Effects of Reduced Tillage on Soil Temperature and Plant-Extractable Water

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ABSTRACT

Tillage systems influence soil temperature, available water, and subsequently, growth of cotton (*Gossypium hirsutum* L.). Field experiments were conducted in Corpus Christi, Texas, to determine how conventional tillage (CT) and reduced tillage (RT) systems influence soil temperature and plant-extractable water. Cotton was planted following sorghum [*Sorghum bicolor* (L.) Moench], the residues of which were managed either by reduced or conventional tillage. The study consisted of field measurements of soil temperature and volumetric water content. Average soil temperatures under RT were about 2 °C lower than CT. Plant-extractable water was 2.1 cm (0.8 inches) greater in RT than CT.

Tillage and cropping systems offer promising alternatives for crop producers on the coastal plain of Texas, where 12 or more tillage operations are typically required for a cotton crop. Interest has surged in tillage systems that reduce the number or depth of tillage operations and maintain crop residues on the soil surface all or part of the year. Much of this interest stems from higher yields with reduced tillage under semi-arid conditions (Unger and Wiese, 1979; Lyle and Bordovsky, 1987).

Crop residues can influence soil physical properties and subsequent crop response. Crop residues directly influence soil water content, evaporation, percolation and capillarity (Jones et al., 1969; Lal, 1976). The upper soil layers in an RT field are generally wetter and cooler than comparable CT fields (Thomas and Frye, 1984). Anderson (1987) reports that during the growing season, RT and CT have the same minimum temperatures at 5 to 7 cm depth, but RT has lower maximum soil temperatures. Growing conditions favor cotton where the mean temperature is not less than 25 °C. The minimum, optimum, and maximum temperatures for germination and early growth of cotton are about 16, 34, and 39 °C, respectively. Most rapid growth and flowering occurs at temperatures of 33 to 36 °C (Martin et al., 1976).

The objective of this study was to compare the effects of reduced tillage (RT) and conventional tillage (CT) on soil temperature and plant-extractable water in a cotton-sorghum rotation on the coastal plain of South Texas. Although soil water content is related to soil temperature, this study did not attempt to describe that relationship.

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MATERIALS AND METHODS

The study was conducted at the Texas A&M Research and Extension Center, Corpus Christi, Texas. The climate in this region is subtropical and semiarid. Humidity is high during most of the year because the prevailing southeasterly winds bring moist air from the Gulf of Mexico.

The RT employed in this study was developed at the Texas A&M Center. It differed from CT in primary tillage, and in number and depth of tillage operations. Primary tillage was done by sweeps in RT and by bedder in CT. Tillage depth in RT was 7.5 cm (3 inches) and in CT was 15 cm (6 inches). Table 1 shows the tillage operations performed during the 1989-90 crop growing season. Cotton (TAMCOT CAB-CS) was planted on 19 March 1990.

Table 1. Sequence and number of field operations for cotton under conventional tillage (CT) and reduced tillage (RT),Corpus Christi Texas, 1989-1990.

Operation	CT	RT
Shred sorghum stubble	1	1
Disk stubble	1	1
Plow stubble	1	
Cultivate middles		1
Root plow		1
Apply herbicide	1	1
Cultivate middles	1	1
Re-bed	1	
Cultivate middles	1	
Disk beds	1	
Disk and apply herbicide	1	1
Mark rows	1	
Apply fertilizer	1	1
Plant and apply herbicide	1	1
Roll crop	1	1
Cultivate	3	3
Total number of operations	16	13

The experimental site included three soil types: Victoria Clay (Fine, montmorillonitic, hyperthermic Typic Pellusterts), Clareville Complex (Clareville series is Fine, montmorillonitic, hyperthermic Pachic Argiustolls), and Orelia Fine Sandy Loam (Fine-loamy, mixed, hyperthermic Typic Ochraqualfs). Blocking was used to minimize variation due to soil types. Tillage was the main-plot factor, and soil depth was the sub-plot factor in a split-plot design with four replications. Plots contained 18 61-m (200-foot) crop rows.

