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Effects of Conservation Systems on Soil Moisture and Productivity in Cotton

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Abstract. *Southeastern soils are characterized by low organic matter levels and consolidated soil layers that limit root growth. The low productive potential of many of these soils, coupled with recent poor crop prices and short-term droughts has placed many farmers in an untenable position. Soil-specific conservation systems can improve the profitability of Southeastern farms, mainly by increasing soil water storage and availability to crops during periods of short-term drought common in the region. Cropping and soil management systems are needed that increase soil quality and productive potential of these soils while decreasing inputs and increasing net returns. The objectives of this study were to examine the effects of non-inversion tillage operations and winter cover crops on soil moisture and crop productivity. Three conservation tillage systems (no-till, strip-till, and paratill) were evaluated in a cotton production system. The tillage was applied in the fall or the spring. Two winter cover crop systems, rye and no cover, were also compared. The cover crop was killed chemically before planting of cash crop and managed with a roller-crimper. Yield, soil moisture, leaf temperature, cover crop biomass, and cover crop chemical analysis data were collected. Results from the first two years of this study indicate that winter cover crops have negatively impacted crop yields, potentially due to Nitrogen availability in the soil. Spring tillage significantly increased cash crop yields. Fall tillage was not significantly different from no-till due to soil reconsolidation. As work continues on this study the results should indicate which tillage and cover crop systems increase soil quality, productivity, and profitability in these degraded soils.*

Keywords. cotton, soil moisture, conservation tillage, cover crop

Introduction

Soils in the Southeastern US are often described as degraded. Low organic matter content and consolidated soil layers that limit root growth are commonplace (Campbell *et al*, 1974). Through the years heavy erosion on unprotected soils has also occurred. When combined with short-term droughts which invariably occur during times of peak growth, these factors can place producers in an untenable and non-sustainable position. For these reasons conservation systems utilizing winter cereal cover crops and non-inversion tillage are useful tools for increasing productivity in this region.

Winter cover crops have been shown to have many advantages for conservation cotton production systems ranging from increasing carbon, reducing erosion, increasing infiltration and available soil moisture, to weed control through physical and chemical allelopathic effects. Following a winter cereal cover crop, however, management of cotton cash crops can be much different from management following winter fallow. One of the most notable differences has been shown to be Nitrogen management (Bauer and Reeves, 1999; Reiter *et al*, 2002; Wiatrak *et al*, 2002). Higher rates of N may need to be applied to combat N immobilization. Cereal cover crops take in N throughout the winter making it available to subsequent crops. Residue from cereal cover crops have a high C/N ratio (>30:1) making N prone to immobilization.

In the sandy soils of the Coastal Plains, in-row subsoiling has become an annual operation. While some research has pointed toward biennial sub-soiling being sufficient, concerns regarding a plant's ability to reach water during drought years has convinced many producers to sub-soil on an annual basis (Raper *et al*, 2004). Sub-soiling is typically conducted at one of two periods in the growing season: in the fall following harvest or in the spring prior to planting.

The effects from both cover crops and conservation tillage on crop yields have been well established. When considered from a conservation systems approach, however, more information on the total effects on the crop and the soil is needed. Therefore, the objectives of this on-going experiment are to compare the effects of different spring and fall non-inversion tillage operations on soil moisture conditions and crop productivity, and to compare the effects of winter cover systems on soil moisture conditions and crop productivity.

Materials and Methods

A field was selected at the Alabama Agricultural Experiment Station's E.V. Smith Research Center, Field Crops Unit located near Shorter, AL, which contained a Compass loamy sand (Coarse-loamy, siliceous, subactive, thermic Plinthic Paleudults). This soil is moderately well drained and has a moderately slow permeability.

