Yield Response and Nitrogen Requirement of Cotton as Affected by Tillage and Traffic

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INTRODUCTION

There are many tillage systems available to farmers for cotton production in the Southeast. Among these are conservation tillage systems, which have been shown under some growing conditions to have a beneficial effect for cotton production in the sandy coastal plain soils of this region (Touchton and Reeves, 1988). The formation of tillage pans due to soil compaction has also been recognized as a possible limitation for cotton production with these soils (Touchton and Reeves, 1988). There are a number of methods for alleviating soil compaction, including deep plowing, subsoiling, chiseling, crop rotation and controlled traffic (Bowen, 1981), but the most commonly used practice is some form of deep tillage. Because of this, the use of strip-tillage, which combines deep tillage and conservation tillage, has recently begun to be used for cotton production in this region (Touchton and Reeves, 1988).

Controlled traffic has also been investigated as a possible means of relieving soil compaction and the formation of hardpans. Williford (1982) found that cotton yield was significantly increased with controlled traffic beds and suggested that subsoiling every year was unnecessary with controlled traffic systems. Dumas et al. (1973) evaluated systems utilizing controlled traffic and deep tillage (subsoiling) for cotton production. They found that deep tillage, regardless of traffic, resulted in larger cotton plants. Without deep tillage, controlled traffic resulted in a 9% increase in plant height. Both deep tillage and controlled traffic were necessary to obtain maximum yield (4214 lb/acre seed cotton).

Research conducted on controlled traffic has focused on interactions with deep tillage such as subsoiling. There is also a need to investigate tillage systems, including conservation cropping systems, that utiliize controlled traffic and compare them to conventionally trafficked tillage systems. The USDA-ARS National Soils Dynamics Laboratory has recently begun research utilizing a wide frame tractive vehicle (WFTV) designed to allow for 20-ft-wide, untrafficked research plots. A detailed description of the vehicle and its capabilities has been published by Monroe and Burt (1989). Utilization of the WFTV allows for the use of various tillage systems in a zero-traffic environment. The objective of this experiment was to determine the effect of traffic and tillage systems, including a strip-tillage system, on cotton production.

Preliminary results from this experiment indicated that N fertility may also be affected by tillage and traffic. The level at which soil is compacted and the area that roots are able to explore in the soil profile can affect N application efficiency (Jenkinson et al., 1985). The tillage system used can strongly affect fertilizer N utilization by cotton. Factors such as soil moisture and temperature (which are changed with different tillage practices) can lead to great changes in N efficiency (Jansson and Persson, 1982). Furthermore, N fertilizer practices are complicated with the use of conservation tillage, with both increased (Meisinger et al., 1985) and decreased (Moschler and Martens, 1975) N fertilizer application needs reported under different experimental conditions. Therefore, additional research was initiated in 1989 to identify the effects that tillage and traffic have on the N fertilizer requirement for cotton.

MATERIALS AND METHODS

A field study was initiated at the Alabama Agricultural Experiment Station, Auburn University, Agricultural Engineering Research Farm at Shorter, AL. Cotton was grown in a double-cropping system with wheat, with wheat stubble used as surface residue for the conservation tillage treatments. The soil is a Cahaba-Wickham-Bassfeld sandy loam complex (Typic Hapludults). Cation exchange capacity (CEC) and organic matter content for the test site averaged 6.31 meq/l00 g and 1.19%, respectively. The site has a well-developed 3-to-6-in.-thick hardpan from 8 to 12 in. deep. To reduce variation, an effort was made to form a uniform hardpan at a depth of 8 in. by running a motor grader repeatedly in plowed furrows incremental across the experiment site.

