2005 Beltwide Cotton Conferences, New Orleans, Louisiana - January 4 - 7, 2005

EFFECTS OF FALL APPLICATION OF BROILER LITTER AND RYE WINTER COVER CROP ON COTTON YIELD AND SOIL N DYNAMICS

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Abstract

Timing of broiler litter applications has critical effect on the availability of plant nutrients contained in broiler litter. The incorporation of broiler litter for cotton production at different times of the year should significantly influence cotton growth and yield. This experiment was conducted on a Leeper silty clay loam soil at Mississippi Agricultural and Forestry Experimental Station (Plant Science Research Center at North Farm in 2003 and will continue through 2006 to identify if rye winter cover crop seeding after fall application of broiler litter benefits cotton growth and yield. The Experimental design was a randomized complete block with a split-plot arrangement of treatments. The main plots are rye (*Secale cereale* L.) winter cover crop and winter fallow and the sub-plots are broiler litter application rates of 0, 4.5, 9, and 13.4 Mg ha^{-1}. Averaged across broiler litter application rates, cotton plant height and number of bolls at maturity were 18 and 24% greater with a rye-cotton cropping system than those with a winter fallow-cotton cropping systems. At the high broiler litter application rate, cotton lint yield and N content were 10 and 33% greater in the rye winter cover crop than those in winter fallow plots, indicating greater N availability from the soil residual N and the potential of N mineralization from decomposition of cover crop residue. In the spring after killing the cover crop and before planting cotton, soil residual NO3-N concentrations in the rye winter cover crop at 30 cm depth (19-23 mg kg-1) were 50-62% lower than in winter fallow (38-60 mg kg-1), respectively, indicating the ability of the rye cover crop in sequestering soil NO3-N. In the fall after harvesting cotton, soil NO3 concentrations in the rye-cotton sequential cropping system at the high broiler litter application rate in the 0-60 cm depth (13 mg kg-1) was 50% lower than that of in the winter fallow-cotton (26 mg ha-1) cropping system, reflecting the greater potential of N leaching loss for winter fallow. Over seeding a catch crop to fall applied broiler litter for cotton production appears to be agronomically and environmentally beneficial.

Introduction

Commercial broiler production in Mississippi generates 450,000 Mg y^{-1} of broiler litter (manure and bedding material) which is applied to nearby pastures or cropland (Mississippi State University, 1998). Continued broiler litter application increases the potential for enrichment of NO_3-N in groundwater and P in surface water (Edwards et al., 1992; Sharpley et al., 1996). To minimize these risks, producers must obtain additional land area to dilute the litter using N demanding crops and/or using alternative crops to receive broiler litter. Using animal manure as fertilizer in row crop production have been encouraged. Substantial studies have been conducted to determine the effects of broiler litter on corn (*Zea mays* L.) (Brown et al., 1994; Wood et al., 1999) and cotton (*Gossypium hirsutum* L.) (Burmster et al., 1991; Glover and Vories, 1998; Malik and Reddy, 1999). Broiler litter is applied to pastures on a year-round basis. In contrast, application of broiler litter to row crops occurs either in the fall or in the spring. Timing of manure application has critical effects on available plant nutrients (Safety et al., 1986) and provides the best agronomic response in most instances (Hanna et al., 2000). The incorporation of broiler litter for cotton production at different times of the year should significantly influence N availability, cotton growth and yield. Fertilizer effectiveness of manure N has shown to increase with spring application compared to fall application due to reduction in N leaching losses (Smith and Chambers, 1998). Traditionally, animal manures are often applied to the soils in the fall possibly due to limiting space capacity in storing manure. In Mississippi due to wet winter months and high precipitation in early spring, broiler litter is applied in fall to prevent delayed planting in spring. However, Fall application of broiler litter over a winter fallow can result in considerable N leaching loss (Andraski et al., 2000). Any cultural practices that prevent or reduce N loss from leaching during the winter and recycle the mineralized N for the subsequent crops in the spring could be beneficial to the producer.