The experimental design was a replicated 5x2 factorial. The main factor was no cover and rye cover. The sub-factors were: no-till, Fall strip-till, Spring strip-till, Fall paratill and Spring paratill. The cover treatments and tillage treatments were applied every year. The plots were four 1.02 m (40 in) rows wide by 15.2 m (50 ft) in length. The tillage was applied in fall, after harvest, and spring, before planting, using a Bingham Brothers (Lubbock, TX) Paratill™ and a Brown (Ozark, AL) strip-till. The paratill was chosen because of growing popularity among farmers using non-inversion tillage and the strip-till was representative of commonly used in-row subsoiling. Both of the tillage implements were 4-row with the shanks following a coulter. The strip-till was equipped with two additional coulters behind and on either side of each shank and a rolling basket closing device. These tillage treatments were augmented with a no-till control. A rye (*Secale cereale L.*) winter cover crop was chosen because of it proven benefits and high biomass production (Raper *et al*.,2000b; Schwab *et al*., 2002). The no cover treatment was allowed to remain fallow, with winter weeds killed at the same time as the rye cover. The cover crop was killed chemically using glyphosate and a curved-bar roller-crimper was used to manage the cover crop and provide directionality prior to planting, when warranted by the amount of biomass. The middle two rows of each plot were harvested using a two-row spindle picker and the seed cotton harvested from each plot was collected in bags and then weighed.

Soil moisture content was determined using ECH_2O (Decagon Devices, Pullman, WA) soil moisture probes. This system employs capacitance measurement of soil moisture and the factory calibration was used to calculate volumetric moisture content. The 20 cm probes were installed vertically, in the row, at a depth of 5 cm (2 in) from the surface. The moisture probes were paired with the EM5 (Decagon Devices) 12-bit analog-to-digital logger set for a 15 minute logging interval. The data were downloaded from the loggers and means for each of the treatments were calculated. Soil moisture data were collected starting in the 2005 growing season.

Leaf temperature measurements were collected using a Raytek (Santa Cruz, CA) non-contact infrared thermometer. Temperature was collected weekly on the top-most full leaf. Since temperature is directly related to solar radiation the temperature was collected at approximately solar noon. There were 20 temperature readings collected from each plot. Means for the treatments were calculated for each day that temperature readings were collected. Leaf temperature data were collected starting in the 2005 growing season.

Above ground biomass samples were collected immediately prior to rolling of the cover crop and chemical burn-down. Eight samples from each cover treatment were collected every year from a randomly selected 0.25 m^2 area. Once collected, the samples were dried in a convection oven at 70°C for 3 days, and then weighed. The samples were ground to pass a 100-mesh screen and were analyzed for Total Carbon and Nitrogen content. The analysis was performed at the National Soil Dynamics Laboratory using a CN-2000 LECO (St. Joseph, MI) dry combustion analyzer.

Statistical analysis of treatments was conducted through an appropriate ANOVA model using SAS (Cary, NC).

Results and Discussion

Soil Moisture

The data displayed are a snapshot of a few days in the peak of growing season, when the presence of available soil moisture would be most important to crop productivity. All of the moisture data indicated almost no difference between any treatment toward the end of the growing season after the plant and bolls were well established.

The volumetric water content collected in 2005 indicated a marked difference between the rye cover and no planted cover treatments (Fig 1). The difference in soil moisture ranged between 7 and 4% with the rye cover crop maintaining higher soil moisture throughout the growing season. This indicates that, when managed effectively, a cover crop does not remove moisture essential for the establishment of the cotton cash crop. Rather, it increases available moisture especially during early peak growth times.

The no-till tillage treatment maintained the highest soil moisture throughout the 2005 growing season (Fig 2). Of the treatments in which non-inversion tillage occurred the fall strip-till treatment displayed the highest moisture content. The fall paratill and spring strip till tillage treatments maintained similar soil moisture contents, and the spring paratill tillage treatment exhibited the lowest soil moisture readings.

