Table 3. Effects of tillage systems and cover crops on plant population of cotton on a Gigger silt loam soil; Macon Ridge Research Station, Winnsboro, LA, 1987-1988.

Tillage System	Cover Crop	Plant Population 1987	1988	2-Year Average
		-plants/acre x 1000-		
Conventional	No Cover Crop	26.0	56.2	41.1
	Crimson Clover	23.7	49.2	36.4
	Hairy Vetch	25.0	54.1	39.5
	Wheat	30.2	47.9	39.0
Ridge Till	No Cover Crop	25.2	22.1	23.6
	Crimson Clover	22.5	40.0	31.3
	Hairy Vetch	21.2	26.0	23.6
	Wheat	32.8	42.3	37.6
No Till	No Cover Crop	25.2	17.9	21.6
	Crimson Clover	26.6	9.3	18.0
	Hairy Vetch	20.6	9.5	15.0
	Wheat	31.2	31.4	31.3
Tillage means across cover crops				
Conventional		26.2	51.8	39.0
Ridge Till		25.4	32.6	29.0
No Till		25.9	17.0	21.5
Cover crop means across tillage systems				
	No Cover Crop	25.4	32.1	28.7
	Crimson Clover	24.3	32.8	28.6
	Hairy Vetch	22.3	29.8	26.0
	Wheat	31.4	40.5	36.0
LSD (0.05) Tillage Systems x Cover Crops		N.S.	13.7	8.1
LSD (0.05) Tillage Systems		N.S.	6.9	6.2
LSD (0.05) Cover Crops		5.4	7.9	7.2
C.V.%		25.0	28.1	26.9

CONTROLLED TRAFFIC RESEARCH WITH A WIDE FRAME SPANNER FOR COTTON DOUBLE-CROPPED WITH WHEAT

D.W. Reeves, C.B. Elkins, H.H. Rogers, J.B. Powell, and S.A. Prior
Research Agronomist, Soil Scientist, Plant Physiologist, Research Leader, and Plant Physiologist, respectively; USDA, ARS, National Soil Dynamics Laboratory, Auburn, AL

Abstract

The advent of the tramline system in cereal production and extrapolation of research results using modified tractors have generated interest in the use of wide-span vehicles (spanners or gantries) for researching soil compaction problems. A field study was initiated in 1987 on a compactible Typic Hapludult with a well developed tillage pan to study the effects of traffic and tillage systems on soil properties and crop performance in a wheat-cotton double-crop system. A wide frame tractive vehicle (WFTV) that allows for 20-ft. wide, untrafficked research plots was utilized to double-crop cotton "McNair 220" with wheat "Coker 9733". The experimental design was a split-plot with 4 replications. Main plots were: 1) Conventionally trafficked and 2) Zero-traffic. Subplots were tillage systems for cotton: 1) Complete surface tillage without subsoiling, 2) Complete surface tillage and annual in-row subsoiling (16-inch depth), 3) Complete surface tillage with one-time only complete disruption of tillage pan, and 4) No surface tillage but planted with in-row subsoiling (strip-tillage). Residual effects of cotton tillage were determined for wheat. Late planting limited seed cotton yields in 1987 and 1988. Neither traffic nor tillage had an effect on seed cotton yield in 1987 (average 896 lb/A). There was a significant traffic X tillage interaction on wheat grain yield and seed cotton yield in 1988. Subsoiling resulted in an average wheat yield of 79 bu/A, a 19% increase over not subsoiling, in zero-traffic plots. In trafficked plots, subsoiling resulted in an average grain yield of 54 bu/A, a 12% reduction from not subsoiling. In-row subsoiling resulted in maximum seed cotton yield (1580 lb/A) in zero traffic plots and lowest yield (1140 lb/A) in trafficked plots. With subsoiling, zero traffic promoted earliness. Strip-tillage in trafficked plots delayed maturity. Preliminary results, if repeatable in the long term, indicate that controlled traffic may be beneficial in double-cropping cotton, but that other systems, e.g., strip-tillage, would be feasible in a monocrop system with a longer growing season.

