CONSERVATION TILLAGE AND POULTRY LITTER EFFECTS ON COTTON AND CORN YIELDS: FIVE YEAR RESULTS

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ABSTRACT

The adoption of conservation tillage in the production of cotton (*Gossypium hirsutum* L.) in northern Alabama has been hindered by the poor emergence, reduced seedling growth, delayed maturity, and reduced yield that have been attributed to conservation tillage systems. The objectives of this study were to evaluate the effects of tillage (no-till, mulch-till, conventional till), cropping system (cotton winter fallow without cover crop, cotton with winter rye (*Secale cereale* L.) cover crop) and N source (poultry litter, ammonium nitrate) on growth parameters and yield of cotton and corn in north Alabama. Cotton lint yield under no-till (NT) was 24%, 7%, 24%, and 8% greater than that under conventional till (CT) in 1997, 1998, 2000, and 2001, respectively. Cover cropping increased cotton lint yields by 6 to 12% compared to cotton winter fallow cropping in 2000 and 2001. Poultry litter (PL) at 100 kg N ha^{-1} gave similar cotton lint yield to ammonium nitrate (AN) whereas at 200 kg N ha^{-1}, lint yields were significantly greater than those at 100 kg N ha^{-1} in the form of AN or PL. Residual N from PL applied to cotton in 1997 and 1998 produced up to 17.3 Mg ha^{-1} of corn biomass (includes 7.1 Mg ha^{-1} of corn grain yield) without additional fertilizer. Poultry litter applied to cotton also increased corn grain quality which was shown by up to 100% increase in grain N content compared to the 0N treatment. These treatments would be appropriate for use in the southeastern U.S.A. where soil erosion is a problem and the disposal of PL from the large poultry industry poses an environmental problem.

KEYWORDS

Conventional tillage, mulch tillage, cropping systems,

INTRODUCTION

The adoption of conservation tillage for cotton production in some counties of north Alabama still lags behind that of other parts of the state. Cotton in northern Alabama is largely grown under conventional tillage, which typically includes shredding cotton stalks followed by primary tillage with moldboard or chisel plow in the fall, spring disking or harrowing, and inter-row cultivation for weed control during the cotton growing season. These tillage operations make the soil susceptible to erosion and hasten the depletion of soil organic matter (Bordovsky *et al.*, 1998). No-till can reduce tillage operations by as many as six to eight operations, which reduces equipment, fuel and labor costs, and increases equipment life and profits. In addition, no-till can reduce soil erosion while maintaining or increasing soil productivity (Triplett *et al.*, 1996). However, some farmers who have tried to adopt conservation tillage systems for cotton production in compliance with the 1985 and 1990 Farm Bills (Federal Register, 1987; Food, Agriculture, Conservation, and Trade Act, 1990) have encountered problems. Cotton seedlings are generally weak, and conservation tillage can result in poor seedling establishment and poor crop growth due to soil compaction, resulting in static or reduced cotton yields (Schertz and Kemper, 1994).

Use of cover crops such as winter rye or organic manure such as poultry litter (PL) in conservation tillage systems may improve cotton seedling emergence, growth and yield. Legumes are often unsuitable for use as cover crops in no-till cotton production in north Alabama, because they are difficult to kill, thus delaying cotton planting and reducing yields. In addition, the toxic ammonia produced by legumes can be most injurious to cotton seedlings. Winter rye displays more vigorous growth, winter hardiness, and mulch persistence than any legume cover. Winter rye cover crops may also reduce leaching losses of residual N fertilizer (Kelly *et al.*, 1992; Nyakatawa *et al.*, 2001a) that could contribute to ground water pollution.

Poultry litter is a relatively inexpensive source of nutrients, particularly N and P. Application of PL to croplands is an

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environmentally friendly way of disposing of the large quantities of PL produced on the multitudinous poultry farms in the American South. An abundant supply of PL is available from the sizable poultry industry in the intensive cotton producing areas of northern Alabama. Therefore, the cotton-producing Tennessee Valley region of northern Alabama could benefit greatly from the use of PL fertilizer. Corn is becoming an important crop for the southeastern USA, especially when grown in rotation with cotton, the major cash crop of this region. Rotating cotton with rye and corn breaks the life cycles of cotton's major pests and diseases, and supplies additional residue to increase soil organic matter. The objectives of this study were to evaluate the effects of no-till and mulch-till with winter rye cover cropping and PL on cotton and corn grown in rotation on a Decatur silt loam soil in North Alabama.