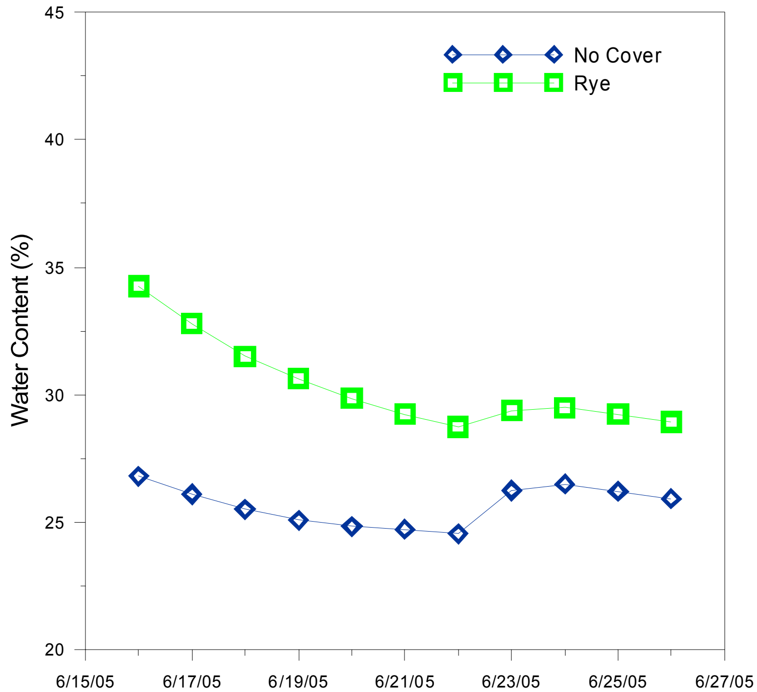

Figure 1. Volumetric Water Content Means by Cover Crop Treatment.

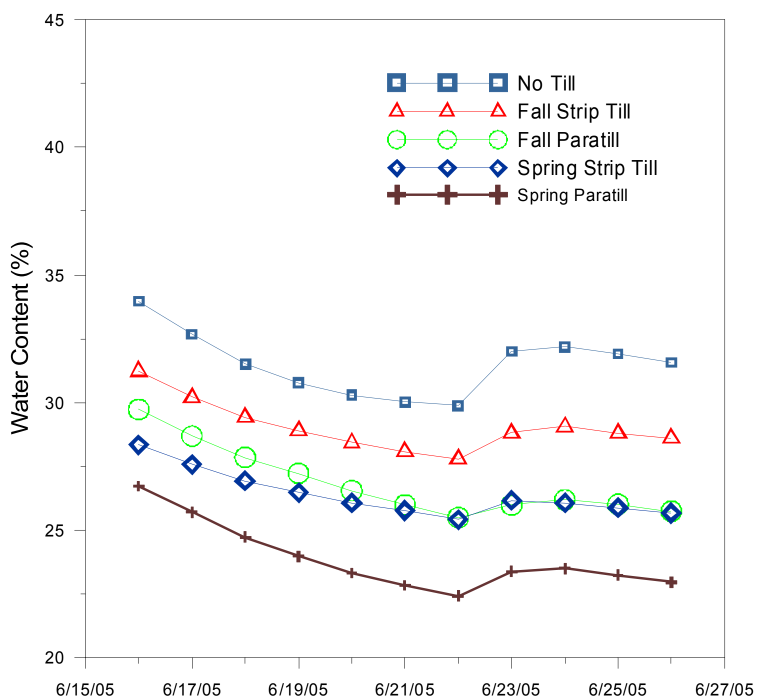

Figure 2. Volumetric Water Content Means by Tillage Treatment.

It should be noted that a preferential flow path for surface water may occur where the vertical section of the paratill shank passes through the soil profile offset from the row. While rainfall from the surface would be available to the plant under the row, at the depth of tillage, it would not be read by sensors placed nearer to the surface.

Yield

There was no interaction between the 2004 and 2005 growing season yield data; therefore, the years were analyzed separately. Similarly, in both seasons, there was no interaction between the cover crop and tillage treatments.

2004 Growing Season

Even with all the documented benefits of a winter cereal cover crop, if not managed properly it can have an adverse effect on yields. There was a significant difference between the seed cotton yields of the no cover and rye cover treatments ($P \leq 0.0020$), the no cover treatment yielded more seed cotton than the rye cover treatment (Fig 3). Without soil moisture data for the 2004 season, it can not be said with certainty that soil moisture was not a limiting factor. Based on information collected from succeeding growing seasons and from chemical analysis of cover crop biomass (Table 1), however, the differences were, most likely, due to N immobilization in the soil.

