Cotton Yield Potential With Conservation Tillage in the Southeastern USA

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ABSTRACT

There is a national drive in the USA to have 50% of the cropped area under conservation tillage by 2002. Benefits credited to conservation tillage include soil and water conservation, lower production costs and greater production efficiency. The southeastern USA has generally lagged behind the Great Plains states in adoption of this technology. Much of the row-crop agriculture in the Southeast, including cotton (*Gossipium hirsutum L*.), is conventionally tilled and fertilized. Cotton is a dominant crop in the Southeast and has steadily increased in area in recent years. But only about 12% of the 0.62 million hectares of cotton in Georgia, for example, is under conservation tillage. We evaluated the performance of cotton under two tillage and two fertilizer treatments to highlight management options for increased adoption of conservation tillage. Three years of research was conducted, beginning in 1996, under a factorial arrangement of tillage (no-till, as conservation tillage, vs conventional tillage) and fertilizer (ammonium nitrate, as conventional fertilizer, vs poultry litter) on a Cecil sandy loam (Clayey, kaolinitic thermic Typic Kanhapludults) near Watkinsville, GA. Lint yield from the no-till exceeded that from the conventional tillage cotton by 28% over three years ($P = 0.0002$). Fertilizing with poultry litter produced 11% more lint ($P= 0.046$) than with conventional fertilizer. Yield from no-till cotton fertilized with poultry litter exceeded that from conventional tillage fertilized with ammonium nitrate by 43% ($P = 0.0003$). Cotton production in the Southeast could be enhanced by using no-till and fertilizing with poultry litter instead of tilling and fertilizing conventionally.

INTRODUCTION

Conservation tillage is any tillage and planting system that leaves 30% or more of crop residue on the soil surface after planting (CTIC, 1998). A cover crop is required in many instances to achieve this level of residue. The USA led the world in developing and using this technology but is now lagging behind competing countries like Canada, Brazil, and Argentina in adoption rates (CTIC, 1998). Nationally, approximately 37% of crops were planted with conservation tillage in 1998 compared to approximately 35% in 1993. There is a coordinated national drive in the USA to increase the use of conservation tillage to 50% of the cropped area by 2002. The system is credited with maintaining or increasing yield, reducing overall production costs, arresting or reversing soil degradation processes and reducing nutrient and pesticide losses by reducing runoff volume (increased infiltration) and soil loss (CTIC, 1998; Domitruk and Crabtree, 1997; Golabi et al., 1995; Langdale et al., 1979; Radcliffe et al., 1998). Technological innovation in conservation tillage implements and products and the need for conservation compliance have also played a part in its increased adoption in the USA.

Much of the agriculture in the Southeast, however, is based on clean-tilled crops grown on sloping land. These crops are grown on soils that are relatively infertile, highly erodible, low in organic matter, and easily compacted by rainfall and machine traffic (Carreker et al., 1977). The soils respond well, however, to good management practices, including adequate levels of nutrients, and cropping systems that restore organic matter and soil structure, increase available water and reduce machine traffic. While conservation tillage is such a cropping system, there is only about 12% adoption in the Southeast (CTIC, 1998).

Cotton and poultry productions are of great economic importance in the Southeast (Rodekohr and Rahn, 1997) and continued rapid growth is projected for both. Improved markets and the boll weevil eradication program has lead to steady increase in cotton acreage in states like Georgia since the mid 1980s. Close to 0.62 million hectares of cotton was grown in Georgia in 1995 compared to 0.11 million hectares 1985. Broiler production is a $10 billion agribusiness in Georgia. An enormous quantity of litter is produced from such a large enterprise some of which can beneficially be used as nutrient source in the increasing cotton hectareage.

