SOIL WATER CONTENT AND CROP YIELD UNDER CONSERVATION TILLAGE

Kyung H. Yoo, Jacob H. Dane, and Bret C. Missildine[1]

ABSTRACT

Cotton *(Gossypium hirsutum* L.) was grown for 5 years on Decatur silty clay loam (clayey, kaolinitic, thermic Typic Paleudults) at the Tennessee Valley Substation of the Alabama Agricultural Experiment Station. Treatments included conventional tillage (CT), reduced tillage (RT), and reduced tillage with a winter wheat (Tritium aestivum L) cover crop (RTC). Soil water was measured biweekly by the neutron scatter method at 20-, 40- 60-, 80-, and 100-cm depths in the soil profile during the 1987 growing season (May 1 - September 30). The 5-year average yields of seed cotton were 2, 261, 2, 364, and 2,296 kg ha^{-1} from CT, RT, and RTC, respectively. There was no significant difference among the yields. Soil water content at the measured soil depths was the lowest for CT throughout the growing season. At 20-cm depth, soil water content was the highest for RTC, but RTC had lower soil water content at depths below 40 em than that of RT. The CT plots showed the lowest potential to hold soil water in all depths measured. A prolonged dry period during the growing season in 1987 caused extremely low soil water content at all depths for all treatments. The depleted soil water was recharged to the level of soil water content during the early part of the growing season after an unusually high rainfall event occurred late in the growing season.

INTRODUCTION

Interest in conservation tillage has been strong for the past decade because it affects soil erosion, soil water conservation, and crop yield. It also appeals to farmers because it conserves time, fuel, and labor (Phillips et al., 1980). Plant residue left on the soil surface is the most important feature of conservation tillage. Residue left on the surface protects the soil, reduces evaporation, slows runoff, and increases infiltration (Blevins et al., 1983; Mannering and Fenster, 1983). Understanding soil water behavior under conservation tillage is important since it directly influences crop yield, as well as runoff and soil erosion. Information regarding interaction between soil water content and crop yield, however, is limited.

Spomer and Hjelmfelt, Jr. (1984) found that soil water was best related with rainfall and crop stage of growth. Jones et al. (1969) measured soil water content under no-tillage systems and found that no-tillage systems effectively reduced evaporation and runoff from the soil surface compared with conventional tillage systems. They found that the average soil water content in the top 15 cm was higher under no-tillage than that for conventional tillage. Johnson, et al. (1984) reported that less water was depleted from no-tilled fields than other conservation tillage fields. The highest depletion by evapotranspiration and drainage was found from the conventionally tilled fields during periods of no rainfall. Spomer and Hjelmfelt, Jr. (1984) also found that soil water storage was not different for conservation and conventionally tilled corn fields.

A study by Shanholtz and Lillard (1969) reported that no-tillage provided higher corn yields mainly due to its efficient use of water. Blevins et al. (1971) indicated that no-tillage systems generally produced higher corn yields due to the different water withdrawal patterns from no-tilled and conventionally tilled soils. They found that no-tilled soils contained more water than conventionally tilled soils. Munawar et al. (1990) found that corn yield for conservation tillage systems was equal to or better than that for conventional tillage systems for a study in Kentucky. Several researchers reported that yield increases with conservation tillage systems were attributed to favorable moisture conditions in soil (Triplett et al., 1968; Jones et al. 1968; Unger, 1978). It was found that additional soil water, along with higher infiltration and lower evaporation during the growing season preserved by high straw mulch rate, increased grain sorghum yield (Unger, 1978). Very little information is available about the effect of soil water content on seed cotton yield under conservation tillage systems. The purpose of this paper is to present soil water content measured in 1987 and seed cotton yields for 5 years (1985 to 1989) under three tillage systems in the Tennessee Valley area of northeast Alabama.

MATERIALS AND METHODS

The study was conducted from 1985 to 1989 under natural rainfall conditions at the Tennessee Valley

[1] Dept. of Agri. Eng.,Auburn University, AL36849-5417.