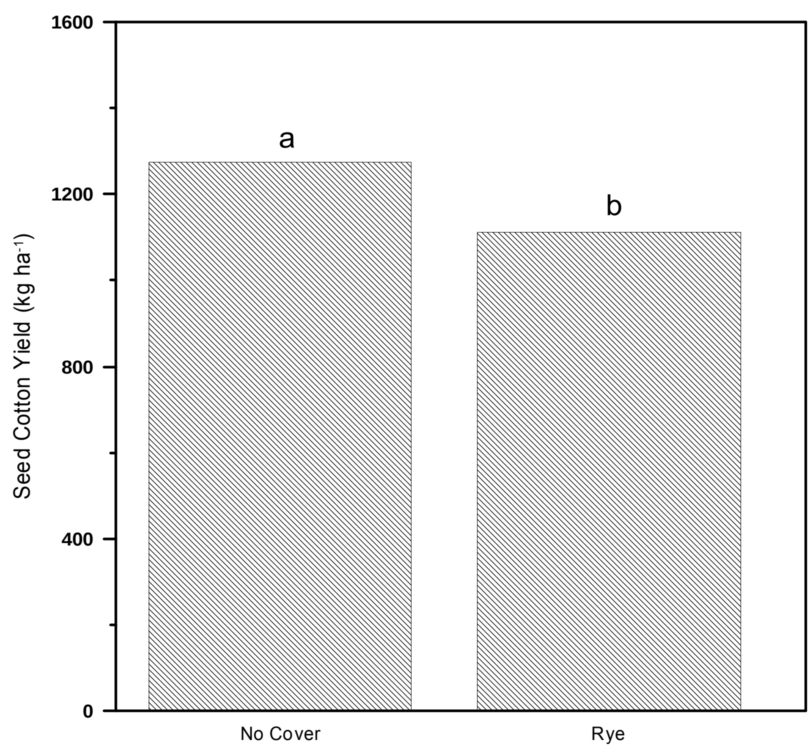

Figure 3. 2004 Seed Cotton Yield by Cover Crop Treatment

The tillage treatments were also significant for the 2004 season ($P \leq 0.0444$, Fig 4). The spring paratill tillage treatment yielded highest, followed by spring strip till. No till, fall strip till, and fall paratill yielded the least with no significant difference among the treatments. The tillage treatments applied in the spring created less resistance to root growth in the row and allowed plants easier access to available soil moisture and nutrients. The 2004 season was dry before planting; after planting, there were some moderate rainfall events. The spring tillage allowed the plants to reach moisture and, when the rain did occur, a path was readily available for water to enter the profile. The fall tillage treatments exhibited similar traits to no till because of ample time for reconsolidation during the winter months.