The performance of cotton on the dominant soils in the Southeast under different tillage and nutrient management systems is not well researched, although considerable experience is accumulating with regard to no-till (one form of conservation tillage) production of cotton on the alluvial and loess soil of Arkansas, Louisiana, Mississippi, and Tennessee (eg. Keisling et al., 1992; Kennedy and Hutchinson, 1993). The objective of this research was to evaluate yield potentials of no-till cotton fertilized with poultry litter compared to that of conventional tillage cotton fertilized with ammonium nitrate, as conventional fertilizer, on a Cecil soil, the dominant soil series in the Piedmont of southeast USA.

MATERIALS AND METHODS

The experiment was conducted in 1996, 1997, and 1998 at the USDA-ARS, J. Phil Campbell, Senior, Natural Resource Conservation Center, Watkinsville, GA (33º54' N lat and 83º24' W long). Factorial combinations of two tillage (no-till vs conventional tillage) and two fertilizer treatments (ammonium nitrate

vs poultry litter), each replicated three times, were imposed in a completely randomized block design on 12 instrumented tile-drained plots, each 10 m by 30 m, located on nearly level (0-2% slope) Cecil sandy loam (Clayey, Kaolinitic thermic Typic Kanhapludults). The tillage treatment had been imposed on the 12 plots since April 1992, for an earlier study.

The conventional tillage consisted of chisel plowing and disking while no-till consisted of coulter planter use only. Nitrogen-based fertilizers were applied at rates of approximately 60 kg available N ha^{-1}. The rate of poultry litter to achieve this level of N was 4.5 Mg ha^{-1} (30% moisture on dry basis) assuming 50 percent mineralization. Potassium was applied based on soil test results. Phosphorous was not applied as soil test results established no need. Cotton pesticides were: Aldicarb (Temik), insecticide for control of thrips and nematodes, at 4.4 kg ha^{-1} (4 lb $acre^{-1}$), Fluometuron (Cotoran), a broadleaf herbicide, at 2.34 L ha^{-1} (2 pt $acre^{-1}$), and Pendimethalin (Prowl), a herbicide for control of annual grass and broadleaf weeds, at 1.75 L ha^{-1} (1.5 pt $acre^{-1}$). Fertilizers and pesticides were applied just before planting and were incorporated into the soil by light disking immediately afterwards in conventional tillage but not in no-till treatment.

In 1996 and 1997, Stoneville 474 variety cotton was planted in 0.86 m (34") rows at 10 to 13 plants per meter. The cotton was planted on 30 May 1996 and 14 May 1997, and was harvested on 1 November 1996 and 4 November 1997. In 1998, cotton was planted in 0.76 m (30") rows on 14 May and was harvested on 12 November. A 'Troy Bilt Rototiller' was used for weed control in conventional till plots about three weeks after germination and one month later. No-till plots were sprayed with 0.73 L ha^{-1} (10 oz $acre^{-1}$) of Fusillade for grass and weed control. Roundup at a rate of 2.36 L ha^{-1} (1 qt $acre^{-1}$) was also used in no-till plots at localized spots of weed/grass infestation. Pix, a growth regulator, was applied to all plots at the rate of 0.58 L ha^{-1} (8 oz $acre^{-1}$) soon after first bloom and 10 days later. Harvade and Prep at rates of 0.58 L ha^{-1} and 1.17 L ha^{-1} (1 pint $acre^{-1}$), respectively, were used as defoliant and boll opener, respectively, and were applied two weeks prior to harvest by a cotton picker. Rye was used as cover crop each winter.

Soil water use was monitored over the cotton growing period in 1998 in one plot from each treatment - 4 total. Each plot was instrumented with two probes of a TDR-based Moisture Point System of Environmental Sensors Inc. (ESI, Victoria, British Columbia, Canada). The system read average soil water content of the 0-0.15, 0.15-0.30, 0.30-0.60, 0.60-0.90, and 0.90-1.20 m depth. Measurements were taken two to three times per week from each of the two probes in each plot and then averaged to give the soil water content per plot. Changes in soil water content between two readings (positive or negative) were cumulatively added to give the temporal net soil moisture change from each plot. Dry plant weights for leaf, petiole, stem and bolls were determined from six randomly selected plants per plot just before harvest from the 1998 crop. Plants were sampled, separated into different plant parts, dried in an oven and weighed. Plant height and leaf area were also measured.