MATERIALS AND METHODS

A field experiment involving soil and crop management strategies for Upland cotton production was initiated at the Alabama Agricultural Experiment Station in Belle Mina, Alabama (34° 41' N 86° 52' W) on a Decatur silt loam soil (clayey, kaolinitic thermic, Typic Paleudults) in 1996.

Treatments and Design

The treatments consisted of three tillage systems: conventional till, mulch-till, and no-till; two cropping systems: cotton-winter fallow (cotton in summer and fallow in winter), and cotton-winter rye sequential cropping(cotton in summer and rye (*Secale cereale* L.) in winter); three N levels: 0, 100, and 200 kg N ha^{-1}; and two N sources: ammonium nitrate and fresh poultry litter. Ammonium nitrate was used at one N rate (100 kg N ha^{-1}) only. The experimental design was a randomized Complete Block design with 4 replications. Plots were 8 m wide and 9 m long, totaling 8 rows of cotton, 1 m apart. Conventional tillage was accomplished by moldboard plowing in November and disking in April. A field cultivator was used to prepare a smooth seedbed after disking. On mulch-till plots, a field cultivator was used before planting to destroy and shallowly incorporate rye residue. A no-till planter was used to place seeds in the untilled soil of the no-till plots.

The N content of the poultry litter was determined by digesting 0.5 g samples using the Kjeldhal wet digestion method (Bremner and Mulvaney, 1982) and followed by N analysis using the Kjeltec 1026 N Analyser (Kjeltec, Sweden). The amounts of poultry litter to supply 100 and 200 kg N ha^{-1} were calculated each year based on the N content of the poultry litter. A 60% adjustment factor was used to compensate for the N availability from poultry litter during the first year. Poultry litter was broadcast by hand and incorporated to a depth of 5 to 8 cm by pre-plant cultivation in the conventional and mulch-till systems. In the no-till system, the poultry litter was surface-applied. Ammonium nitrate and poultry litter were applied to the plots 1 day before cotton planting. The experimental plots received a blanket application of 336 kg ha^{-1} of a 0-20-20 fertilizer to nullify the effects of P and K applied through poultry litter.

Crop management

The winter rye cover crop (cv. Oklon) was planted in fall

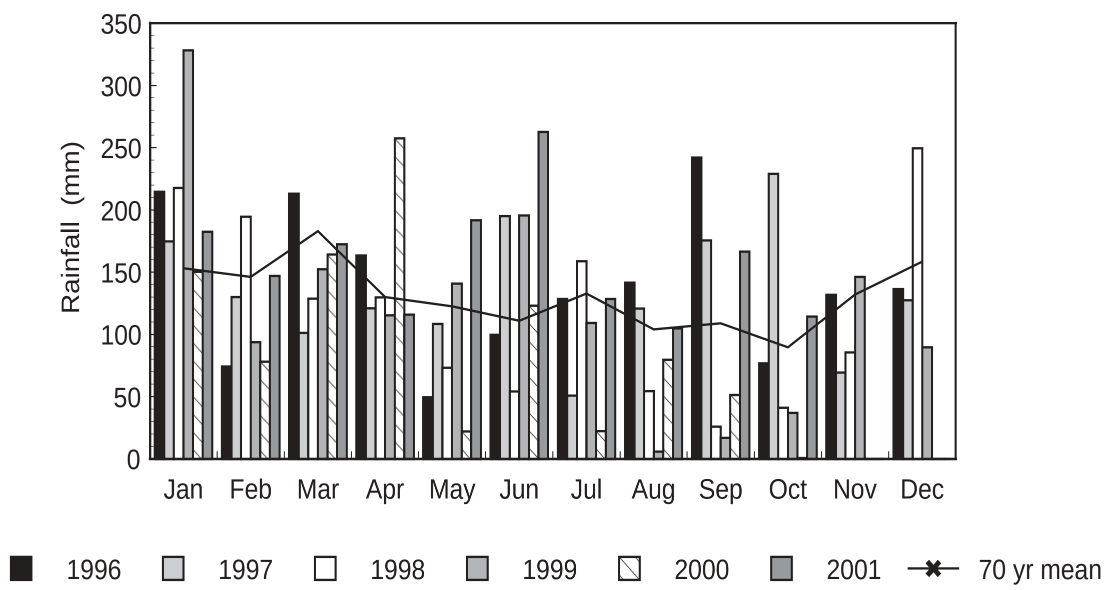

Fig. 1. Total monthly rainfall (mm) and 70-yr mean.