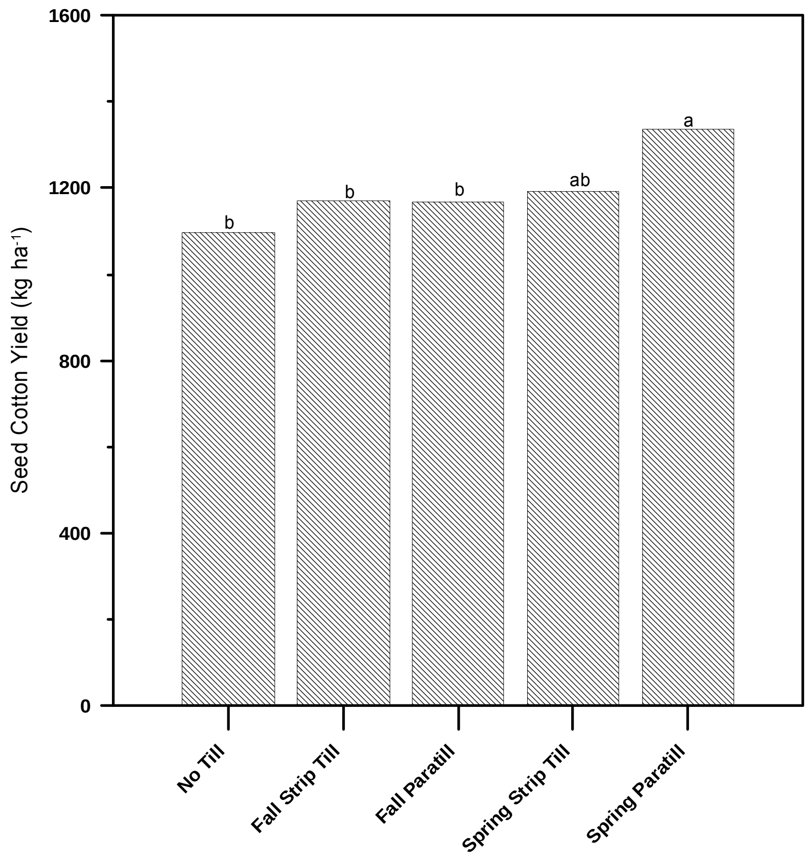

Figure 4. 2004 Seed Cotton Yield by Tillage Treatment.

2005 Growing Season

Overall, yields in the 2005 season were much better than in 2004. The same yield patterns in the rye and no cover treatments, however, were observed (Fig 5). There was a significant difference between the no cover and rye cover treatments ($P \leq 0.0126$); again, the no cover produced a higher yield than rye cover. Unlike the previous year, we do have moisture data covering the 2005 growing season. The moisture data indicated that throughout the growing season the rye cover crop treatment maintained higher soil moisture than the no cover treatment. Knowing that the yield differences can not be attributed to moisture, the next possible cause for yield differences would be nutrient deficiency. In the light of previous research and considering the chemical analysis performed on collected above ground biomass (Table 2), the cause for the difference is most likely N immobilization.

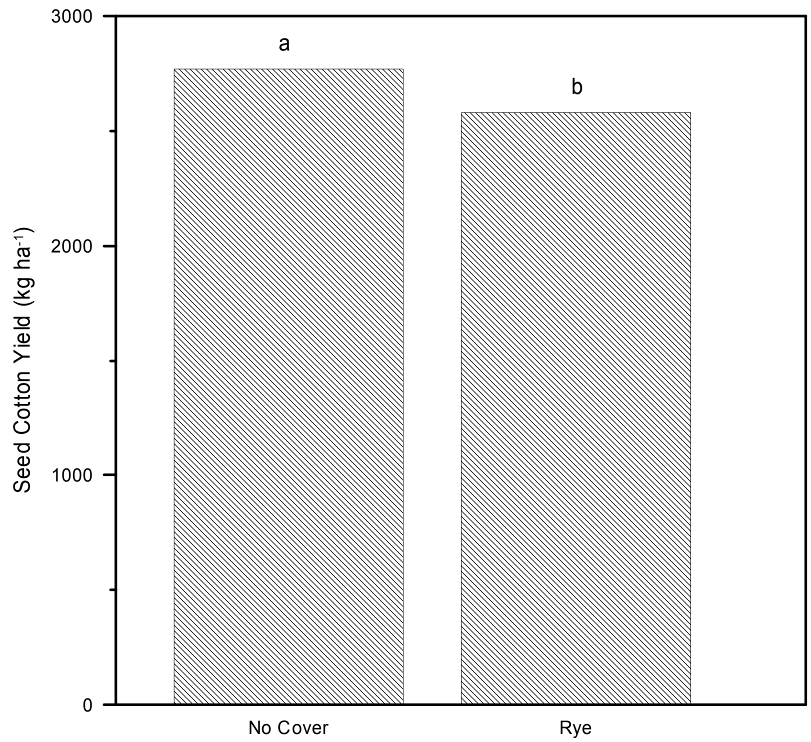

Figure 5. 2005 Seed Cotton Yield by Cover Crop Treatment.