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The experiment design was a split-plot with 4 replications. Main plots (20 ft wide and 600 ft long) were 1) conventional traffic and 2) zero-traffic Main plots were split into subplots (120 ft long) of tillage systems: 1) complete surface tillage without subsoiling (not SS), 2) complete surface tillage and annual in-row subsoiling to 16-in. depth (SS prior cotton), 3) complete surface tillage with one-time-only complete disruption of tillage pan (initial SS) and 4) no surface tillage but planted with in-row subsoiling (strip-tillage). The study was initiated in June of 1987; however, because wheat stubble was needed to implement the strip-tillage treatment, the full complement of treatments was not accomplished until 1988. Complete surface tillage consisted of disking, chisel plowing (8-in. depth), diking and field cultivation. The one-time-only complete disruption of the tillage pan was accomplished by subsoiling to a 20-in. depth on 10-in. centers using a V-ripper in November 1987. The strip-tilled cotton was planted into wheat stubble with a KMC in-row subsoiler planter. In 1990, the tillage subplots were split into sub-subplots (28.5 ft long) of four N rates. The N rates were 0, 40, 80 and 120 lb N/acre, creating a split-split-plot design.

Cotton, 'McNair 220', was planted on 30-in. rows at 90,000 seed/acre as close to 1 June as possible (equipment problems delayed cotton planting in 1988 and 1989). All tillage operations were performed with the WFTV. On the conventionally trafficked plots, a 4440 John Deere tractor or a Hi-boy sprayer was driven through the plots to simulate traffic that would have been applied with each operation. Traffic patterns followed those needed with 4 row equipment. Application of 34 lb N/acre at planting and 76 lb N/acre at first square was made each year through 1989. In 1990, application of 20 lb N/acre as NH_4NO_3 was made at planting to all but the 0 N rate plots. The remaining N fertilizer for each N rate was applied broadcast at first square.

Recommended cultural practices for insect and weed control were used throughout the season on all plots. Cotton was hand picked for yield from 100 ft of row in 1987 through 1989 and from 40 ft of row in 1990 on approximately 1 November of each year. Plant samples were taken from 10 ft of row for dry matter determination.

In 1990 plant and seed samples were analyzed for N content and combined for total plant N uptake. Because of variability of soil type and weed control problems in the fourth replicate, only three replications were used for analysis in the 1990 growing season.

RESULTS AND DISCUSSION

Cotton Yield

Cotton yield was limited in 1988 due to late planting date of cotton. In this year, there was a significant traffic x tillage interaction effect on seed cotton yield (Fig. 1). The SS prior to cotton treatment resulted in maximum yield in the zero-trafficked plots (1580 lb/acre) but lowest yield in the trafficked plots (1140 lb/acre). Within zero-trafficked plots, the initial SS treatment (subsoiling 20 in. deep on 10-in. centers prior to first wheat crop) reduced yields compared to in-row subsoiling at planting. In trafficked plots, however, the initial SS treatment increased seed cotton yield compared to SS prior to cotton. Traffic had little effect on the strip-tillage and the not SS treatments.

The 1989 growing season had a very cool and excessively wet spring with only short periods of water stress for the cotton during the growing season. In this year, there were no significant differences between tillage ($P \leq 0.24$) and traffic ($P \leq 0.27$) treatments for seed cotton yield (data not shown). Strip-tillage resulted in the lowest yields for both the trafficked and zero-trafficked plots, with an average of 1252 lb/acre. This non-significant trend may have been caused by reduced stand vigor due

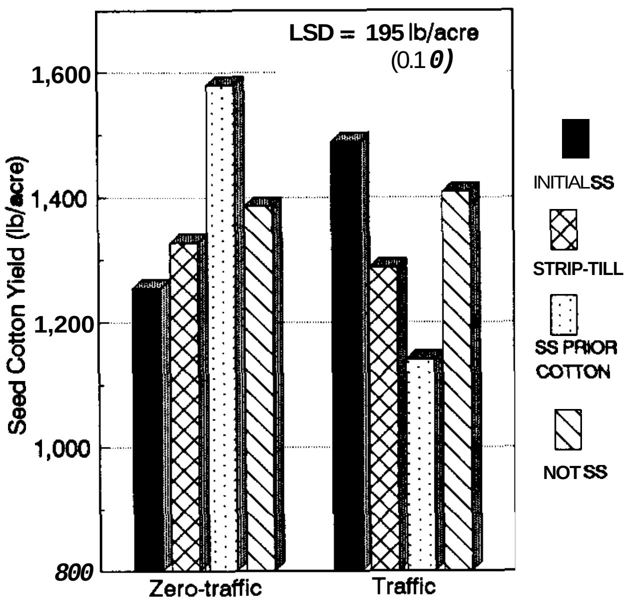

Fig. 1. Seed cotton yield as affected by traffic and tillage system, 1988. Not SS = conventional surface tillage; SS prior cotton = conventional surface tillage with In-row subsoiling; Initial SS = one time only complete disruption of hardpan; and Strip-till = no-till with In-row subsolling into wheat stubble.

to cool and wet conditions in the strip-tillage plots. Reduced N availability under these wet conditions may also have contributed to the yield reductions in these plots. Maximum yield was achieved in the zero-trafficked and not SS plots 1626 lb/acre).