Winter Cover crops have been promoted as a means of protecting N from leaching and maximizing the efficient use of available N to subsequent crops in the spring, resulting in reduced risk of environmental problems associated with NO3-N contamination of surface and groundwater while potentially enhancing profitability through reduced fertilizer N requirements (Shipley et al., 1992; Dekker et al., 1994). Wyland et al. (1996) have reported reductions in leached N of about 65-70% from cover cropped soil compared with winter-fallow soil. Davis and Garwood (1996) found that a rye winter cover crop reduced N leaching loss by more than 90%. McCraken et al. (1994) reported that NO3-N concentration of leachate was almost zero during the fall, winter, and early spring with a rye winter cover crop. The success of cover crops on N sequestration and reducing N leaching loss from soils receiving poultry manure in the fall for cotton production in the spring has not been well documented. The objective of this study was to determine the effects of rye winter cover crop on sequestration of N from fall application of broiler litter and its effect on subsequent cotton growth and yield and residual soil N.

Materials and Methods

Research was conducted on a Leeper soil at the Mississippi Agriculture and Forestry Experiment Station in Starkville, MS in 2003 and will continue through 2006. Initial surface soil samples (0 to 6 in) were analyzed for NH4-N and NO3- N (Keeney and Nelson, 1982), extractable P (Mehlich,1984) soil texture (Day, 1965), and soil pH. Broiler litter was also analyzed for nutrient concentrations. The results of chemical analyses of soil and broiler litter are shown in Table 1.

The Experimental design was a randomized complete block with a split-plot arrangement of treatments replicated four times. The main plots are rye winter cover crop and winter fallow and the sub-plot are broiler litter and a commercial fertilizer application rate. Individual plot dimensions were 3.8 m wide by 9 m long with a 3 m alleyway between the blocks. In October 4, 2003, broiler litter was applied at the rate of 0, 4.5, 9, and 13.4 Mg ha^{-1} yr^{-1}. Broiler litter and commercial fertilizer P and K were applied in the fall incorporated into the soil immediately. After broiler litter application, the rye variety Elbon was planted at a rate of 90 kg ha^{-1} with a row spacing of 17.8 cm using grain drill. In Spring, total aboveground biomass were collected from each plot to determine N and DM accumulation. In each plot, above ground biomass was obtained from 1 m^2. These samples were dried at 65^o C for 48 h in a forced-air oven, weighed, and ground to pass a 1-mm sieve for chemical analysis. Total above ground biomass of rye winter cover crop was collected for dry matter yield and N utilization. Total N content was measured using an automated dry-combustion analyzer (Model NA 1500 NC, Carlo Erba, Milan, Italy). Rye winter cover crop was chemically desiccated with glyphosate (1.1 kg a.i. ha^{-1}) two weeks before planting cotton on April10, 2004. Before planting cotton, soil samples were taken from each plot at depths of 0 to 15, 15 to 30, 30 to 60 and 60 to 90 cm and analyzed for inorganic N accumulation.

Table 1. Selected properties of the soil and broiler litter used in the study.

Parameter	Soil	Broiler litter
Dry matter, %	**---**	**87.6**
pH	**7.6**	**7.4**
Total N, g kg-1	**1.9**	**33.5**
NH4-N, mg kg-1	**27.6**	**3552**
NO3-N, mg kg-1	**22.4**	**1991**
Carbon, g kg-1	**-----**	**308**
Organic matter, g kg-1	**26.5**	**----**
Texture	**SiCl**	
C to N ratio	**----**	**8**

Cotton was planted with 96 cm in row spacing on May 6, 2004 using a conventional four-row planter. At open boll stage, whole cotton plants were taken from a 50 cm in row for determination of total above ground biomass and N utilization. Cotton samples were oven dried at 65 ^{o} C until they obtained a stable dry weight, ground to pass a 1-mm sieve and analyzed for total N concentration using a carbon/nitrogen auto analyzer. Cotton was picked using a two row picker and lint yield was recorded.