Introduction

Soil compaction has long been recognized as a problem in cotton production, especially on sandy Coastal Plain soils. Bowen (1981) reviewed a number of methods for alleviating soil compaction. These included deep plowing, subsoiling, chiseling, crop rotations, and controlled traffic. 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/A seed cotton). Colwick et al. (1981) reported that controlled traffic beds tended to result in yield decreases on a Leeper silty clay loam (Vertic Haplaquept). The yield reduction may have been due to less efficient water infiltration on controlled traffic beds. Williford (1982, 1987) modified conventional equipment to establish traffic zones and permanent beds for cotton. On a Bosket very fine sandy loam (Mollic Hapludalf), annual subsoiling increased yields in 5 of 6 years. However, subsoiling was not necessary in the controlled traffic system. Yields from the subsoiled conventional-trafficked system and the nonsubsoiled controlled-traffic system were equivalent.

Although, research with controlled traffic has focused on interactions with deep tillage, i.e., subsoiling, there is a critical need to: 1) investigate tillage systems that utilize controlled traffic; and 2) to compare conventionally-trafficked tillage systems, including conservation tillage systems, to systems that utilize controlled traffic as a component.

The development of early maturing cotton and wheat cultivars has introduced an alternative to the traditional wheat-soybean double-crop system in the Southeast (Baker, 1987). Timeliness of operations in a wheat-cotton system is critical, as windows for planting and harvesting are narrow. Controlled-traffic systems, with permanent traffic lanes, offer wider windows for operations, making this system more feasible.

One hundred thirty years ago, in England, Clarke (1859) recognized the value of a "wide-spanning stage or platform" tillage system; developed by P. A. Halkett, for preventing soil compaction by "men, implements, horses, or tractive power". Other advantages for the spanner system were timeliness and precision of applying cultural practices. The advent of the tramline system in cereal production and extrapolation of research results using modified tractors have regenerated interest in the use of wide-span vehicles (spanners or gantries) for researching soil compaction problems. The USDA-ARS National Soil Dynamics Laboratory has recently begun a research program with a wide frame tractive vehicle (WFTV). The WFTV allows for 20-ft. wide, untrafficked research plots (Fig. 1). A detailed description of the vehicle and its capabilities has been published (Monroe and Burt, 1987).

A wheat-cotton double-cropping system was chosen to efficiently utilize the WFTV's research capabilities. Commercial development of wide-frame spanners would require an intensive cropping system with high returns to offset the high initial cost of the machine. Intensively managed wheat, and cotton offer potentially high returns. Wheat and cotton, both respond to deep tillage on compactible soils, and double-cropping them provides an opportunity for research on both a fibrous (wheat) and tap-rooted (cotton) crop.

Materials and Methods

A field study was initiated in June of 1987 at the Alabama Agricultural Experiment Station, Auburn University, Agricultural Engineering Research Farm at Shorter, AL. The soil is a Cahaba-Wickham-Bassfield sandy loam complex (Typic Hapludult). Cation exchange capacity (C.E.C.) and organic matter for the test site averaged 6.31 meq/100 g, and 1.19 %, respectively. Initial pH was 5.93. Initial P and K averaged 118 and 108 lb/A, respectively. Lime (1 ton/A) and K (66 lb/A) were applied in April 1987. The site has a well developed 3-to-6-inch thick hardpan from 8 to 12 inches deep. To reduce variation, an effort was made to form a uniform hardpan at the 8 inch depth by running a motor grader repeatedly in plowed furrows incrementally across the experimental site.

The experimental design was a split-plot with 4 replications. Main plots were: 1) Conventionally trafficked and 2) Zero-traffic. Subplots were tillage systems for cotton: 1) Complete surface tillage without subsoiling, 2) Complete surface tillage and annual in-row subsoiling (16-inch depth), 3) Complete surface tillage with one-time only complete disruption of tillage pan, and 4) No surface tillage but planted with in-row subsoiling (strip-tillage). Main plots were 20-ft wide and 600-ft long; divided into 150 ft sections for subplots. Complete surface tillage consisted of disking, chisel plowing (8-inch depth), disking, and field cultivating. The one-time only complete disruption was in November, 1987 prior to planting the first wheat crop. These plots were subsoiled to a 20-inch depth on 10 inch centers, using a V-ripper. The strip-tilled cotton (Treatment 4) was planted into wheat stubble with a KMC in-row subsoiler planter.

Subplot treatments (tillage treatments) were imposed on cotton only. The residual effects of these treatments were determined on wheat. After harvesting cotton, stalks were mowed, all plots were disked, chisel plowed (8-inch depth), disked, and field cultivated to prepare for planting wheat.