Soil temperatures were measured by thermocouples placed at depths of 0, 2.5, 7.5, 12.5, 17.5, 27.5, 42.5, and 72.5 cm (0, 1, 3, 5, 7, 11, 17, and 29 inches) in randomly selected sites within cotton-after-sorghum plots (Fraser, 1968). At each depth a pair of thermocouples was oriented in opposite directions to obtain an average reading. Thermocouple readings were taken using a microcomputer thermometer. Soil temperatures were measured once, twice or three times per day, on a random basis. Volumetric soil water content was measured by neutron probe. Plant-extractable water for each depth and plot was considered to be the difference between soil water contents on the days the soil is wettest and driest (Ritchie, 1981).

RESULTS

Rainfall for the first two months of 1990 was 105 mm (4.1 inches). After planting cotton in March, the growing season was one of the warmest and driest of the decade. Rain occurred on four days in March, seven days in April, five days in May, three days in June, and eight days in July. Rainfall totals were 53 mm for March, 100 for April, 37 for May, 9 for June, and 38 for July (2.1 inches for March, 3.9 for April, 1.5 for May, 0.4 for June, and 1.5 for July).

Temperature

Soil temperature readings were grouped and analyzed according to time of day (Table 2). Temperature differences were significant between tillage systems ($P < 0.05$) and soil depths ($P < 0.01$). There was no significant interaction between depth and treatment. In general differences between treatments were slight in the morning and appreciable in the afternoon and evening. Late in the season, the differences in soil temperature diminished, presumably because of less ground cover resulting from severe drought.

Water

By 6 June, soil water content, at most depths were greater in RT than in CT. Water content declined steadily from the first reading on 25 April through 11 July. The last reading, taken on 24 July, indicated a slight increase over 11 July in RT plots. The effect of RT and CT on soil water content is shown in Figure 1. Plant-extractable water (Table 3) was based on the difference between water contents on 25 April and 11 July. Considering the mean of the five soil depths from 15 cm to 90 cm (6 to 35 inches), RT significantly ($P < 0.05$) increased plant-extractable water. Effects of soil depth were also significant ($P < 0.01$). However, differences between tillage treatments at any single depth were not significant, nor was there a significant interaction between depth and treatment. Adding over the five soil depths indicates a total increase of 2.1 cm (0.8 inches) of plant-extractable water in the soil profile under RT (Table 3). Water content in the upper 15 cm (6 inches) could not be measured by neutron probe and was omitted from the statistical analysis. By gravimetric analysis, however, topsoil volumetric water content means were estimated to be 26 % for CT and 24 % for RT on 25 April, with standing water in CT. On 11 July, topsoil water content means were estimated to be 7.3 % for CT and 8.5 % for RT.

Table 2. Soil temperatures from depths of 0 to 72.5 cm (0 to 29 inches) for conventional tillage (CT) and reduced tillage (RT), averaged over the 1990 cotton growing season, Corpus Christi, Texas.

Soil Depth (cm)	Treatment CT	Treatment RT
	---------- °C ----------	
Morning (0800 to 1200 hr)		
0.0	34.9	32.7*
2.5	32.4	32.1
7.5	30.9	30.2
12.5	30.5	30.1
17.5	30.8	30.5
27.5	31.4	30.9
42.5	31.3	30.8
72.5	29.9	29.7
Afternoon (1201 to 1700 hr)		
0.0	44.9	42.4*
2.5	40.2	38.4*
7.5	36.5	34.5*
12.5	33.9	32.5*
17.5	32.5	31.3*
27.5	31.1	30.6
42.5	30.8	30.3
72.5	29.7	29.4
Evening (1701 to 1900 hr)		
0.0	42.8	41.5*
2.5	38.6	38.7
7.5	36.5	35.2*
12.5	34.4	33.2*
17.5	33.1	31.7*
27.5	31.1	30.3*
42.5	30.5	29.6*
72.5	29.4	28.7

*Means in the row are significantly different ($P < 0.05$).