Soil samples were taken in mid-October to a depth of 90 cm to determine soil residual NO_3- N accumulation at the end of growing season. Samples were combined by depth, placed in plastic bags and frozen at – 4^o C until analyzed.

The General Linear Model (GLM) procedure in SAS (SAS Inst., 1987) was used to perform analysis of variance for each of the dependent variables of lint yield, total DM yield and plant N concentration at maturity, and soil residual N before planting cotton and at the end of growing season. All statistical tests were performed at a 0.05 level of significance.

Results and Discussions

Cover crop biomass and N content

In spring at killing time, rye above ground biomass increased linearly with increasing broiler litter rates applied in the fall. Rye aboveground biomass production ranged from 655 kg ha^{-1}at 0 Mg ha^{-1} to 5524 kg ha^{-1} at 13.4 Mg ha^{-1} broiler litter application rate. Rye winter cover crop N content followed the same pattern as biomass production. In general, the literature shows that rye N content ranges from 40 kg N ha^{-1} to 90 kg N ha^{-1} (Bollero and Bullock, 1994; Odhiambo and Bomke, 2001). Rye N content increased linearly with increasing broiler litter application rates, reaching a maximum of 105 kg ha^{-1} at the 13.4 Mg ha^{-1} broiler litter application rate. A similar pattern was obtained for soil residual NO3-N content reflecting the scavenging ability of the rye winter cover crop. The higher broiler litter application and higher N mineralization at the site provided for a larger source of available N for the rye and resulted in greater N content compared with the control. In our study, rye winter cover crop N content showed a great response to N availability from broiler liter applications and its ability to take up large amount of soil mineral N. The large amounts of rye biomass produced and its N content was highly correlated to soil residual NO3-N content at the top 30 cm of the soil profile. This demonstrates that rye winter cover crop has the potential to reduce NO3-N leaching and provide valuable environmental services.