Yield data were analyzed as random complete block with a factorial arrangement of treatments, and repeated measures design using MIXED procedure of SAS (Little et al., 1996). Three variance groupings were created based on checks on homogeneity of variance associated with treatments and were included in the statistical analysis by using the grouping option on the repeated statement.

RESULTS
Lint Yield

Average yield from each treatment for each of the three years is presented in Figure 1. Yield from no-till and poultry litter treatments exceeded that from conventional tillage and conventional fertilizer treatments each year. In plots under conventional fertilizer treatment, no-till produced 34.8, 30.6, and 32.4 % higher yield than conventional tillage in 1996, 1997 and 1998, respectively (Average 32.4%, P = 0.001). In plots under poultry litter treatment, the equivalent yield increments were 19.9, 13.2 and 39.3% (Average 24.1%, P = 0.018). In the no-till treatment, plots that received poultry litter produced 6.3, 3.6, and 13.4% higher yield than those receiving conventional fertilizer for the three consecutive years (Average 7.8%, P = 0.246). In the conventional tillage treatments, plots that received poultry litter had 19.5, 19.5, and 7.8% higher yield than those that received conventional fertilizer for the three consecutive years (Average 15.6%, P = 0.093). No-till cotton fertilized with poultry litter produced 43.2, 35.3, and 50.2% higher yield than conventional tillage cotton fertilized with ammonium nitrate in 1996, 1997 and 1998, respectively (Average 42.9%, P = 0.0003). Year had significant effect on yield (P = 0.0006). No interaction was observed between treatments. Differences are considered significant if P is less than 0.05.

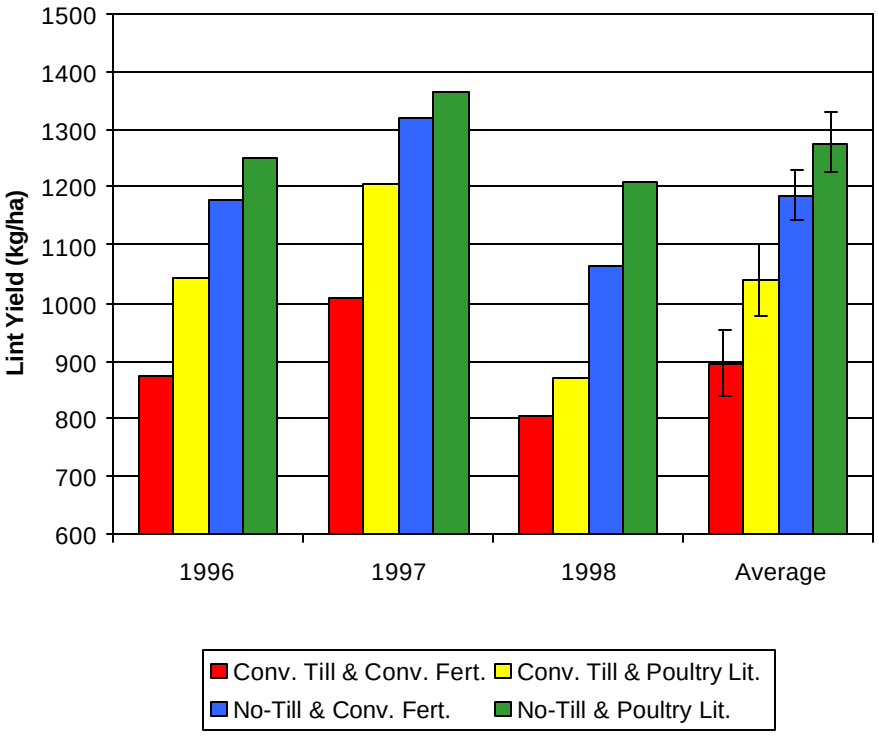

Fig. 1. Lint yield in kg ha^{-1} across treatments for 1996, 19967, 1998, and the average over the three years with standard error bars.