and killed by Roundup herbicide (glyphosate) about 7 days after flowering in spring. A Tye no-till grain drill (Glascock Equipment and Sales, Veedersburg, IN) was used to plant the rye cover crop at 60 kg ha^{-1}. Cotton (cv. Deltapine NuCotn 33B) was planted in all plots at 16 kg ha^{-1}, using a no-till planter. A herbicide mixture of Prowl (pendimethalin) at 2.3 L ha^{-1}, Cotoran (fluometuron) at 3.5 L ha^{-1}, and Gramoxone Extra (paraquat) at 1.7 L ha^{-1} was sprayed on all plots before planting in May for weed control. In addition, all plots received a band application of 5.6 kg ha^{-1} Temik (aldicarb) for early-season control of thrips. During the season, a cultivator was used for weed control in the conventional till system, while spot applications of Roundup using a knapsack sprayer were used to control weeds in the no-till and mulch-till systems. Aphids were controlled by spraying Bidrin (dicrotophos) at 0.4 kg ha^{-1}, and bollworms were controlled with Karate (cypermethrin). A growth regulator (Pix, at 0.8 kg ha^{-1}) was applied to cotton to reduce vegetative growth 2.5 months after planting. The cotton was defoliated with a mixture of Finish at 2.3 L ha^{-1} and Def at 0.6 kg ha^{-1} two weeks before the first harvest. Corn (cv. Dekalb 687™) was planted in all plots using a no-till planter in spring of 1999 and 2002, at a plant population of 30,000 plants $acre^{-1}$. When the corn was about 15 cm tall, each plot was sub-divided lengthwise into three sub-plots, each 3 m long with 8 rows of corn, 1 m apart. Three N treatments (0, 100, and 200 kg N ha^{-1}) were randomly applied to the sub-plots in each main plot. Nitrogen, in the form of AN (34% N) was evenly broadcast by hand in each sub-plot when the soil was moist, five weeks after corn planting.

Data collection

Seed cotton yield was determined by mechanically harvesting open cotton bolls in the four central rows of each plot. Lint yield data were determined by multiplying the seed cotton yield by the ginning percent. At physiological maturity, five corn plants were randomly selected from the four central rows of each plot and cut at ground level. The leaves and stems were dried to constant weight in an oven at 65°C and weighed. Seed weights were adjusted for a moisture content of 15.5%. The weight of the stalks was combined with that of the stems. Each of the grain, leaf, and stem samples were ground to pass through a 2 mm sieve with a Wiley mill (A.H. Thomas Co., Philadelphia, PA). The samples were analysed for total N content using Kjeldhal wet digestion. Nitrogen uptake of the grain, leaf, and stem samples was calculated by multiplying the percent total N by the sample weight, expressed in kg ha^{-1}. Corn grain yield was obtained by manually harvesting ears in the two center rows of each sub-plot. The ears were shelled using a small-plot combine and yield was calculated after adjusting for seed moisture content as before. Rainfall data (Fig. 1) were taken from an automatic weather station at the Experiment Station.

