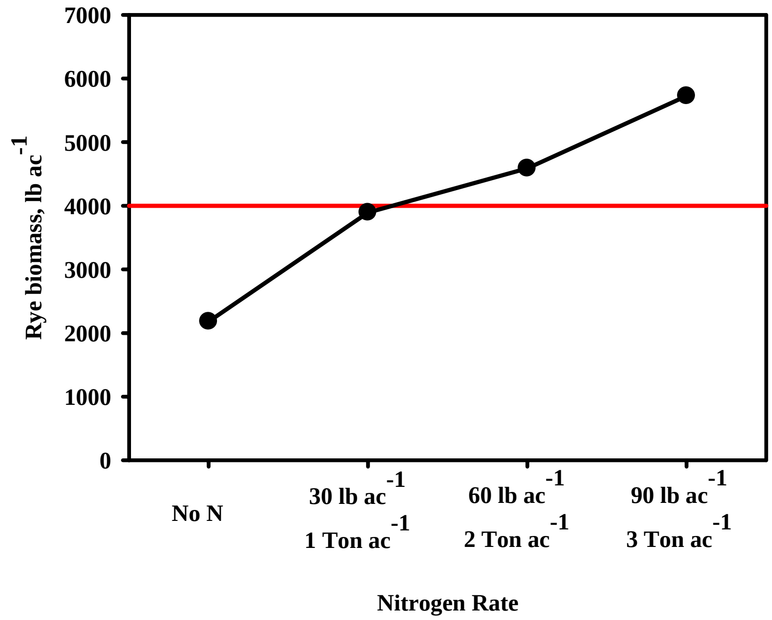

Figure 1. Average rye biomass production measured across N rates, regardless of source and time of application during the 2005-2006, 2006-2007, and 2007-2008 winter growing season at the Wiregrass Research and Extension Center in Headland, AL. The red line is a minimum biomass level for a high residue conservation system in Alabama proposed by Reiter et al. (2003).

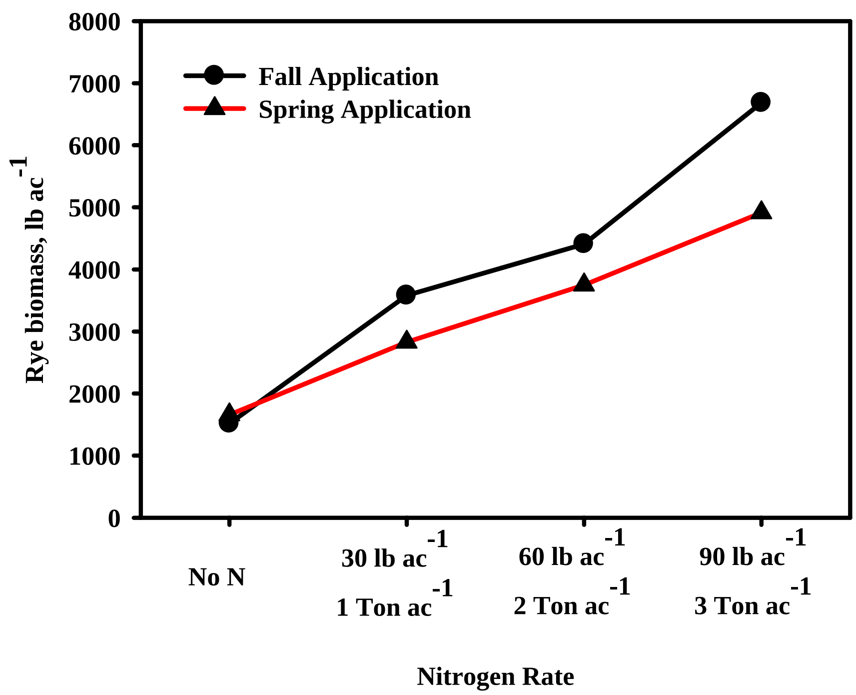

Figure 2. Rye biomass production measured following fall and spring application across N rates, regardless of source during the 2006-2007 winter growing season at the Wiregrass Research and Extension Center in Headland, AL.

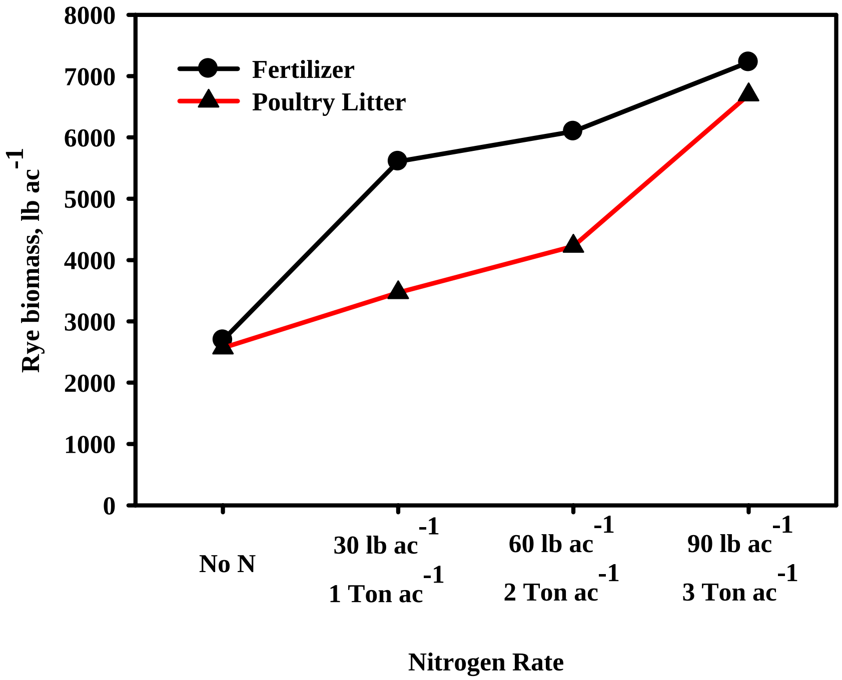

Figure 3. Rye biomass production measured between N sources across rates, regardless of time of application during the 2007-2008 winter growing season at the Wiregrass Research and Extension Center in Headland, AL.

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