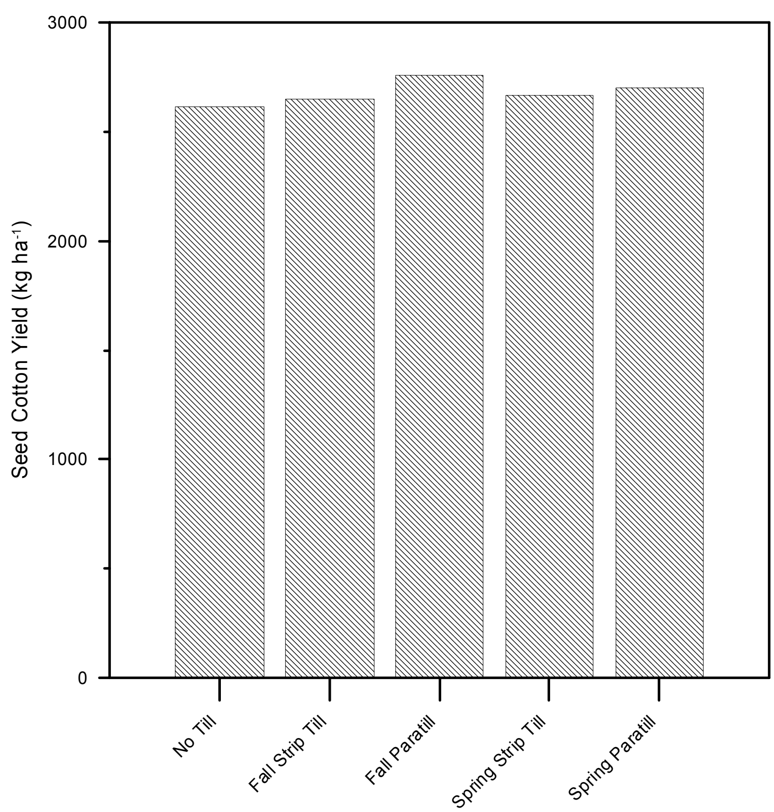

Figure 6. 2005 Seed Cotton Yield by Tillage Treatment.

No statistical differences among the tillage treatments were found in the 2005 growing season. There are two major topics for consideration in the analysis of these results. First, when there is more than adequate moisture available for plants, tillage will not create substantial differences in yield. March 2005, alone, recorded more than 10 in of rainfall; April, May, June and July of 2005 accounted for approximately 19 in of rainfall. When as much moisture is available at six inches of depth as 18 inches in the soil profile, the plant will not pursue water to the depth of tillage; essentially, when moisture is not a limiting factor on plant growth, tillage effects are negated. Second, the unmeasured effects of hurricanes and associated wind, rain, and hail damage, on yields can not be discounted. These climactic events will remove bolls from the plants and lint from open bolls, and these data were not adjusted for these effects.

Above Ground Biomass

Analysis of the above ground biomass provides insight into yield differences between the no cover and rye cover treatments. Both the no cover and rye cover treatments exhibited ample biomass production for the 2004 growing season (Table 1). The rye cover provided strong soil protection from erosion and raindrop impact. There were also noticeable allelopathic effects on weed populations. The reason for negative yield effects can be seen in the C:N ratio. As determined by chemical analysis, the rye cover treatment above ground biomass was determined to have a 69:1 C:N ratio while the no cover treatment a 22:1 C:N. The rye cover C:N ratio was well above the accepted 30:1 C:N at which immobilization occurs, the no cover C:N ratio was in the range at which N mineralization occurs. These differences account for the differences in yield between treatments.

Table 1. 2004 Winter cover above ground biomass, N content, C:N Ratio.

Treatment	Mean Biomass kg/ha (lb/ac)	Mean N Content kg/ha (lb/ac)	Mean C:N Ratio (%)
No Cover	2140 (1909)	45 (40)	22
Rye Cover	5468 (4878)	40 (36)	69

Similar to the previous growing season, the same benefits were seen in the rye cover treatments as well as negative yield effects (Table 2). As stated previously, soil moisture data indicated higher moisture in the rye cover treatment as compared to the no cover treatment. The rye cover treatment was, again, under N immobilization conditions and the no cover in mineralization condition.

Table 2. 2005 Winter cover above ground biomass, N Content, C:N Ratio.