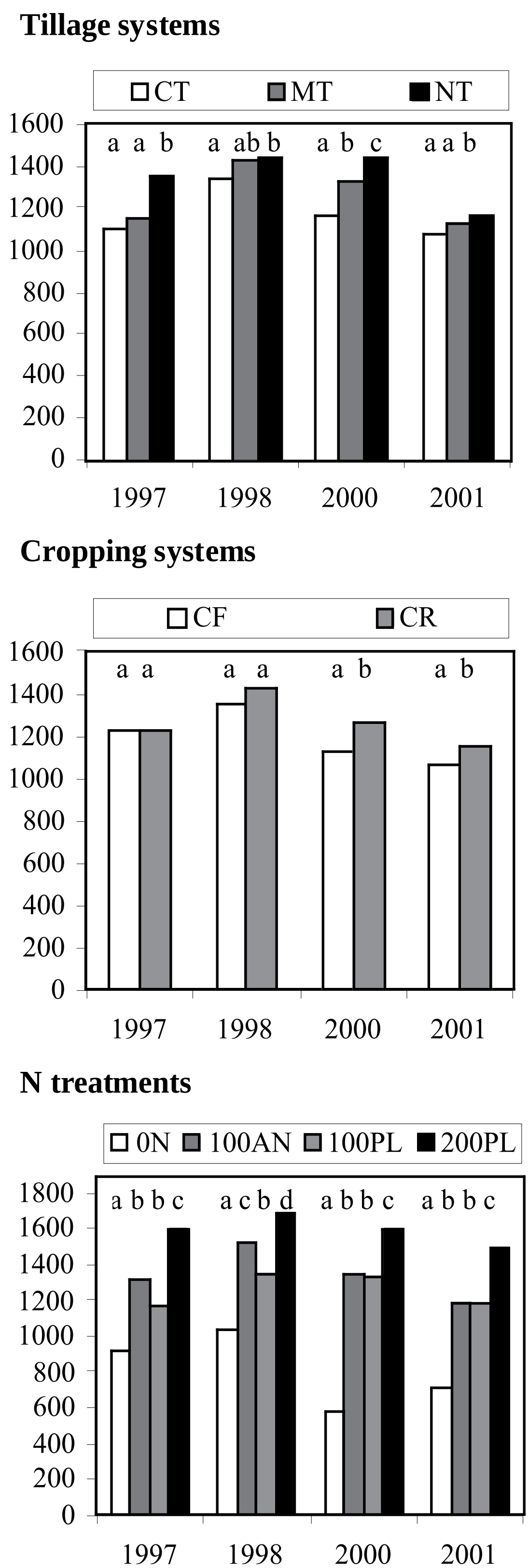

Fig 2. Effect of tillage system, cropping system, and N treatment on seed cotton yield.

Table 1. Means for grain and stover yield of no-till corn as influenced by three applied rates of N (0, 10(and 200 kg N ha^{-1}) in plots previously cropped to cotton under conventional till (CT),mulch-till (MT), no-till (NT) systems, with N from ammonium nitrate (AN) and poultry litter (PL), Belle Mina, AL, 19 (Significance levels of contrast analyses given in parenthesis)

	Tillage treatments applied to cotton from 1996 to 1998		
	CT	MT	NT
Contrast	---------------------------- Stover yield (Mg ha^{-1}) -----------------------------------		
0 vs 100	6.8 vs 13.7 (***)	6.2 vs 15.0 (***)	7.6 vs 15.2 (***)
0 vs 200	6.8 vs 16.0 (***)	6.2 vs 17.8 (***)	7.6 vs 18.9 (***)
100 vs 200	13.7 vs 16.0 (*)	15.0 vs 17.8 (NS)	15.2 vs 18.9 (**)
	-------------------------------- Grain yield (Mg ha^{-1}) --------------------------------- ----		
0 vs 100	5.2 vs 9.5 (***)	5.2 vs 10.4 (***)	5.9 vs 9.3 (***)
0 vs 200	5.2 vs 11.6 (***)	5.2 vs 10.2 (***)	5.9 vs 11.2 (***)
100 vs 200	9.5 vs 11.6 (**)	10.4 vs 10.2 (NS)	9.3 vs 11.2 (***)

	N sources applied to cotton from 1996 to 1998			
	0N	100AN	100PL	200PL
Contrast	------------------------------- Stover yield (Mg ha^{-1}) ---			
0 vs 100	6.4 vs 13.2 (***)	6.8 vs 15.6 (***)	6.9 vs 12.6 (***)	10.2 vs 18.4 (*)
0 vs 200	6.4 vs 15.7 (***)	6.8 vs 17.6 (***)	6.9 vs 17.8 (***)	10.2 vs 21.3 (**)
100vs 200	13.2 vs 15.7 (**)	15.6 vs 17.6 (***)	12.6 vs 17.8 (***)	18.4 vs 21.3 (NS)
	------------------------------------- Grain yield (Mg ha^{-1}) ------------------------------------- -----			
0 vs 100	4.6 vs 9.7 (***)	5.2 vs 9.7 (***)	5.9 vs 9.5 (***)	7.1 vs 8.8 (NS)
0 vs 200	4.6 vs 12.6 (***)	5.2 vs 11.3 (***)	5.9 vs 10.5 (***)	7.1 vs 10.1 (*)
100vs 200	9.7 vs 12.6 (***)	9.7 vs 11.3 (**)	9.5 vs 10.5 (NS)	8.8 vs 10.1 (NS)