The 1990 growing season was very dry, causing water stress in the cotton plants throughout most of the growing season. While no differences were found among the tillage treatments for seed cotton yield, seed production was significantly affected by tillage, with strip-tillage having significantly higher seed yield than SS prior to cotton when averaged over traffic treatment (787 and 662 lb/acre, respectively). Similar but non-significant trends were seen in cotton lint production (data not shown).

In this year, a significant decrease in both seed and lint production resulted from the zero-traffic treatment, with 1338 vs. 1213 lb seed cotton/acre produced for traffic and zero-traffic, respectively. Seed yield increased with traffic, with 763 vs. 707 lb/acre ($P \leq$ 0.10 for traffic and zero-traflic, respectively. Yield reductions in soybeans and wheat have also been reported for controlled traffic systems in dry years (Reeves et al., 1990; Voorhees, 1989; Voorhees et al, 1985). As in 1988, traffic in the strip-tillage or not SS treatments resulted in relatively constant yields compared to the SS prior to cotton treatment.

Total dry matter production at harvest was highest for the not SS plots (Fig. 2). A significant reduction in total dry matter occurred when complete surface tillage was combined with subsoiling, with 2659 lb/acre dry matter compared to 3075 lb/acre with and without subsoiling, respectively. No significant difference occurred between the not SS and the strip-tillage treatments.

Total dry matter was significantly increased with increasing fertilizer N application similarly in all tillage and traffic treatments (Fig. 3), but no significant difference in seed or lint production was seen. Percent lint of seed cotton was signiiicantly decreased with increasing fertilizer N application, with 42.7% with no N application vs. 41.1% with 120 lb N/acre application. Similar N response to lint percentage was reported by Perkins and Douglas (1965). Consequently, while cotton seed production tended to increase with increased application of N, lint production was highest for the 0 lb/acre N application (1.12 and 1.09 bales/acre with 0 and 120 lb N/acre application, respectively). This indicates that the beneficial response of cotton to fertilizer N application may be limited under extremely dry growing conditions.

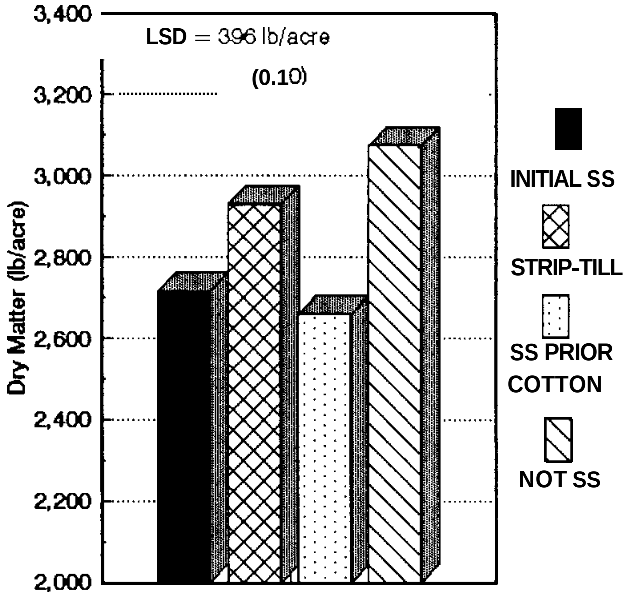

Fig. 2. Cotton dry matter production as affected by tillage system, 1990. Not SS = conventional surface tillage; SS prior cotton = conventional surface tillage with in-row subwiling; Initial SS = one time only complete disruption of hardpan; and Strip-till = no-till with In-row subsoiling into wheat stubble.