Biomass

Treatment differences also lead to differences in overall vigor of growth of cotton. In general, cotton in no-till plots was taller and had more biomass by first bloom than cotton in conventional tillage plots. The contrast was greater between no-till-poultry-litter and the other treatments. Result from the 1998 sampling is given in Table 1. This table shows that plant height, leaf area index, and average dry weights of petiole, leaf, stem, and bolls were between 17 and 60% higher in no-till than in conventional tillage plots. Differences were higher (39 to 98%) between no-till-poultry-litter and conventional-tillage-conventional-fertilizer treatments. The largest differences were for stems and bolls. Statistical significance was analyzed with the General Linear Models procedure of SAS (SAS Inst., 1990). All the differences except for CT vs NT petiole are significant at the 95% probability level.

Soil water use

Cumulative net soil water change between June 8, and November 4, 1998 for all depths is presented in Figure 2. Temporal net soil water change in the 0-0.15 m depth during the same period is shown in Figure 3. Generally there was more net change from no-till than conventional tillage plots. Most of the negative change was due to evapotranspiration (limited drainage events during the period) indicating greater availability of soil water from no-till. The average net change was 3.71 time more in no-till than conventional tillage plots in the 0-0.15 m depth. In the subsequent depths, it was 1.26, 1.53, 3.72, and 5.32 times more, respectively. About 68% of the change for no-till and 83% of the change for conventional tillage plots occurred in the 0-0.60 m depth. In the 0.60-0.90 m depth, the equivalent change was about 22 and 13%. There was very little change below 0.90 m (10% no-till and 4% conventional tillage). The poultry litter treated plots had slightly more change than those under conventional fertilizer treatment.

Table 1. Average plant height, leaf area, and biomass dry weight for 1998 for six randomly selected plants from one each of conventional tillage (CT), no-till (NT), conventional tillage and conventional fertilizer (CTCF) and no-till and poultry litter (NTPL) treatment plots.

Treatment	Plant	Leaf Area	Average dry weight in g†			
Plots	Height-cm	sq cm	P	L	S	B
CT‡	58.3**a**	8615**a**	6.8**a**	59.9**a**	123.8**a**	281.0**a**
NT‡	74.8**b**	10453**b**	8.2**a**	72.6**b**	197.8**b**	4440.0**b**
CTCF§	57.0**c**	7378**c**	6.4**c**	54.9**c**	107.1**c**	253.3**c**
NTPL§	77.2**d**	10830**d**	9.1**d**	76.7**d**	211.4**d**	457.36**d**
NT/CT	1.288	1.213	1.174	1.214	1.599	1.566
NTPL/CTCF	1.351	1.467	1.428	1.397	1.975	1.805

† P-petiole,; L-leaf; S-stem; B-boll

‡ Means with the same letter (a,b) per column are not significant at alpha = 0.05

§ Means with the same letter (c,d) per column are not significant at alpha = 0.05