Substation of the Alabama Agricultural Experiment Station at Belle Mina in northeast Alabama. The soil was Decatur silty clay loam. Each plot, sized 305 x 305 m (100 x 100 ft), was on a 2% slope. The experimental design was a randomized complete block design of three tillage treatments of cotton ('McNair 235') with two replications. The treatments were conventional tillage (CT), reduced tillage (RT), and reduced tillage with a winter wheat ('Coker 747') cover crop (RTC). Cotton was planted on the contour in a 1.02-m (40-inch) row width at a seeding rate of 20 seeds/m (6 seeds/ft). For all tillage systems, the crop residue was shredded and distributed evenly on the soil surface after harvest. Soil test results from the Soil Test Laboratory of the Alabama Agricultural Experiment Station were used as a guide for fertilizer and lime applications.

In 1985 and 1986, both RT and RTC plots were planted with a John Deere Maxsmerge planter attached to a Brown-Harden Rotill subsoiler. After 1987, these plots were planted with a John Deere. Flex-71 no-till planter. All conventional tillage plots were planted with a John DeemMax-emecge planter. A combination of 5.6 kg ha^{-1} (active ingredient) of Temik (aldicarb) and 112 kg ha^{-1} of Terrachor Super X {Pentachloronitrobenzene (PCNB), 28% + 5-Ethoxy-3-(trichloromethyl)-1,2,4-thiadiazole, 5.8%) were applied on all plots during planting. The RTC plots were tilled with a chisel plow and disked prior to planting winter wheat. Acombination of 1.7 kg ha^{-1} of prowl and 1.7 kg ha^{-1} of cotoran on all plots and 0.6 kg ha^{-1} of paraquat (1, l'-dimethyl-4, 4'-bipyridinium ion) on RT and RTC plots were broadcast to kill the cover crop and control weeds prior to planting cotton. Seed cotton yield was determined by hand-picking 10 ft of the center four rows of each plot. Cotton was harvested twice in 1985 and 1987 and once in the other years. Table 1 shows cultivation practices and dates for the three tillage systems in 1987. All other years had very similar cultivation practices to those of 1987, except for cultivation dates.

Physicalcharacteristics of the surface 10 cm of soil are: 13% sand, 54% silt, 33% clay, and 13% organic matter. Soil water content was measured on each plot during the growing season of 1987 by the neutron scatter method. No soil water data were collected for other study years. Access tubes were installed near the center of the plots, and neutron probe readings were recorded on a weekly basis from planting until the first harvesting. The readings were made at the 20-, 40-, 60-, 80-, and 100-cm depths. Gravimetric soil water determinations were made at each depth with 103 cm^3 soil samples. The results were used to calibrate the neutron probe by developing regression equations to calculate volumetric water content (θ) in cm^3 water cm^{-3} soil. The regression equations are (Missildine, 1988):

for 20-cm depth

θ = (relative count · 022) ÷ 2.1

and for the 40-, 60-, 80-, and 100-m depths

θ = (relative count · 035) ÷ 1.9

where, relative count = field count/ standard count

Rainfall was measured at the site using a tipping bucket rain gauge with a 0254-mm (0.01 in.) sensor. Thegauge was read and recorded at 5-min intervals by a data logger (CR7X, Campbell Sci. Inc., Logan, Utah). Other climatic data collected at the site were ambient temperature, wind direction and speed, and pan evaporation.

RESULTS *AND* DISCUSSION

Seed **Cotton** Yield

Table 2 shows total rainfall during the growing season (May 1to September 30) and seed cotton yields for the three tillage systems. Yields were high in 1985 and 1989 and extremely low in 1987 and 1988. This trend followed the amount of rainfall during the growing season. The low yields also were attributed to poorly developed roots. The high yield in 1985 was attributed to well distributed rainfall during the growing season. Average yield for the 5 years was the highest for RTC and the lowest for CT. However, yields from the three treatments were not significantly different ($P < 0.05$).

Soil water

Comparisons of the soil water content distribution with depth for the tillage treatments are presented in Figures 1, 2,and 3. Figure 4 shows the distribution of daily rainfall during the growing season in 1987. These figures represent three field conditions; planting, drought, and heavy rainfall, respectively. Figure 1 shows volumetric soil water content measured 25 d after planting (May 5). There was a total of 16 mm of rainfall during this period. Soil water content values at the 20 cmdepth were very close for all treatments. The RT had the highest water content followed by RTC and CT at depths greater than 20 cm.

