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Tillage and Poultry Litter Application Effects on Cotton Growth and Yield

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Adoption of no-tillage cotton production in the southern U.S. increased from about 254,000 ha in 1998 to 784,000 ha in 2002. Conservation-tillage cotton acreage nearly tripled in Alabama and Georgia during this period. A survey by the National Cotton Council of America reported that 57% of the total cotton hectarage in the southeast U.S. was under no-tillage, which resulted in an average savings of $50.03 per ha ($20.13 per acre) for fuel and labor compared with conventional tillage.

Problems reported with no-till cotton include soil compaction, poor seedling emergence, poor plant establishment, stunted growth and reduced yields. Cotton does not produce enough residues to supply the C necessary to increase soil organic matter and improve soil tilth in the seed zone. Also, cotton residues do not last long after harvest to protect the soil from erosion and reduce loss of soil moisture from evaporation. Therefore, without additional residues to supplement cotton residues, soils under no-till cotton may develop a crust at the surface and a compacted layer in the top 5 to 10 cm.

Inclusion of winter cover crops in no-till cotton systems can provide crop residues to make conservation-tillage cotton production systems comply with the standards set by the Natural Resources Conservation Service. Benefits include improving soil water retention, increasing soil organic matter and reducing erosion. Winter cover crops may also reduce nitrate leaching to groundwater by picking up excess nutrients remaining from the summer cotton crop.

Crop rotations of different genus or species improve soil fertility, reduce erosion, reduce the buildup of pests and increase net profits. Corn can be grown as a summer crop in rotation with cotton to break the life cycles of major cotton insect pests and diseases. Corn also supplies additional residues to increase soil organic matter in conservation-tillage cotton production systems. Cotton, corn and winter rye, which are dicot, monocot and monocot respectively, have root systems that complement each other in nutrient uptake when grown in rotation, making them more efficient in using soil nutrients. This may reduce buildup of excess nutrients such as P, which is associated with application of poultry litter based on N content.

Application of poultry litter as a source of N and P has been shown to increase yields of crops such as corn and pastures. Furthermore, our studies have shown that poultry litter improves soil chemical properties compared with inorganic sources of N such as ammonium nitrate. Application of poultry litter to cotton will provide an environmentally sustainable way of disposing of the large quantities of waste in this region.

The objective of this study was to evaluate the effect of tillage systems on growth and yield of cotton grown in rotation with a winter rye cover crop with poultry litter and ammonium nitrate fertilizer application in north Alabama. A field study was conducted at the Alabama Agricultural Experiment Station, Belle Mina, AL, on a Decatur silt loam soil from 1996 to 2001. Treatments consisted of three tillage systems: conventional till, mulch till and no-till; two cropping systems: cotton in summer and fallow in winter and cotton in summer and rye in winter; three N levels: 0, 100 and 200 kg N ha^{-1}; and two N sources: ammonium nitrate and poultry litter. Ammonium nitrate was used at one N rate (100 kg N ha^{-1}), which is the recommended rate for cotton in the Tennessee Valley region.

Poultry litter was broadcast by hand and incorporated to a depth of 5 to 8 cm by preplant cultivation in conventional tillage and mulch tillage systems, whereas in the no-tillage system, it was not incorporated. The ammonium nitrate and poultry litter were applied to the plots 1 day before cotton planting. Before planting, the plots received a blanket application of 336 kg ha^{-1} of a 0–20–20 fertilizer each year from 1996 to 1999, 112 kg ha^{-1} of a 0–0–60 fertilizer in 2000, and 224 kg ha^{-1} of 5–20–20 fertilizer in 2001 and 2002 to minimize the effects of P and K applied through poultry litter.

RESULTS AND DISCUSSION

The years 1998, 2000 and 2001 had poor rainfall distribution for cotton. The years 1998 and 2000 were characterized by droughts in May or June and/or July while 2001 had excess rainfall over the same period.

Winter Rye and Surface Residue Cover. In 1998 winter rye biomass yield in plots that had received 100 and 200 kg N ha^{-1} in the form of poultry litter under cotton was 112% and 130% greater than in plots that received 100 kg N ha^{-1} in the form of ammonium nitrate, respectively. Similar figures in 2000 were 14% and 68% greater, and in 2001, 50% and 150% greater, respectively. Cumulative winter rye cover crop biomass yields due to application of 100 kg N ha^{-1} in the form of ammonium nitrate, 100 kg N ha^{-1} in the form of poultry litter, and 200 kg N ha^{-1} in the form of poultry litter were 4,329, 5,402 and 7,638 kg ha^{-1}, respectively.