Initial Cotton Crop-1987

Cotton, "McNair 220", was seeded on 30-inch rows, at 90,000 seed/A, on 24 June. Planting was delayed from the proposed date of 1 June due to the WFTV still being in a state of development. In conventionally trafficked plots, primary tillage operations were with a John Deere 4440 tractor. Secondary operations, i.e., cultivating, planting, spraying, etc. were done with the WFTV and the 4440 or a Hi-boy sprayer driven through the plots to simulate traffic that would have been applied by each operation. A liquid starter fertilizer (18-18-0) to supply 23 lb N/A and 10 lb P/A was banded over the row at planting. At first square, 70 lb N and 13 lb S/A (ammonium nitrate-ammonium sulfate blend) was broadcast on all plots. All operations were set up to be done with 4 row equipment. Recommended cultural practices for insect and weed control were used throughout the season on all plots.

This crop initiated the cropping system experiment. Therefore, the complete set of tillage treatments could not be imposed this year. All plots were surface tilled, and treatments with in-row subsoiling as a component were planted with an in-row subsoiler. Thus, with this initiation crop, tillage treatments 2 (conventional surface tillage with in-row subsoiling) and 4 (strip-tillage) were both surface tilled. Treatments 1 and 3 were not subsoiled.

Plant samples for dry weight determination were taken every 2 weeks, starting 4 weeks after planting. Cotton from 100 ft of row was hand picked on 30 October, and unopened bolls were counted.

Wheat-1988

Following cotton harvest, stalks were mowed and raked to the end of plots with a field cultivator. This was done to facilitate the use of a 4-inch drill. Plots were disked and a V-ripper was used to completely disrupt the hardpan in tillage treatment 3. All plots were then disked, and leveled with a field cultivator. On 23 November, wheat (Coker 9733) was seeded at 220 lb/A (20 seed/ft row) with a Marliss drill in 4 inch row widths. At planting, 26 lb N, [illegible] lb P, 130 lb K, and 25 lb S were broadcast. The wheat was managed intensively with traffic applied to appropriate plots for 2 additional N applications ([illegible] and 64 lb N/ac), 2 fungicide applications and an insecticide application for Hessian fly. Traffic patterns were uniform for these applications.

At anthesis, soil water was monitored in positions relative to traffic patterns in all plots using time domain reflectometry (Topp, 1987). Plots were harvested 3 June with a plot combine suspended from the WFTV. Grain yield was standardized to 13% grain moisture.

Cotton-1988

A forage harvester was used to mow wheat straw (8 inches high) and a hay rake was used to rake straw off the plots. Although wheat was harvested within the proposed window for the double-cropping system, a drought delayed planting. An intensive cropping system utilizing a WFTV would certainly require irrigation to maximize productivity. Irrigation was incorporated into the research plan, but the irrigation system was not operable until 15 June. On this date, 1 inch of water was applied to the test area, and on 17 June McNair 220 cotton was seeded as in 1987. An 8 row subsoiler-planting unit was used to plant all plots. Subsoiler shanks were dropped from the unit for appropriate treatments. A liquid starter fertilizer was applied over the row to supply 34 lb N and 49 lb P/ac. At first square, 76 lb N and 14 lb S/A was banded beside the row.

This second cotton crop was the first to incorporate all tillage treatments in the design. The traffic pattern for trafficked plots was based on 8 row equipment.

Plant samples for dry weight determination were taken every 2 weeks, starting 4 weeks after planting. Soil water was monitored (same system as with wheat) beginning at first square and extending until 2 weeks before harvest. Cotton from 100 ft of row was hand picked on 3 November, and unopened bolls were counted.

Results and Discussion

Initial Cotton Crop-1987

Generally, plant growth (dry matter production) was increased with zero-traffic, with most of the effect being observed during the early portion of the growing season (data not shown). Seed cotton yields were low due to the extremely late planting date and drought. Seed cotton yields for zero and trafficked plots averaged 960 and 831 lb/A, respectively ($P \leq 0.23$).

Although subsoiling significantly increased dry matter production throughout most of the growing season (data not shown), it had little effect on seed cotton yield. Seed cotton yields averaged 884 and [illegible] lb/A with and without in-row subsoiling, respectively ($P \leq 0.76$).

There was a significant traffic X tillage interaction ($P \leq 0.07$) for unopened bolls at final harvest. Subsoiling had no effect on the number of unopened bolls in zero-traffic plots (average [illegible] unopened bolls/A). In trafficked plots, however, subsoiling resulted in more unopened bolls (30,000 vs. 14,000 bolls/A for subsoiled and nonsubsoiled plots, respectively).