*, **, *** significant at 0.05, 0.01, and 0.001 levels, respectively

Statistical analysis

The data were analysed using the General Linear Model procedures of the Statistical Analysis System (SAS, 1987). Main effects of the treatment factors were determined by contrast analysis procedures. Regression analysis was used to determine the response functions of corn yield to N from PL.

RESULTS AND DISCUSSION

COTTON

Cotton lint yield under no-till (NT) was 24%, 7%, 24%, and 8% greater than that under conventional till (CT) in 1997, 1998, 2000, and 2001 respectively (Fig. 2). Improved soil moisture conservation in NT plots was largely responsible for improved lint yields in this system. Results from our study are similar to the findings of Harmen*et al.* (1989), who found a significant increase in cotton lint yield under no-till compared to conventional till on a Sherm clay loam soil in Texas. Cover cropping increased cotton lint yields by 6 - 12% compared to cotton winter fallow cropping in 2000 and 2001 (Fig. 2). Poultry litter (PL) at 100 kg N ha^{-1} generally gave similar cotton lint yield to ammonium nitrate (AN), whereas at 200 kg N ha^{-1}, lint yields were 25 - 38% significantly greater than those at 100 kg N ha^{-1} in the form of AN or PL. Soil moisture measurements in the top 7 cm of the soil taken during the first 4 days of cotton seedling emergence showed a greater volumetric soil moisture content in NT plots compared to CT plots with or without PL (Nyakatawa and Reddy, 2000). Poultry litter improved soil water holding capacity of the soil which resulted in higher soil moisture content in NT and PL plots during dry spells. Residues left at the surface and the mulch provided by PL under NT reduced loss of soil moisture by evaporation which resulted in higher yields in NT and PL plots (Nyakatawa *et al.*, 2001b).

CORN

Application of N at 100 or 200 kg N ha^{-1} to corn in 1999 to plots previously under CT, MT or NT cotton from 1996 to 1998 increased corn stover yield by over 100% compared to no N application (Table 1). In 1999, N applied to