The above data show that poultry litter application to cotton has more residual positive effects on the amount of biomass produced by the winter rye cover crop compared with ammonium nitrate when used at the same rate of 100 kg N ha^{-1}. The significance of these results is that since the winter rye crop is grown without additional fertilizer, it can scavenge residual N from the poultry litter, which would otherwise be susceptible to leaching during the winter and spring. The winter rye cover crop may also reduce sediment loss of P from the plots by tying P in plant biomass during the winter when there is no cotton.

There was a significant year x tillage x cropping system interaction on surface residue cover estimated immediately after cotton planting. Surface residue cover immediately after cotton planting in conventional tillage with winter rye cover cropping was 20% and 13% in 1997 and 1998, respectively, compared with 1% in conventional tillage with winter fallow. Similar values for 2000 and 2001 were 36% and 34%, respectively, in conventional tillage with winter rye cover cropping compared with an average of 5% in conventional tillage with winter fallow cropping.

There was a significant tillage x N source interaction on surface residue cover immediately after cotton planting. In the conventional tillage system, where crop residues were incorporated into the soil, application of 100 kg N ha^{-1} in the form of poultry litter increased surface residue cover to 30% compared with 23% for 100 kg N ha^{-1} in the form of ammonium nitrate. However, in mulch tillage and no-tillage systems, where crop residues were either partially incorporated into the soil or not incorporated at all, there was no improvement in surface residue cover due to application of poultry litter compared with ammonium nitrate. This was expected since a greater proportion of the soil surface would already be covered with crop residues under mulch tillage and no-tillage systems and should not be taken to imply that application of poultry litter did not increase the amount of residues left on the soil surface.

Our results suggest that surface application of poultry litter instead of ammonium nitrate can offer further protection to the soil against erosion in a conventional tillage system.

Cotton Seedling Emergence and Establishment. Inadequate cotton seedling emergence and establishment and consequently variable crop stands have been blamed for poor adoption of conservation tillage in cotton production for the southeastern U.S. There was a significant year x tillage system interaction on cotton seedling counts. Cotton seedling counts under conventional tillage averaged over cover cropping systems and N treatments were similar to those under no-tillage and mulch tillage systems in each year of study. The rate of emergence in no-till was significantly greater than that in conventional tillage. Also, in plots that received 100 kg N ha^{-1} in the form of poultry litter and 200 kg N ha^{-1} in the form of poultry litter, rate of seedling emergence was significantly greater than in plots that did not receive N and plots that received 100 kg N ha^{-1} in the form of ammonium nitrate in all years. This was attributed to higher volumetric soil moisture content in the top 7 to 10 cm of the soil. The optimum number for cotton seedling establishment is about 10 plants m^{-1}. Our results show that final cotton seedling counts were in this optimum range in 1997 and 2001. In 1998 and 2000, when soil moisture was most limiting during seedling emergence, surface residue cover was positively correlated with final cotton seedling counts, which in turn were positively correlated to leaf area index, number of bolls per plant, biomass and lint yield.

COTTON GROWTH AND YIELD PARAMETERS

Plant Height — There was a significant year x tillage system and year x N source interaction on cotton plant height. In 1997, plant height under no-tillage was 10 cm greater than under conventional tillage. This can be attributed to the fact that no-tillage improved cotton growth by conserving soil moisture during the drought period of July 1997. Cotton plant height for plants that received 100 kg N ha^{-1} in the form of ammonium nitrate was 20, 12 and 15 cm greater than plants in plots that received 100 kg N ha^{-1} in the form of poultry litter in 1997, 1998 and 2001, respectively. However, in 2000 there were no differences in plant height between plants that received 100 kg N ha^{-1} in the form of ammonium nitrate and those that received 100 kg N ha^{-1} in the form of poultry litter, which may indicate poultry litter was able to compensate for lower nutrient availability by conserving soil moisture during the dry spells of May and July. Plant height significantly correlated with number of bolls per plant, biomass yield and lint yield over the 4-year period, indicating plant height is a good indicator of cotton productivity.