Wheat-1988

Tillage treatments imposed on the previous cotton crop (in-row subsoiling or no in-row subsoiling) and the complete disruption of hardpan just prior to planting wheat (tillage treatment 3) significantly interacted with traffic treatments to affect grain yield (Fig. 2). Within zero-traffic plots, in-row subsoiling the previous cotton crop resulted in yields equivalent to complete disruption of the tillage pan (subsoiling 20 inches deep on 10 inch centers) just prior to planting wheat. In trafficked plots, however, in-row subsoiling the previous cotton crop reduced yields 19 and 11% compared to complete disruption (tillage treatment 3) prior to planting wheat, and not subsoiling, respectively.

Soil water content of the 0 to 40 inch depth during the period from anthesis to maturity offers an explanation for the traffic X tillage interaction effect on grain yield (Fig. 3). Subsoiling cotton increased soil water in zero-traffic plots and reduced soil water in the trafficked plots. Grain yield response was likely due to traffic and tillage effects on water infiltration, root growth and consequent water extraction.

Cotton-1988

Tillage treatments affected early season plant growth (data not shown). Generally, dry matter accumulation until bloom was retarded by strip-tillage and increased by conventional tillage with in-row subsoiling. Traffic had no effect on dry matter production.

The late planting date limited seed cotton yield. There was a significant traffic X tillage interaction effect on seed cotton yield (Fig. 4). Complete surface tillage with in-row subsoiling at planting resulted in maximum yield in the zero-traffic plots, but lowest yield in the trafficked plots. Within zero-traffic plots, the initial subsoiling treatment (subsoiling 20 inches deep on 10-inch centers prior to first wheat crop) reduced yields compared to subsoiling in-row at planting. In trafficked plots, however, the initial subsoiling treatment increased seed cotton yield compared to complete surface tillage with in-row subsoiling at planting.

Earliness, as evidenced by the number of unopened bolls left after picking, was affected by a traffic X tillage interaction (Fig. 5). Within trafficked plots, conventional surface tillage with in-row subsoiling and strip-tillage resulted in the greatest number of unharvested bolls. Without the benefit of any deep tillage, the number of unopen bolls was not significantly affected by traffic. In general, with deep tillage (tillage treatments 2-4), zero-traffic promoted earliness. This trend was also noted in 1987 on the initial cotton crop. In trafficked plots, the delay in maturity with strip-tillage, evidenced by unharvested bolls, was dramatic.

Because the cotton was planted 3 weeks behind schedule, the potential yield (based on the number of unharvested bolls and average seed cotton weight/boll) was calculated (Fig. 6). A comparison of Figs. 5 and 6 shows the potential of strip-tillage in trafficked plots. Further research is needed to determine the limitations of this system because of its delay in earliness. In a wheat-cotton double-crop system the delay in maturity may be too limiting. In a cotton monocropping system, if the current research results are repeatable, strip-tillage system may be an economical alternative for managing soil compaction compared to the use of a WFTV.

There was a consistent tillage treatment effect on soil water (0 to 40 inch depth) during the 47 day period starting at first bloom (Fig. 7). Rainfall during this period was drastically below normal. Traffic had no effect on soil water. Soil water in nonsubsoiled and initial-subsoiled plots (tillage treatments 1 and 3, respectively) were equivalent. The greater soil water content mantained in the strip-tilled plots can probably be attributed to greater infiltration, smaller plants due to retarded development compared to plants in surface-tilled plots, and the mulch effect of wheat stubble. The decreased soil water in the complete surface tilled plots with in-row subsoiling is likely due to more rapid extraction of soil water by larger plants with more extensive root systems.

Conclusions

Although late planting severely depressed yields, preliminary data suggest that controlled traffic, by promoting earliness, may be beneficial in a wheat-cotton double-cropping system for soils of the Southern Coastal Plain that require subsoiling. In a cotton monocropping system, with a longer growing season, strip-tillage might offer yields comparable to controlled traffic. The data also suggest that subsoiling in conventional tillage systems (with surface tillage) can be detrimental to crop performance of both fibrous-rooted crops (wheat) and tap-rooted crops (cotton). Firm conclusions from the data cannot be made at this time. This test is designed as a long term experiment, in order to properly assess the effects of tillage and traffic on soil properties and crop performance. The WFTV is yet another tool to be used by scientists to address means for understanding the effects of soil compaction; and to develop techniques for ameliorating the limitations that soil compaction imposes on crop performance.