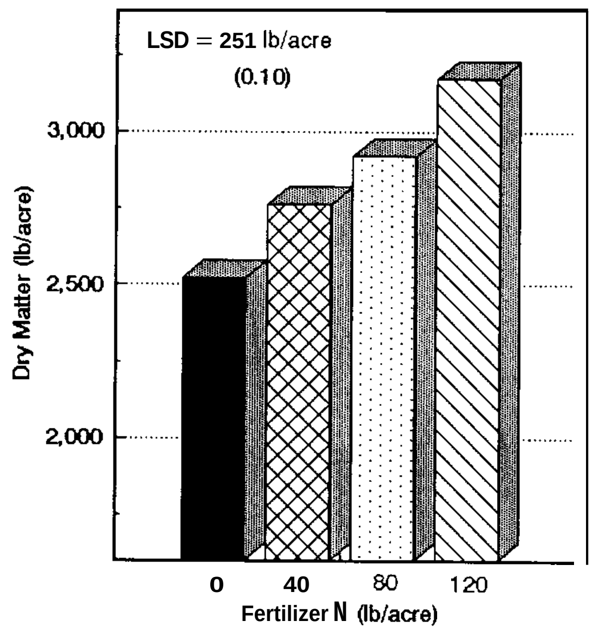

Fig. 3. Cotton dry matter production as affected by fertilizer N application, 1990.

Nitrogen Uptake

The dry growing season of 1990 resulted in extremely limited fertilizer N uptake by the cotton plants, with an average fertilizer N uptake efficiency of 17% for the 120 lb N/acre rate. Increased rate of fertilizer N application significantly increased total N uptake in the plant, with most of the differences in plant N being accounted for in the stalks (Fig. 4). Fertilizer N application had very little effect on seed N content, with only the 120 lb N/acre rate having significantly higher N content in the seed than the no fertilizer N application.

Total N uptake significantly increased with tractor traffic compared to zero-traffic, increasing from 65 to 69 lb N/acre. While N uptake in the stalk had the greatest response to differences in N rate application (Fig. 4) no difference in stalk N uptake was found for tractor traffic. This indicates that differences in N uptake due to traffic were most likely due to differences in dry matter production, especially seed production, among treatments rather than to differences in N availability.

N uptake was significantly affected by tillage treatment, with not SS having the greatest N uptake (Fig. 5). The not SS treatment resulted in 72 lb N/acre compared to 62 lb N/acre for the SS prior to cotton treatment. Most of these differences can also be explained by differences in dry matter production among treatments. However, some differences due to N availability were evident in the strip-tillage treatment. While stalk dry matter production was not significantly different for the strip-tillage treatment compared to the not SS, N uptake in the stalks was significantly reduced (Fig. 6). A probable explanation for this is that increased organic matter in the strip-tillage plots may have tied up available N and resulted in some reduction in N uptake. This indicates that in years when moisture conditions will allow better utilization of available N, strip-tillage may require additional fertilizer N application for maximum yield.

CONCLUSIONS

Results from this study indicate that the effect of tillage and tractor traffic on cotton production is variable depending on the moisture condition during the growing season. In years of below-normal rainfall during the growing season, strip-tillage was found to maintain seed cotton yields near the maximum, even though the effect of subsoiling was variable with both beneficial and detrimental effects occurring. Zero-traffic resulted in a non-significant increase in seed cotton yield in most years but was

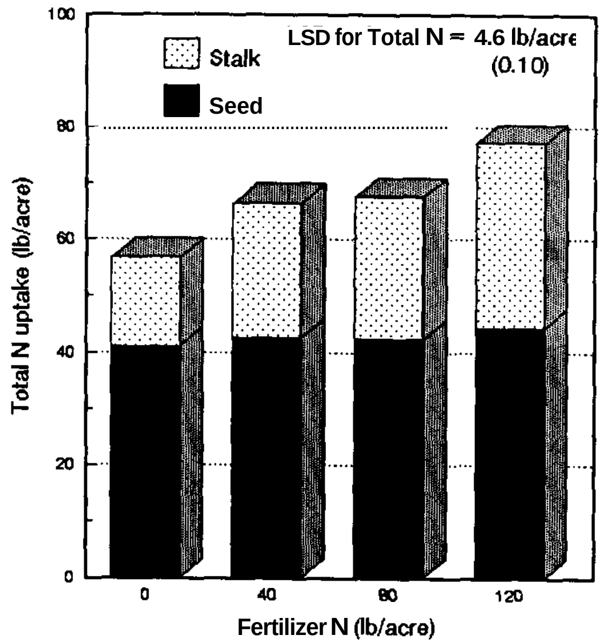

Fig. 4. Total N uptake in cotton as affected by fertilizer N application, 1990. Stalk = N uptake in cotton stalk, Seed = N uptake in the cotton seed.