Leaf Area Index — There was a significant tillage x cropping system and year x N source interaction on cotton leaf area index at full bloom. In conventional tillage plots, cotton leaf area index was 5.80 with winter rye cover cropping compared with 4.80 without winter rye cover cropping. However, in no-till with winter rye cover cropping, cotton leaf area index was 5.30, which was only 0.2 units higher compared with winter fallow cropping. Cotton following winter rye had higher leaf area index compared with cotton after winter fallow, but differences were not significant. Also, cotton leaf area index for cotton winter rye cropping system under conventional tillage was 0.5 units higher than that under no-till. Leaf area index for plants that received 100 kg N ha^{-1} in the form of ammonium nitrate was 1.90, 1.00 and 1.40 units greater than for plants that received 100 kg N ha^{-1} in the form of poultry litter in 1997, 1998 and 2001, respectively. Leaf area index is a good indicator of plant growth and soil conditions for plant productivity, and it positively correlated with bolls per plant, biomass yield and lint yield.

Number of Bolls per Plant — There was significant tillage x cropping system, tillage x N source and year x tillage interaction on number of cotton bolls per plant. In no-tillage system, winter rye cover cropping increased the number of bolls per plant by 7 compared with cotton winter fallow cropping, which had 21 bolls per plant. However, in conventional tillage, winter rye cover cropping did not have a significant effect on bolls per plant. Without rye cover cropping, no-tillage had slightly lower bolls per plant compared with conventional tillage. However, with rye cover cropping, no-till had, on average, 6 more bolls per plant compared with conventional tillage, showing that rye cover cropping was essential to the reproductive development of cotton under no-tillage system.

In mulch tillage and no-till plots, plants that received 100 kg N ha^{-1} in the form of ammonium nitrate had 9 and 8 more bolls per plant compared with plants that received 100 kg N ha^{-1} in the form of poultry litter, respectively. No-tillage system had 4 and 2 more bolls per plant compared with conventional tillage system in 1997 and 2001, respectively. Number of bolls per plant positively correlated with cotton biomass yield and lint yield.

Lint Yield — There was significant year x N source and tillage x N source interaction on cotton lint yield. In 1998 cotton lint yield in plots that received 100 kg N ha^{-1} in the form of ammonium nitrate averaged 1,536 kg ha^{-1}, which was 19%, 15% and 34% greater than lint yields in 1997, 2000 and 2001, respectively. In plots that received 100 kg N ha^{-1} in the form of poultry litter, the highest lint yield was 1,354 kg ha^{-1} in 1998, which was 17% and 15% greater than lint yields in 1997 and 2001. This variation in yield responses in each year can be explained in terms of rainfall distribution during May, June and August.

There were no significant differences in cotton lint yield between 100 kg N ha^{-1} ammonium nitrate and 100 kg N ha^{-1} poultry litter treatments in plots under conventional tillage system. However, for mulch tillage and no-tillage systems, plants in plots that received 100 kg N ha^{-1} ammonium nitrate had 12% and 11% higher lint yield compared with plots that received 100 kg N ha^{-1} poultry litter, respectively. In plots that received 100 kg N ha^{-1} in the form of ammonium nitrate, lint yield in mulch tillage and no-tillage systems was 7% and 13% greater than in conventional tillage. However, in plots that received 100 kg N ha^{-1} in the form of poultry litter, lint yield in conventional tillage system was 12% greater than under mulch tillage system and 4% greater than under no-till. These results can be attributed to the fact that soil incorporation of poultry litter under conventional tillage speeds up mineralization whereas in mulch tillage and no-tillage systems, poultry litter mineralization is slower. In no-tillage with winter rye cropping, lint yields averaged about 100 kg ha^{-1} greater than in no-tillage with winter fallow cropping during the same period. Compared with conventional tillage with winter fallow cropping, lint yields in no-tillage with winter rye cropping averaged 137 kg ha^{-1} higher during the study period.

The key to increasing cotton lint yields is using conservation tillage (mulch-till or no-till) with adequate N fertility and soil moisture in the critical stages of cotton growth and development; namely, seedling emergence, squaring, flowering and boll development to maturity. These stages include the months of May, June, July and August. Benefits of conservation tillage are mainly a result of keeping crop residues on the soil surface, which improves the plant environment by holding additional moisture. This will further improve soil organic matter and reduce soil erosion.