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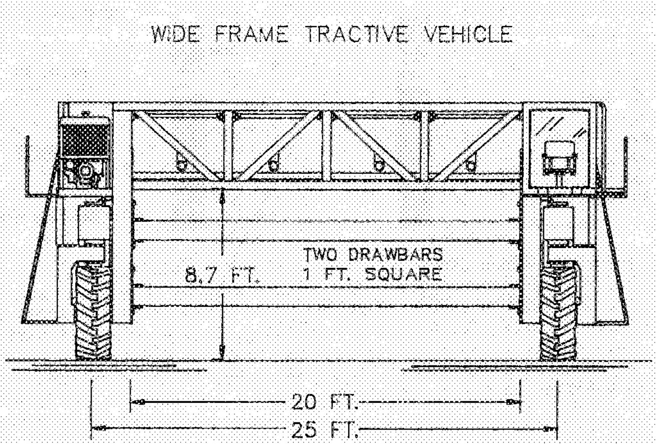

Figure 1. Wide Frame Tractive Vehicle (WFTV) used in soil compaction research at USDA-ARS National Soil Dynamics Laboratory.

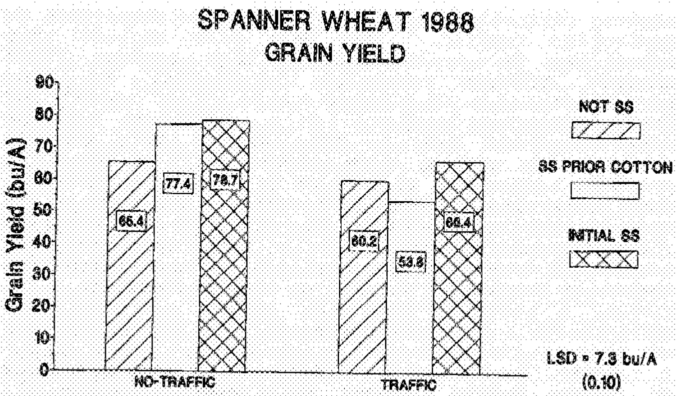

Figure 2. Wheat grain as affected by traffic and tillage in a wheat-cotton double-crop system. Not SS = previous cotton crop not subsoiled, SS prior cotton = previous cotton crop in-row subsoiled, and Initial SS = one-time only complete disruption of hardpan prior to planting wheat.

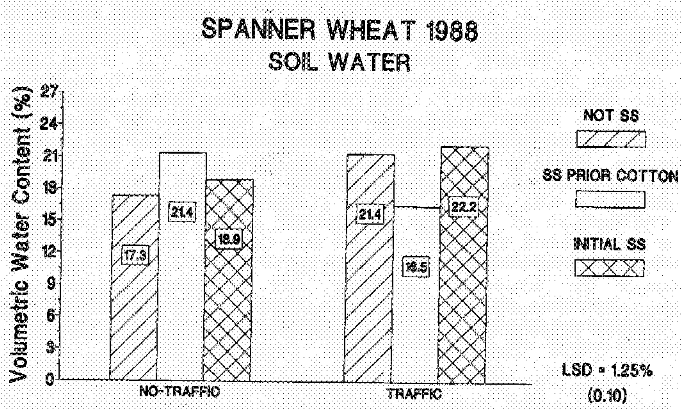

Figure 3. Average soil water (0-40 inch depth) from wheat anthesis to maturity. Not SS = previous cotton crop not subsoiled, SS prior cotton = previous cotton crop in-row subsoiled, and Initial SS = one-time only complete disruption of hardpan prior to planting wheat.

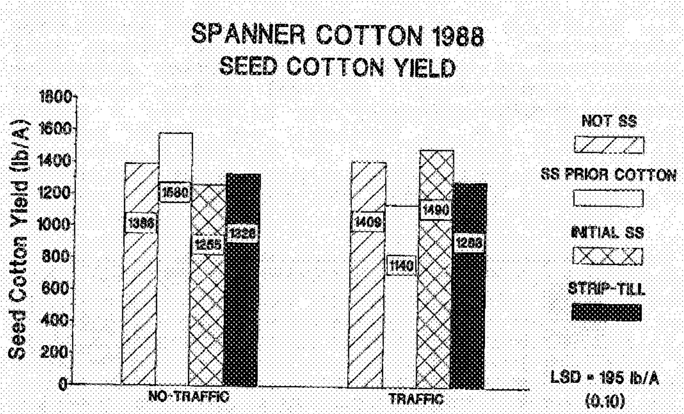

Figure 4. Seed cotton yield as affected by traffic and tillage in a wheat-cotton double-crop system. Not SS = conventional surface tillage, SS prior cotton = conventional surface tillage with in-row subsoiling, Initial SS = one time only complete disruption of hardpan prior to planting previous wheat crop, and Strip-till = no-till with in-row subsoiling into wheat stubble.