Treatment	Mean Biomass kg/ha (lb/ac)	Mean N Content kg/ha (lb/ac)	Mean C:N Ratio (%)
No Cover	1596 (1424)	31 (28)	25
Rye Cover	2184 (1949)	25 (22)	45

Leaf Temperature

Cotton leaf temperature data can be used as an indicator of drought stress. As stated previously, adequate rainfall was received during the 2005 growing season. While conclusions can not be drawn with statistical certainty, the leaf temperature means appear to trend together with only slight differences. The no cover treatment starts at a higher leaf temperature than rye cover, however, at the end of the sampling period the rye cover treatment is exhibiting a higher leaf temperature. In the tillage treatments the spring paratill treatment appears to start with a higher temperature, however, in the middle of the sampling period the fall strip till treatment exhibits a higher temperature.

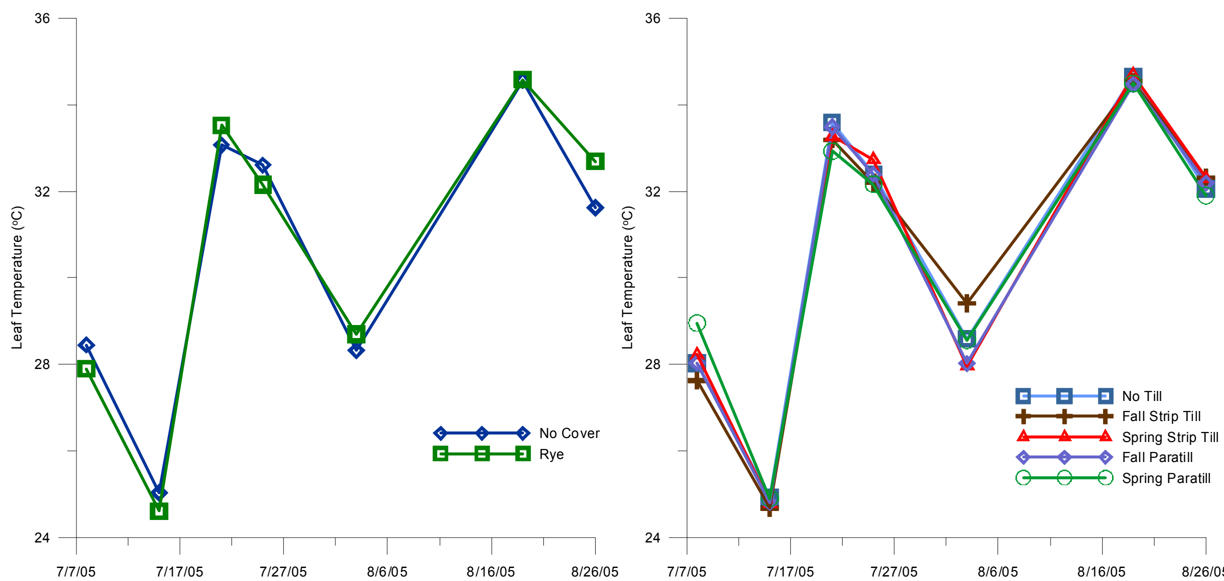

Figure 7. 2005 Uppermost Cotton Leaf Temperature by Cover and Tillage Treatments.

Conclusions

Conservation tillage practices can be beneficial in Coastal Plains soils. These soils have a tendency to form consolidated layers that can be partially disrupted with non-inversion tillage. Nevertheless, timing of tillage operation is important for these soils. Spring tillage operations appear, thus far, to be more beneficial than fall tillage. The natural tendency of these soils to reconsolidate, combined with the large amounts of rainfall received during the winter months, make fall tillage less effective.

Winter cereal cover crops, such as rye, have the potential to benefit cotton production in Coastal Plain soils of the southeast. Large amounts of biomass produced by the cover will protect the soil from erosion during the winter months and diminish weed growth during the summer season. Further, rye used as a cover increased soil moisture content. However, N needs to be managed carefully since the decomposing rye biomass can reduce N availability to the cotton crops. Still, conservation practices have great potential to benefit cotton production in this region. For this reason, adequate management practices must continue to be developed.

Disclaimer

The use of trade or company names does not imply endorsement by the USDA - Agricultural Research Service.

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