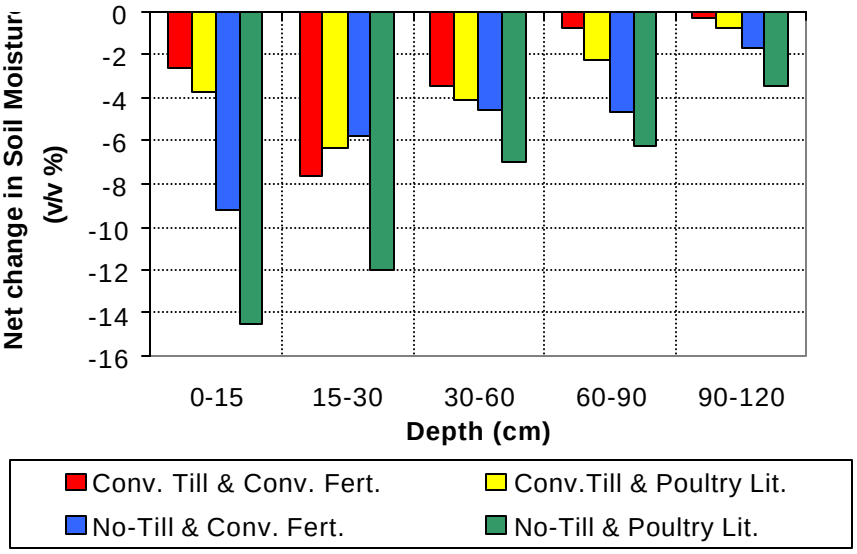

Fig. 2. Cumulative net soil water change between June 8 and November 4, 1998 for 4 plots of contrasting treatments.

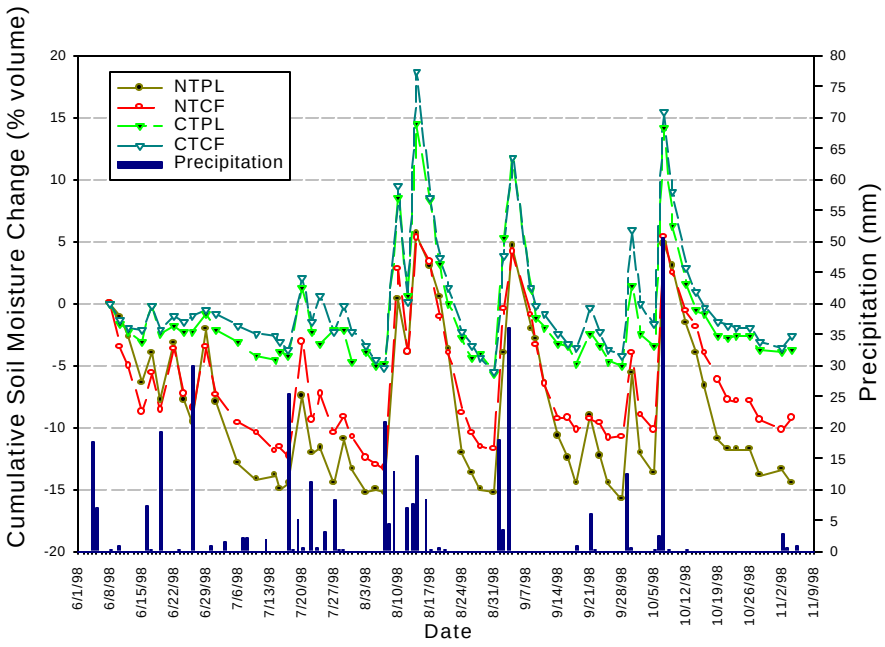

Fig. 3. Temporal net soil water change from no-till and poultry litter (NTPL), no-till and conventional fertilizer(NTCF), conventional tillage and poultry litter(CTPL), and conventional tillage and conventional fertilizer (CTCF)

treatments in the top 0.15 m of soil.

SUMMARY AND CONCLUSIONS

In three years of research on a Cecil sandy loam soil of the Southern Piedmont near Watkinsville, GA, yield from no-till cotton exceeded that from conventional tillage cotton by 28% (P = 0.002). No-till cotton fertilized with poultry litter out-yielded conventionally tilled and fertilized cotton by 43% (P = 0.003). Above ground biomass measured in 1998 was 52.4% more for no-till compared to conventional tillage cotton, and by 78.9% for no-till cotton fertilized with poultry litter compared to conventionally tilled and fertilized cotton. Soil water use in the top 0.6 m was almost double for no-till compared to conventional tillage and about 2.4 time more in no-till-poultry-litter compared to conventional-tillage-ammonium-nitrate treated cotton. Although most cotton in Georgia and the southeast is grown under conventional tillage with conventional fertilizer, such as ammonium nitrate, production could be improved by adopting no-till and fertilizing with poultry litter. This would create a useful outlet for the large amount of litter produced from the poultry industry. The system would also give additional insurance against crop failure arising from short term summer drought by enhancing soil water use.

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