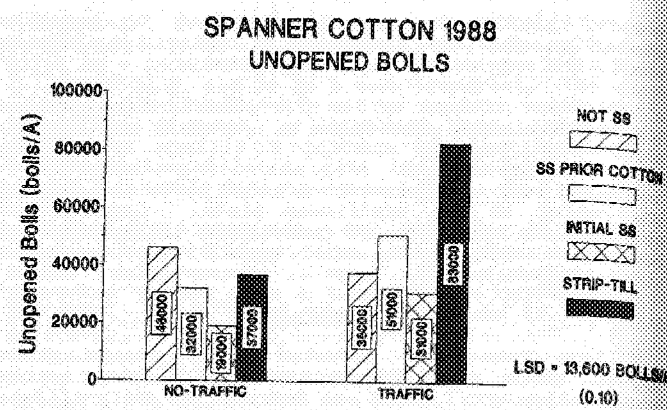

Figure 5. Unopen (unharvested) bolls as affected by traffic and tillage in a wheat-cotton double-crop system. Not SS = conventional surface tillage, SS prior cotton = conventional surface tillage with in-row subsoiling, Initial SS = one-time only complete disruption of hardpan prior to planting previous wheat crop, and Strip-till = no-till with in-row subsoiling into wheat stubble.

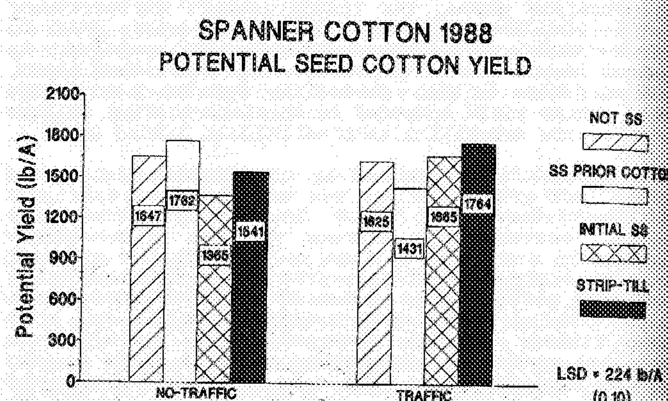

Figure 6. Potential seed cotton yield as affected by traffic and tillage in a wheat-cotton double-crop system. Not SS = conventional surface tillage, SS prior cotton = conventional surface tillage with in-row subsoiling, Initial SS = one-time only complete disruption of hardpan prior to planting wheat crop, and Strip-till = no-till with in-row subsoiling into wheat stubble.

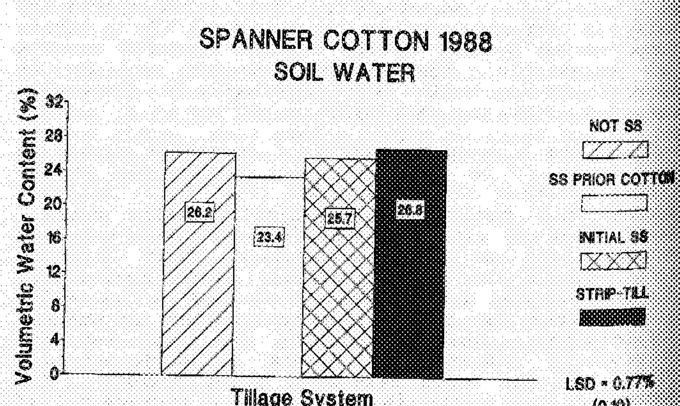

Figure 7. Effect of tillage system for cotton on average soil water (0-40 inch depth) during bloom of cotton in a wheat-cotton double-cropping system. Not SS = conventional surface tillage, SS prior cotton = conventional surface tillage with in-row subsoiling, Initial SS = one-time only complete disruption of hardpan prior to planting previous wheat crop, and Strip-till = no till with in-row subsoiling into wheat stubble.