In 1987, the total rainfall for the period of July 14 until September 5 was only 35 mm, which decreased the soil water content to very low levels (Fig. 2). Soil water

Table 1. Cultivation dates for the three tillage systems in 1987. Cultivation for other years are similar except for dates.

Date	CT	RT	RTC
3/4			Broadcast 36 kg N ha”
4/6	Chisel, disk		
4/20[a]	Broadcast 78 kg N ha^{-1} and Planting cotton	Broadcast 78 kg N ha” and Planting cotton	Broadcast 78 kg N ha^{-1} and Planting cotton
6/24	Cultivate		
9/1	Defoliate	Defoliate	Defoliate
9/9[b]	1st harvest	1st harvest	1st harvest
9/23[b]	2nd harvest	2nd harvest	2nd harvest

[a] John Deere Flex-71 for RT and RTC and John Deere Max-emerge for CT.
[b] Harvested by hand pick.

Table 2. Total rainfall and seed cotton yield for the 1985, 1986, 1987, 1988, and 1989 growing season (May 1- September 30) at the Tennessee Valley Substation of the Alabama Agricultural Experiment Station in northeast Alabama.

Year	Rainfall (mm)	Tillage	Yield[a], kg ha^{-1} Plot 1	Plot 2
1985	591	CT	2,814	4,241
		RT	3,912	3,692
		RTC	4,131	3,518
1986	551	CT	1,682	2,195
		RT	1,756	1,975
		RTC	2,487	1,462
1987	509	CT	1,901	1,528
		RT	1,785	1,656
		RTC	1,593	1,122
1988	318	CT	1,426	1,829
		RT	1,682	1,829
		RTC	1,975	1,280
1989	784	CT	2,323	2,670
		RT	2,816	2,542
		RTC	3,255	2.140

	5-year average yield[b] CT	RT	RTC
Rainfall 550 Yield	2,260	2.364	2.296

[a] Average yield of seed cotton in the study area ranges from 2,400 to 2,600 kg ha^{-1}.
[b] Not significantly different ($P \leq 0.05$).

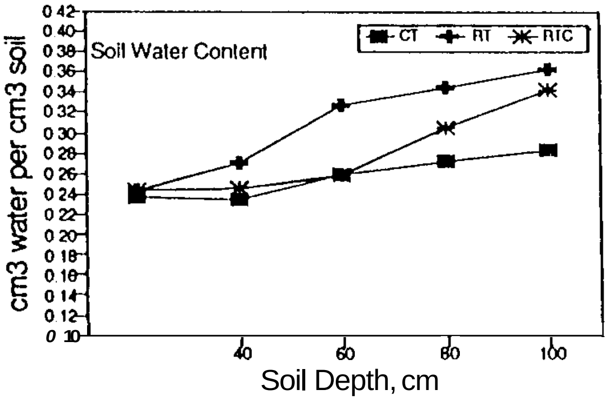

Figure 1. Soil water content distrihution with deplh for three tillage systems 25 d after planting (May 5) in 1987.

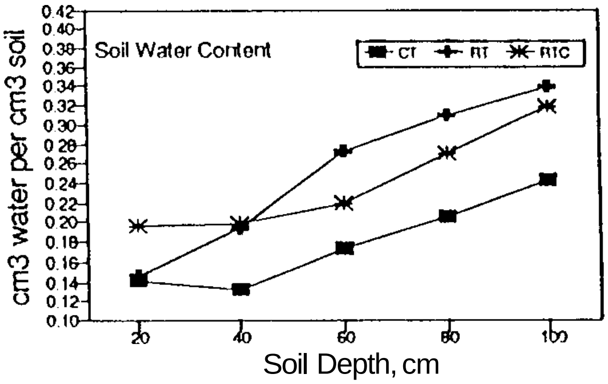

Figure 2. Soil water content distribution with depth for three tillage systems 133 d after planting (August 31) in 1987.