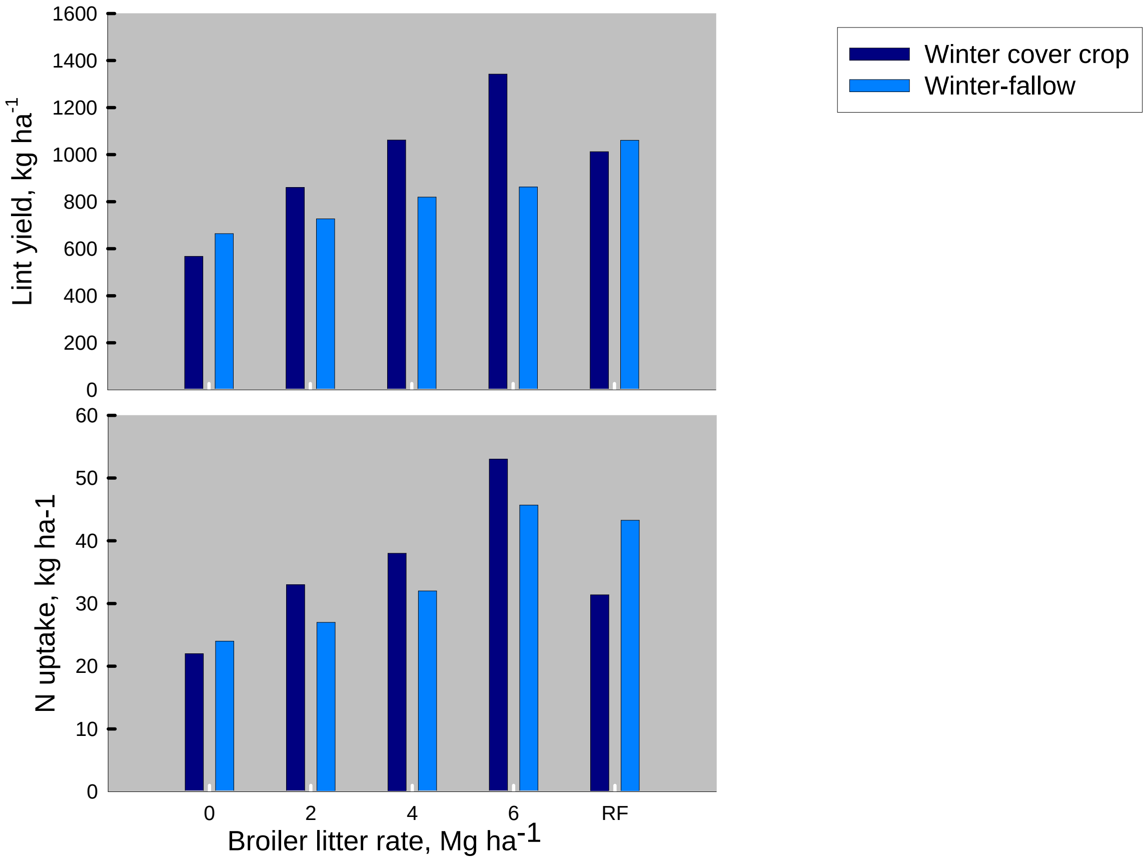

Fig. 1. Effects of rye winter cover crop and winter fallow on cotton yield and N utilization responses to fall applied broiler litter

The C:N ratio of rye cover crop planted over fall applied broiler litter has been used as a tool for predicting the rate of decomposition. The C/N ratio decreases with N availability (Ditsch et al., 1993). Similarly, in our study C/N ratio of rye over seeded to fall applied broiler litter decreased by 31% as compared with rye grown with no broiler litter application. The rye winter cover crop had an average C/N ratio of 26:1, compared with 37:1 for the rye grown with no broiler litter application, suggesting that rye over seeded to fall applied broiler litter has lower potential for N immobilization than a rye grown with no broiler litter application (Wagger, 1989b). The greater N availability from N mineralization of the fall applied broiler litter at high application rate allowed for greater N uptake by the rye winter cover crop, facilitating nutrient cycling, and minimizing the potential N leaching loss from applied broiler litter.

Cotton yield and N uptake

Averaged across broiler litter application rates, cotton height and number of bolls at maturity in winter cover crop plots were 18 and 24 % greater than those under winter fallow. Cotton lint yield significantly increased with increasing broiler litter applications. Lint yield for plants receiving 13.4 Mg broiler litter ha^{-1} was 40 and 11% greater than those with no broiler litter application under winter cover crop and in winter fallow plots, respectively. Using a cropping system, the magnitude of cotton yield and cotton N utilization responses to added broiler litter was greater for rye winter cover crop than those for winter fallow. Consequently, at the high broiler litter application rate (13.4 Mg broiler litter ha^{-1}), above ground dry matter, N content and cotton lint yield were 6, 10, and 33% greater in rye winter cover crop than those with winter fallow. Contradictory findings were reported by Nyakatawa et al. (2000) who did not find significant increases in cotton yield after planting into rye cover crops as compared to winter fallow. The difference between that study and our study is probably due to difference in time of broiler litter application (spring vs fall), and the fact that Nyakatawa et al. (2000) did not over seed rye winter cover crop to fall applied broiler litter. Therefore, less N was available for rye cover crop as compared with our study. It is possible that in their study the rye winter cover crop grown with no broiler litter applications had greater C/N ratio than the one in our study, indicating greater potential for N immobilization and resulting in decreasing N availability for cotton plants. At the recommended commercial fertilizer application rate, cotton lint yield was 7% greater in rye cover crop plots that those under winter fallow.

Soil residual NO3-N

In spring 2004 after killing cover crop and before planting cotton the soil NO3-N concentrations for the rye winter cover crop in the 0 to 30 cm depth (19-23 mg kg-1) were 50-62% lower than in the winter fallow (38-60 mg kg-1), respectively (Fig. 2). This was attributed to the ability of the rye winter cover crop in sequestering soil NO3-N and to the possible N immobilization by soil microbs during the early stage of winter cover crop residue decomposition (Nyakatawa et al., 2001) minimizing potential leaching of N. Similar results were reported by Sainju et al. (1998) who found lower soil NO3 concentration following a rye cover crop due to its high root density which removed a considerable amount of NO3 from the soil.