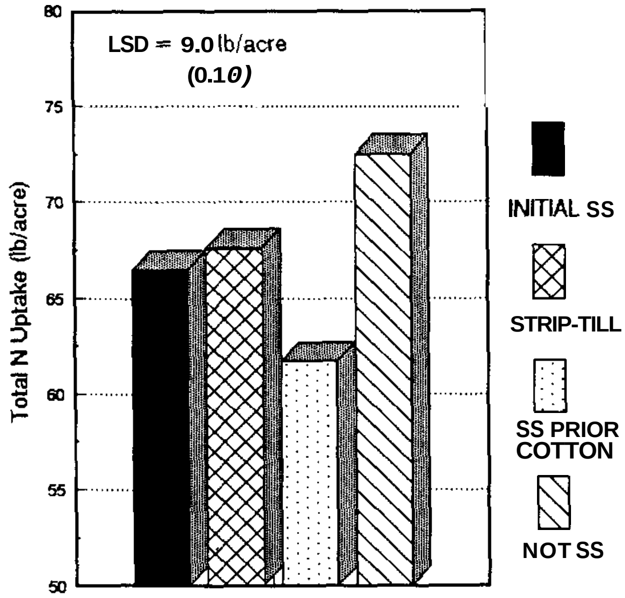

Fig. 5. Total N uptake by cotton as affected by tillage system, 1990. Not SS = conventional surface tillage; SS prior cotton = conventional surface tillage with in-row subsoiling; Initial SS = one time only complete disruption of hardpan; and Strip-till = no-till with in-row subsoiling into wheat stubble.

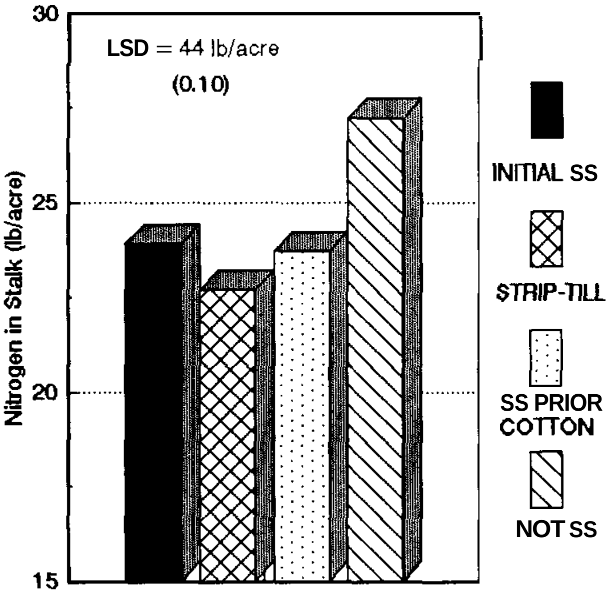

Fig.6. Cotton stalk N uptake as affected by tillage system, 1990. Not SS = conventional surface tillage; SS prior cotton = conventional surface tillage with in-row subsoiling; Initial SS = one time only complete disruption of hardpan; and Strip-till = no-till with in-row subsoiling into wheat stubble.

found to significantly reduce seedcotton yield and total N uptake in an extremely dry year. Fertilizer N application had no effect on cotton yield in an extremely dry growing season, indicating that the beneficial effect of fertilizer N may be limited under these conditions. Plant uptake of N was affected by tillage system, with most of the differences being attributed to differences in dry matter production. However, results indicate that reduced N uptake in the strip-tillage plots may have resulted from reduced N availability in these plots. This research will be continued to examine the effect of traffic on conservation tillage systems under different weather conditions during the growing season.

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