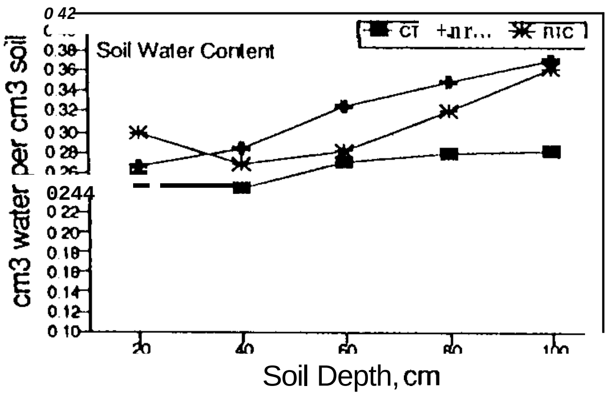

Figure 3. Soil water content distribution with depth for three tillage systcms 147 d after planting (Septemher 14) in 1987.

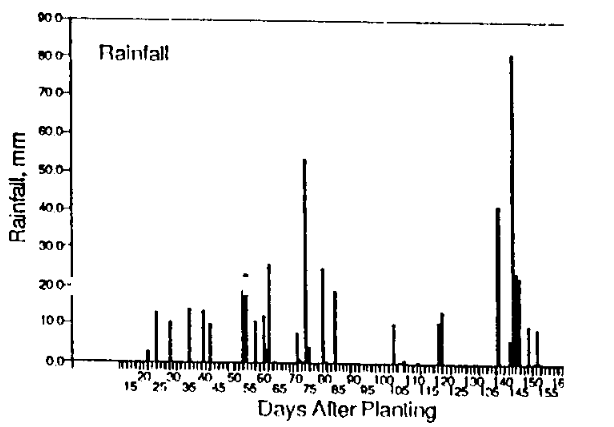

Figure 4. Daily rainfall distribution during the growing season (May 1 - Scptcniher 30) in 1987.

content measured 133 d after planting (August 31). Soil water content at 20-cm depth for RTC was the highest but was extremely low for all treatments. This indicates that the residue left in the field was effective, reducing evaporation losses from the shallow soil during the dry period. At depths below 40 cm, RTC and CT showed lower soil water content values than that of RT. This order of soil water contents is similar to that of 25 d after planting but very low. Most of the soil water reduction occurred in the upper two soil depths. At 80- and 100-cm depths, very little or no soil water was lost, indicating minimum root development in these depths.

A few high intensity rainfall events occurred during September following the long dry period, giving a total rainfall of 211 mm (Fig. 4). As shown in Figure 3, soil water content values measured 147 d after planting (September 14) had increased above or equal to those of May 5 at all depths for all treatments. The total rainfall after the last soil water measurement (August 31) was 175 mm (6.9 in.). The level of soil water contents shown in Figures 1 and 3 indicate that CT plots had the lowest potential to hold soil water in all depths. The soil water contents shown in Figure 3 were the highest values measured in this study. The pattern of the soil water content was very similar for all three measurements; highest for RTC at 20-cm depth, highest for RT at depths below 40 cm, followed by RTC and CT. This is due to lower percolation into the deep soil depths in RTC and CT plots than that of RT.

The observations of soil water content after a long dry period followed by high rainfall events indicated that all treatments responded well to recharging of the soil profile (Fig. 3). RT and RTC plots maintained higher soil water contents at all depths throughout the growing season. Average surface runoff during the growing season in 1987 was the highest for CT (66 mm (2.6 in.)} followed by RTC {20 mm (0.8 in.)} and RT (13 mm (0.5 in.)}, indicating higher infiltration into the soil depths in the RTC and RT plots than that of CT plots.

Figure 5 shows the seasonal variation of soil water content under the three tillage treatments. The RTC showed the highest volumetric water content at 20-cm depth throughoul the season. At this depth, the water content values for the RT and CT treatments were close but both were lower than that for the RTC treatment. The high soil water content of the RTC treatment reflected additional residue left from the cover crop, which reduced evaporation and increased infiltration into the shallow soil depths. At 40-cm depth, water content values of RT and RTC were close and higher than that of CT. The RT treatment had the highest water content values at the depths below 40 cm followed by RTC and CT. Water content values at 60 and 80 cm for RTC were lower than RT and was attributed to the water used by the cover crop. All treatments quickly responded to the high rainfall events during late in the growing season.