In the fall after harvesting cotton soil NO3-N concentrations in the rye-cotton sequential cropping system at the high broiler litter application rate in the 0-60 cm depth (26 mg kg-1) was

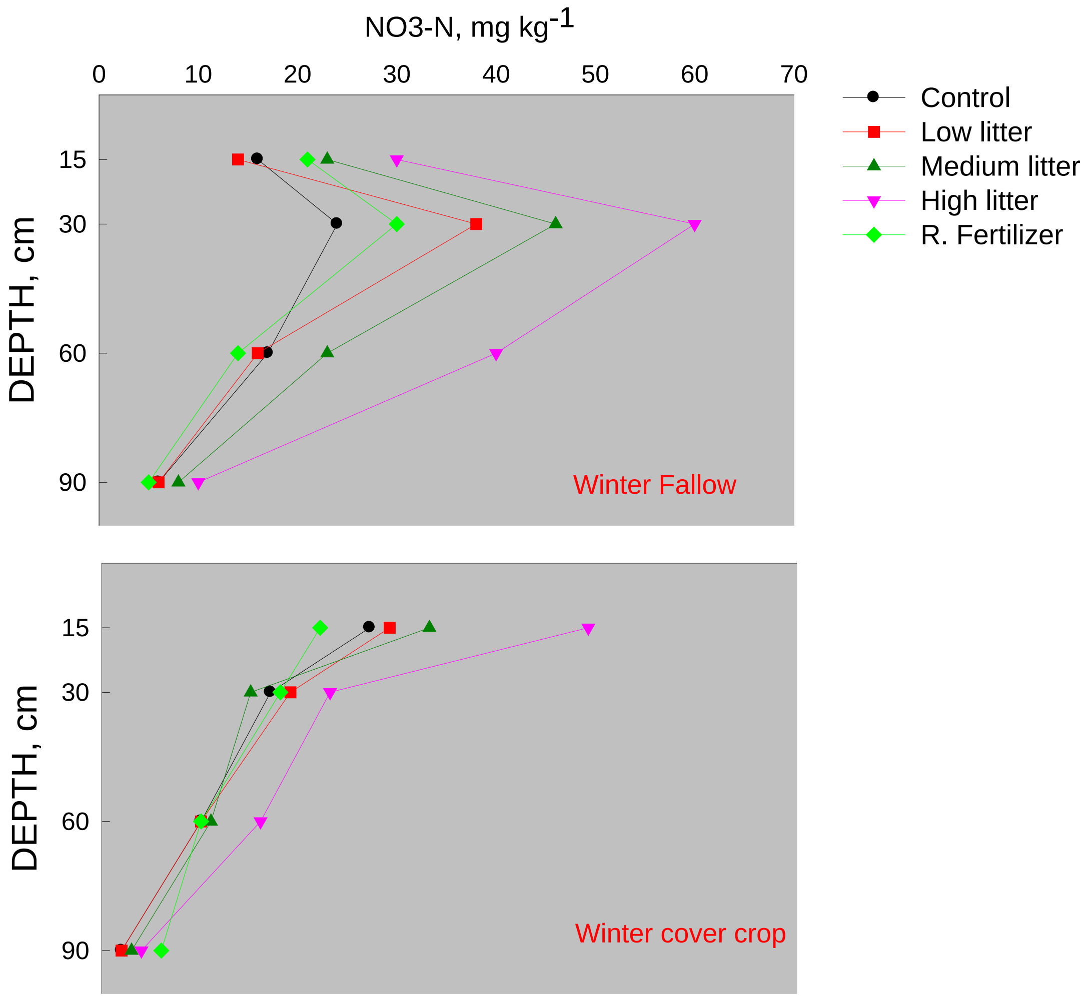

Fig. 2. Spring soil residual NO3-N as affected by the rye winter cover crop and winter fallow in response to fall applied broiler litter.