Breaking up and incorporation of crop residues during tillage leaves little or no residue on the surface. Therefore, the benefits of cover cropping such as reduction in surface evaporation and erosion control are diminished. In addition, crop residue incorporation results in immobilization of inorganic N, which affects early plant growth. Tillage promotes oxidation of crop residues and soil organic matter, which are important in soil moisture conservation. Therefore, for benefits of cover cropping to be realized, crop residues need to be left intact on the soil surface to reduce soil moisture evaporation and also to slow down the rate of decomposition. Without winter rye cover cropping, no-tillage with 100 kg N ha^{-1} gave similar or slightly lower yields compared with conventional tillage with the same N rate of 100 kg N ha^{-1}.

Nitrogen application in the form of ammonium nitrate or poultry litter significantly increased cotton lint yield in conventional tillage except for the 100 kg N ha^{-1} in the form of poultry litter treatment in 1997. In mulch tillage plots where poultry litter was incorporated into the soil, there were no significant differences in lint yields between the 100 kg N ha^{-1} in the form of ammonium nitrate and the 100 kg N ha^{-1} in the form of poultry litter treatments in all years. With 200 kg N ha^{-1} of poultry litter and cotton winter rye cover cropping, lint yields under no-tillage were up to 28% (or 351 kg N ha^{-1}) greater than under conventional tillage with 100 kg N ha^{-1} of ammonium nitrate and winter rye cover cropping. However, with 100 kg N ha^{-1} of poultry litter, no-till did not do better than conventional tillage with 100 kg N ha^{-1} in the form of ammonium nitrate, which further supports the need for adequate N fertilization in no-tillage.

SUMMARY

Mulch tillage and no-tillage systems did not have adverse effects on cotton seedling emergence and establishment compared with conventional tillage, contrary to previous reports. Generally, cotton growth parameters in plots that received the same rate of N in the form of ammonium nitrate were better than those that received poultry litter. However, during drought years, no-tillage compensated for reduced availability of N from poultry litter by conserving soil moisture. In the no-tillage system, winter rye cover cropping significantly increased number of cotton bolls compared with winter fallow cropping. Use of no-tillage without a cover crop in cotton production may not give significant benefits. Rainfall distribution in May, June, July and August had significant effect on cotton lint yields. Similarly to what was observed with cotton growth parameters, application of poultry litter at the rate of 100 kg N ha^{-1} generally gave lower or similar cotton lint yield compared with ammonium nitrate at the same rate, whereas at 200 kg N ha^{-1}, lint yields were significantly greater than those at 100 kg N ha^{-1}, irrespective of the N source.

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May/June Self-Study Examination

DETACH HERE

1. During the period from 1998 to 2002, no-till cotton acreage in the southern U.S.

[ ] a. decreased.
[ ] b. stayed the same.
[ ] c. doubled.
[ ] d. tripled.

2. Seedling emergence may be compromised in no-till continuous cotton because of

[ ] a. soil crusting.
[ ] b. heavy residue cover.
[ ] c. nitrogen tie-up.
[ ] d. allelopathy.

3. A reason to use a winter rye cover crop in a no-till cotton production system is to

[ ] a. increase soil organic matter.
[ ] b. increase residual soil nitrates available to following crops.
[ ] c. break cotton insect and disease cycles.
[ ] d. eliminate herbicide carryover.

4. This research study of tillage and poultry litter application included

[ ] a. four nitrogen levels.
[ ] b. two nitrogen sources.
[ ] c. two types of poultry litter.
[ ] d. three site/years.

5. Growth of a winter rye cover crop in this study was highest using a nitrogen source of

[ ] a. poultry litter.
[ ] b. ammonium nitrate.
[ ] c. anhydrous ammonia.
[ ] d. diammonium phosphate.

6. Cotton plant height is a good indicator of

[ ] a. lint yield.
[ ] b. lint quality.
[ ] c. tillage system used.
[ ] d. boll size.

7. At 100 kg N ha^{-1} applied as poultry litter, the highest yields came from

[ ] a. subsurface banding.
[ ] b. mulch tillage.
[ ] c. no-till.
[ ] d. conventional tillage.

8. As compared to ammonium nitrate treatments in conventional tillage, lint yields using poultry litter in conventional tillage were

[ ] a. similar.
[ ] b. higher.
[ ] c. lower.
[ ] d. much lower.

Over

9. As compared to cotton after winter fallow, the leaf area index of cotton following winter rye was
[ ] a. significantly lower.
[ ] b. slightly lower.
[ ] c. slightly higher.
[ ] d. the same.

10. The most important months for cotton to benefit from adequate soil moisture include
[ ] a. April, May, June, and July.
[ ] b. May, June, July, and August.
[ ] c. July, August, and September.
[ ] d. August, September, and October.

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