The CT sbowed the lowest water content throughout the growing season, except at the 20-cm depth where soil water content of CT was close to that of RT. The higher soil water content for the conservation tillage systems agrees with the findings of Jones et al. (1969) and Johnson (1984). Seasonal variation of soil water content was similar for RT and CT at 20-cm depth and for RT and RTC at 40- and 100-cm depths. The favorable water content of RTC at the shallow soil depths was not reflected in the seed cotton yield. Seed cotton yield from RTC was the lowest among the three treatments in 1987. It was observed that the crop in these plots did not have well developed roots.

SUMMARY

Conservation tillage systems for cotton were studied for their effects on soil water content and seed cotton yield. Seed cotton yields in conservation tillage systems were equal to or better than in conventional tillage on a Decatur soil even though there were no significant differences. Soil water content at soil depths below 20 cm were lower for the conventional tillage (CT) treatment throughout the growing season than for the reduced tillage (RT) and reduced tillage with cover crop (RTC) treatments. During the early part of the growing season, soil water contents at 20-cm depths were close for all treatments. Winter wheat cover crop of RTC caused lower soil water content at the intermediate depths (60- and 80-cm) than those of RT. However, RTC maintained the highest water content at the 20-cm depth throughout the growing season. Additional residue left from the cover crop decreased the evaporation losses and increased infiltration from the shallow soil depth more for the RTC than for the RT and CT treatments. During a prolonged dry period, the soil profiles of all treatments were extremely depleted of soil water, which caused the low seed cotton yield in 1987. The depleted soil water was recharged from heavy rainfall events late in the growing season, which increased the soil water content to higher values than those shown shortly after the planting time when soil water content was high.

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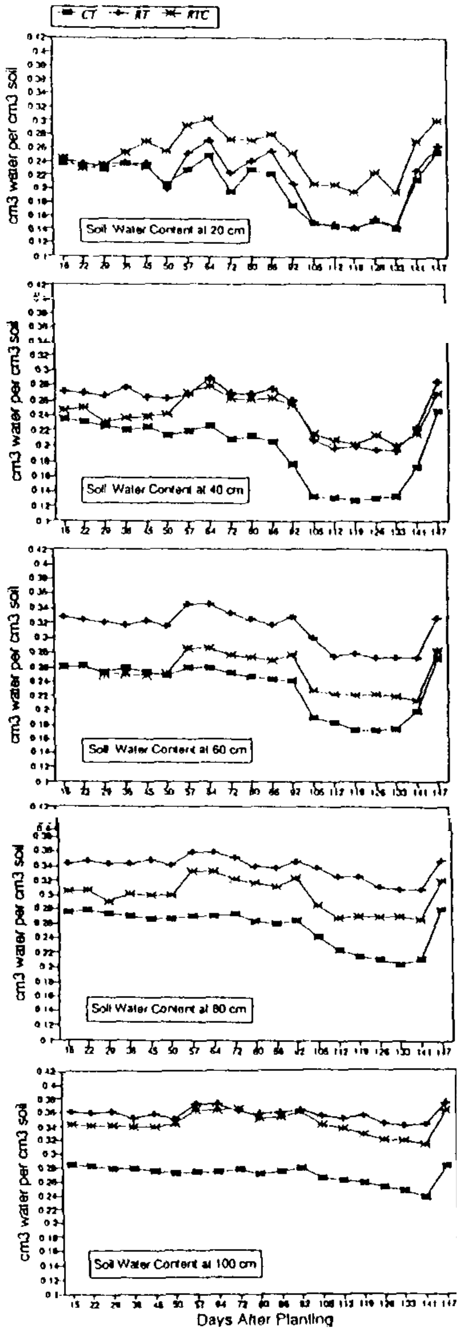

Figure 5. Soil water content with soil depth during the growing season under three tillage systems on a Deratiir soil in 1987. Each data point represents the mean of two plot measurements.