50% lower in the winter fallow-cotton cropping system (13 mg kg-1) (Fig. 3), reflecting the greater potential for leaching in the winter fallow-cotton cropping system. After cotton harvest in October 2004 in the rye cover crop-cotton cropping system, the soil NO3-N was uniformly distributed in the soil profile and no significant differences in NO3-N concentration was obtained among the broiler litter application rates, suggesting that the high NO3-N content in the soil profile had most likely been depleted by plant uptake.

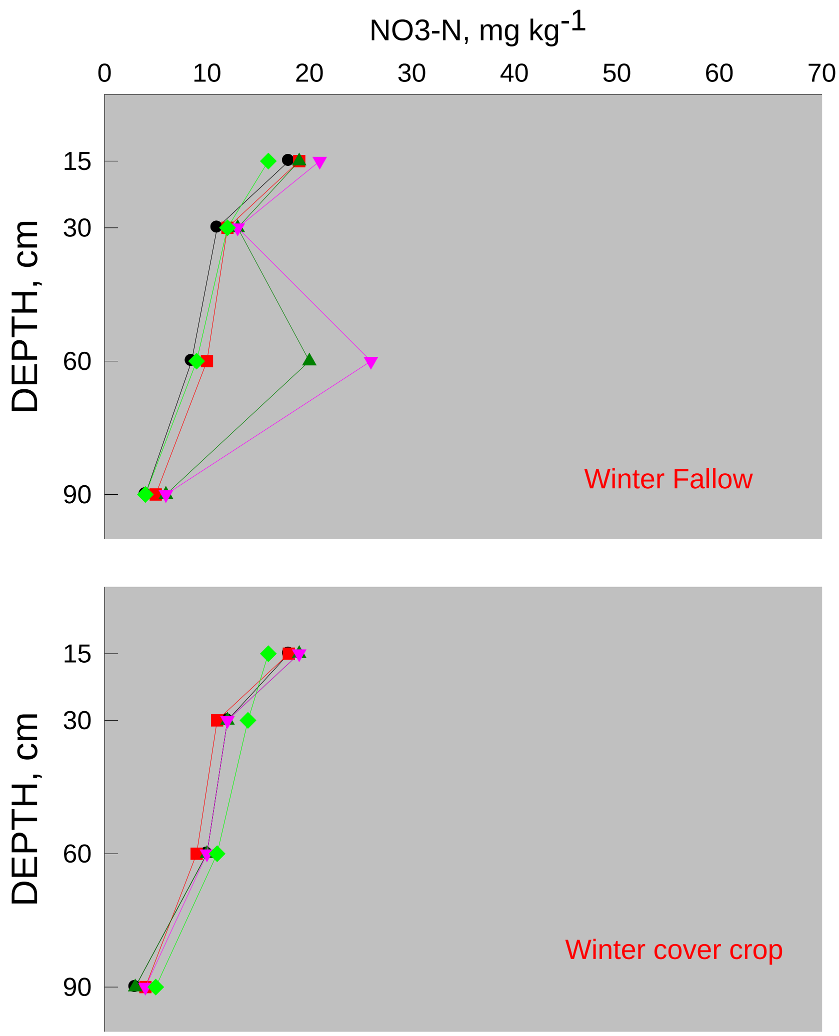

Fig. 3. Effects of rye winter cover crop and winter fallow on post-harvest soil NO_3-N concentrations in response to fall applied broiler litter.