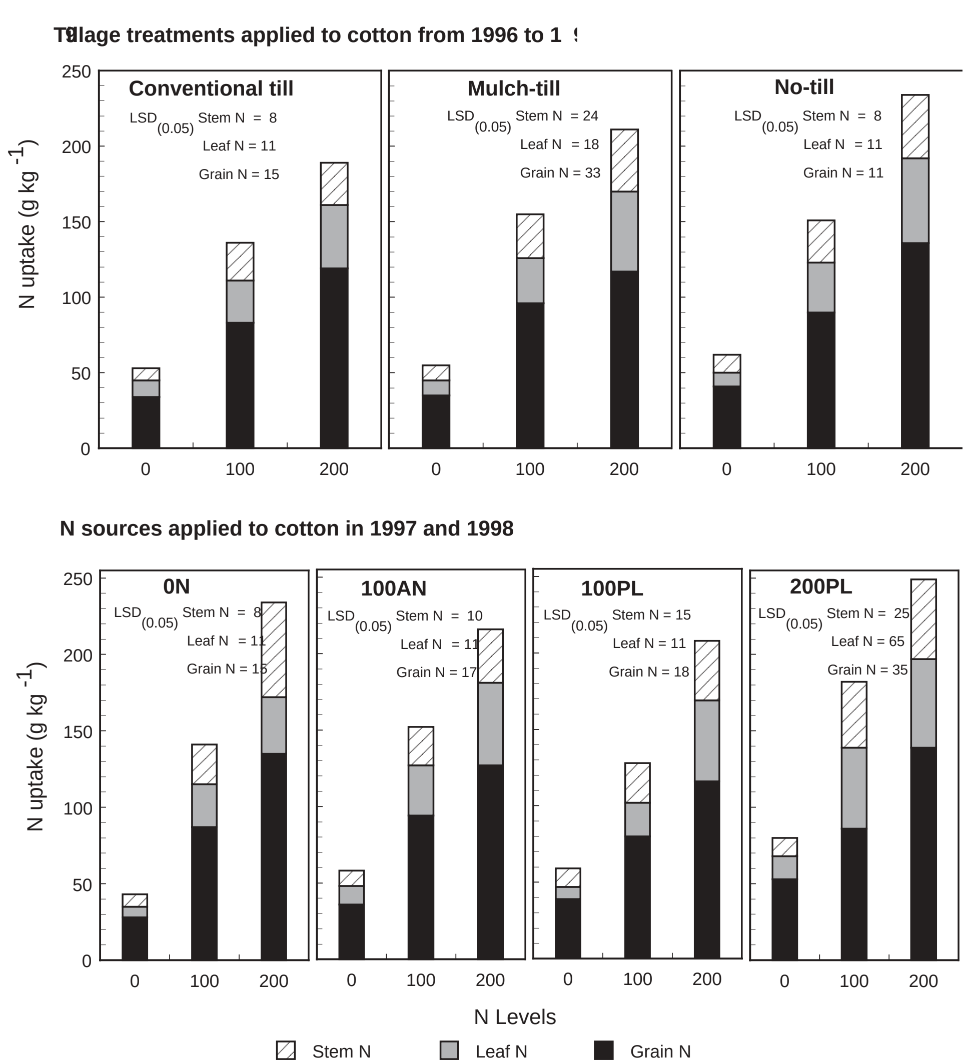

Fig. 3. Effect of tillage system (upper panels) and N-treatment (lower panels) on N uptake of cotton.

corn at 200 kg N ha^{-1} gave significantly greater stover and grain yield, compared to the 100 kg N ha^{-1} N level in plots previously under CT or NT, but not in plots previously under MT. The response of corn stover yield to the 200 kg N ha^{-1} treatment compared to the 100 kg N ha^{-1} N in 1999 was greater in plots previously under NT cotton ($P = 0.01$) compared to that in plots previously under CT cotton ($P = 0.05$). Similar results for the response of corn grain yield to the 200 kg N ha^{-1} treatment in plots previously under NT and CT cotton were significant by $P = 0.001$ and $P = 0.01$, respectively, compared to 100 kg N ha^{-1} treatment. The greater N uptake with N applied to corn in 1999 in plots previously under NT suggests a greater yield potential by corn in plots previously under NT cotton. Our results show that residual N from PL applied to cotton at 100 or 200 kg N ha^{-1} in 1997 and 1998 was capable of meeting about half of the N requirements of the following corn crop in 1999. In addition to reducing costs of fertilizer, this will reduce the amount of nitrate N available for leaching and pollution of surface and ground waters.

At 0, 100, and 200 kg N ha^{-1} levels of 1999, corn grain N concentration in plots previously under NT cotton was, respectively, 21%, 8%, and 14% greater than that in plots previously under CT (Table 1). This suggests that NT applied to cotton from 1996 to 1998 increased corn grain quality compared to CT. Nitrogen applied to the corn crop in 1999 increased grain N uptake at each of the previous 0N, 100AN, 100PL or 200PL N cotton treatments of 1997 and 1998 (Fig. 3). At the 0 kg N ha^{-1} level of 1999, plants in plots which previously received 100PL in 1997 and 1998 under cotton had 14% and 39% higher leaf and grain N concentration, respectively, than those which previously had not received N (Fig. 3). Similar figures for the 200PL treatment of 1997 and 1998 were 114% and 89%, respectively. However, at 100 or 200 kg N ha^{-1} level applied to corn in 1999, there were generally no significant differences in leaf and grain N concentration among the N treatments of 1997 and 1998 (Fig. 3), which suggest that readily available inorganic N satisfied corn N needs.