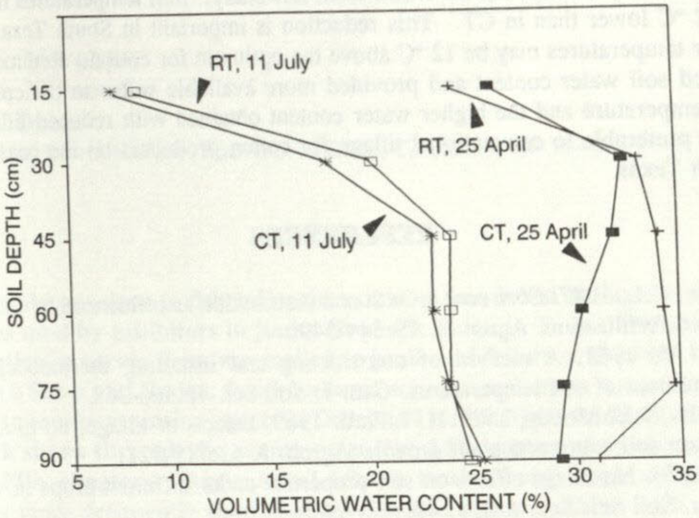

Figure 1. Effects of conventional tillage (CT) and reduced tillage (RT) on volumetric water content when greatest (25 April 1990) and least (11 July 1990) during the cotton growing season in Corpus Christi Texas. Water contents are reported at soil depth increments of 15 cm (6 inches).

Table 3. Plant-extractable water between 15 and 90 cm (6 and 35 inches) soil depth, for cotton grown in Corpus Christi, Texas, 1990, as affected by conventional tillage (CT) or reduced tillage (RT).

	Treatment	
Soil Depth (cm)	CT	RT
	-------- cm -------	
15 to 30	2.0	2.1
30 to 45	1.6	1.8
45 to 60	1.1	1.8
60 to 75	0.7	1.3
75 to 90	0.4	0.7
Mean	1.1	1.5*
Total	5.6	7.7

*Means in the row are significantly different ($P < 0.05$).

CONCLUSIONS

Practical implications can be drawn from this study. Soil temperatures in RT are about 2 °C lower than in CT. This reduction is important in South Texas, where summer temperatures may be 12 °C above the optimum for cotton. Reduced tillage increased soil water content and provided more available water to the crop. The lower temperature and the higher water content obtained with reduced tillage may make it preferable to conventional tillage for cotton producers on the coastal plain of South Texas.

REFERENCES

Anderson, E.L. 1987. Corn root growth and distribution as influenced by tillage and nitrogen fertilization. Agron. J. 79:544-549.

Fraser, J.V. 1968. A method of constructing and installing thermocouples for measurement of soil temperatures. Can. J. Soil Sci. 48:366-368.

Jones, J.N., J.E. Moody, and J.H. Lillard. 1969. Effects of tillage, no tillage, and mulch on soil water and plant growth. Agron. J. 61:719-721.

Lal, R. 1976. No-tillage effects on soil properties under different crops in western Nigeria. Soil Sci. Soc. Am. J. 40:762-768.

Lyle, W.M. and J.P. Bordovsky. 1987. Integrating irrigation and conservation tillage technology. p. 67-77. In T.J. Gerik and B.L. Harris (eds.). Conservation tillage: today and tomorrow. Texas Agric. Exp. Stn. MP:1634.

Martin, J.H., W.H. Leonard, and D.L. Stamp. 1976. Cotton. Ch. 33. In Principles of Field Crop Production, 3rd ed. Macmillan Publ. Co., Inc., New York.

Ritchie, J.T. 1983. Soil water availability. Plant Soil 58:327-338.

Thomas, G.W., and W.W. Frye. 1984. Fertilization and liming. p. 87-126. In R.E. Phillips and S.H. Phillips (eds.) No-tillage agriculture. Van Nostrand Reinhold Co., New York.

Unger, P.W. and A.F. Wiese. 1979. Managing irrigated winter wheat residues for water storage and subsequent dryland grain sorghum production. Soil Sci. Soc. Am. J. 43:582-588.