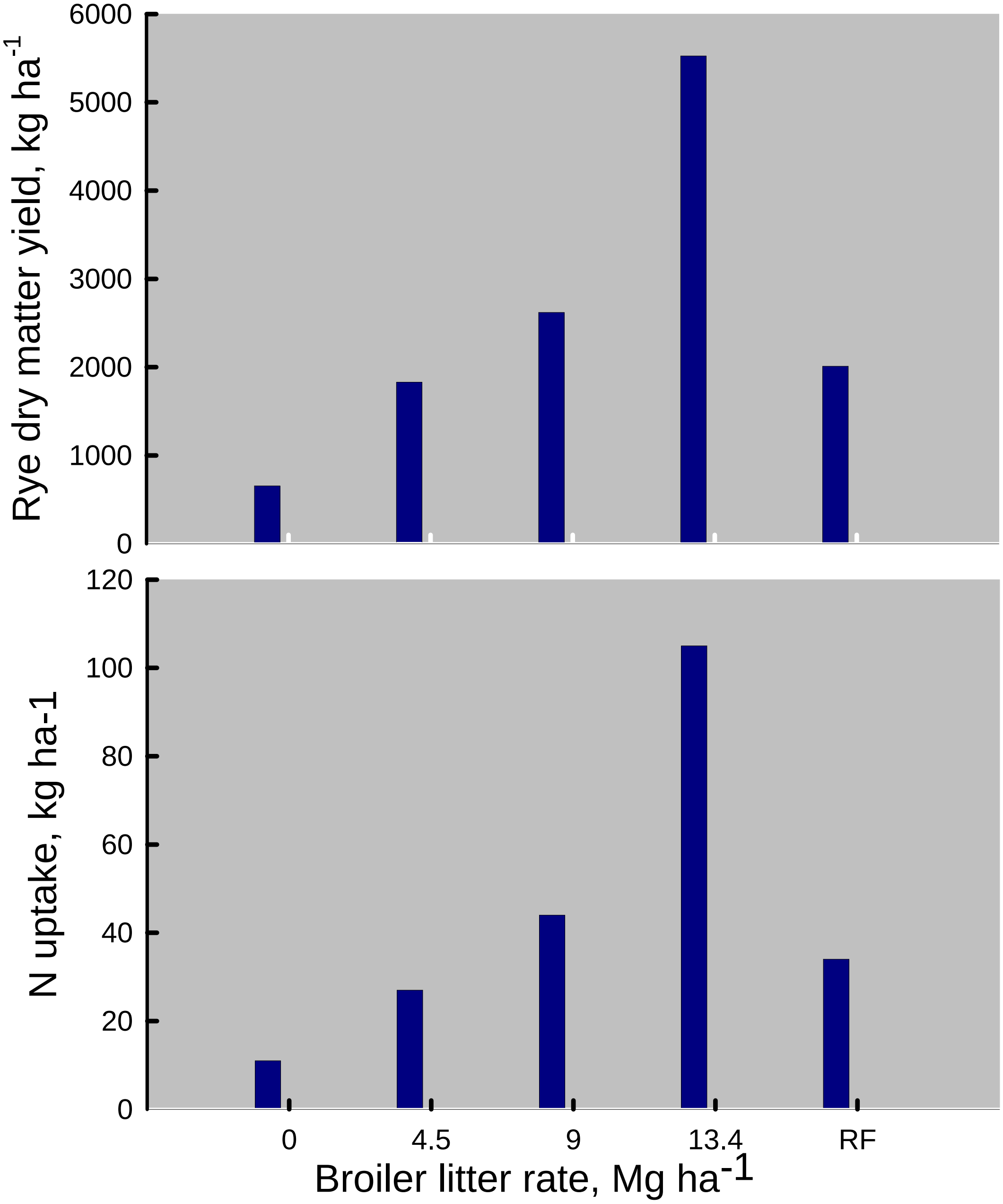

Fig. 4. Rye aboveground biomass production and N utilization from fall applied broiler litter

Conclusions

Results from the first year of this study show that over seeding a catch crop to fall applied broiler litter appeared to be a desirable cultural practice from a N standpoint, maximizing the efficient use of available N from broiler litter applications for subsequent cotton growth and yield and resulting in reduced risk of environmental problems.

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