Quadratic response curves for corn stover yield to N levels applied to corn in 1999 show no gains in stover yield at N levels beyond 200 kg N ha^{-1} in plots which previously received 0N, 100AN and 200 PL (Fig. 4). However, in plots which previously received 100PL, corn stover yield increased linearly with N applied in 1999. Corn grain yield increased linearly with N applied in 1999 in plots which had previously received 100PL or 200 PL under cotton in 1997 and 1998 (Fig. 4). These results suggest that corn in plots which previously received PL under cotton may give higher grain yield at N rates above 200 kg N ha^{-1}. Residual N from PL applied to cotton that slowly becomes available to the corn crop may reduce the amount of N needed to increase corn yields under NT system, thereby reducing nitrate pollution of surface and ground waters.

CONCLUSIONS

Results from our study indicate that NT significantly increased yields of cotton. Poultry litter at 100 kg N ha^{-1} gave similar lint yields to AN. However, at 200 kg N ha^{-1} lint yields were significantly greater than those at 100 kg N ha^{-1} from AN or PL. The PL previously applied to cotton also increased grain and stover yields of corn in1999, which was grown in the same plots following two years of cotton. Inorganic N application to corn in 1999 showed that residual N from PL applied to cotton in 1997 and 1998 was capable of meeting part of the N requirements of the corn, which can reduce N fertilizer costs for the corn and the potential leaching of excess nitrate N. In practical terms, NT, cover cropping, and surface application of PL at 200 kg N ha^{-1} into crop residues will be useful for soil moisture conservation in cotton and corn production systems in the southeastern USA, where erosion is a problem, abundant PL is available, and its disposal is becoming a problem.

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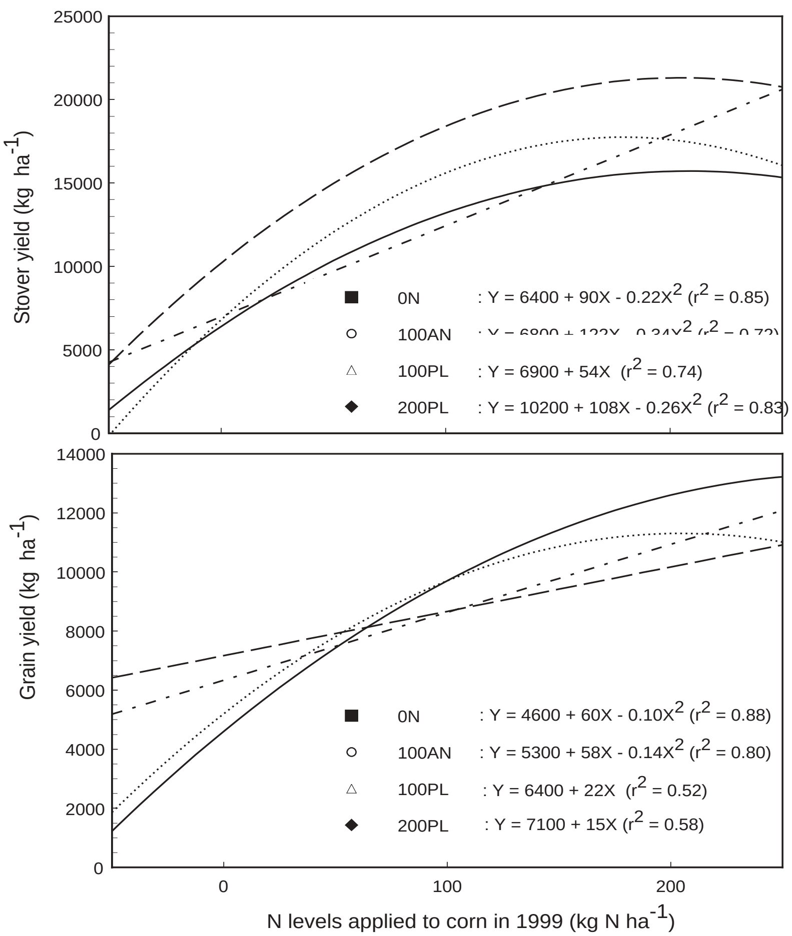

Fig. 4. response functions of corn stover and grain yield to levels of inorganic N (0, 100, 200 kg N ha-1) as influenced by ammonium nitrate (AN) and poultry litter (PL) applied to cotton in 1997 and 1998 at Belle Mina, AL.