THE EFFECTS OF VARIOUS TILLAGE SYSTEMS ON SELECTED SOIL PHYSICAL PROPERTIES AND COTTON PLANT RESPONSE

By

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CHAPTER I

INTRODUCTION

Crop production is affected by many factors, several of which man significantly influences. Soil physical conditions that exist in a soil during plant growth are examples of one class of variables that influence plant growth. A primary determinant of plant growth in many soils is the extent to which the plant roots are distributed; this distribution can be altered by the type of soil tillage system used.

In recent years, systems of minimum tillage, or even no-tillage in some instances, have been used in the production of various crops. These systems involve fewer trips over the soil surface with farm machinery. The advent of herbicides for weed control has facilitated minimum tillage practices as well as providing the grower with an opportunity to change his total tillage system.

This research study was initiated to evaluate and compare various tillage systems for cotton production. Several soil physical properties were measured during the growing season. These properties include soil strength, bulk density, soil-water content, and soil temperature. The response of the cotton plant in the various tillage systems was quantitatively established through plant heights, characteristics of the root system, and yield.

The relationships that existed between the tillage system and the soil and plant responses were evaluated. This is of particular importance since these relationships will be used in determining the application of minimum or no-tillage practices for dry-land cotton production in Oklahoma.

CHAPTER II

LITERATURE REVIEW

To have optimum soil physical conditions for plant growth in the field, the soil should be readily penetrable by plant roots. Sometimes this is not the case, owing to soil compaction. Soil compaction has been defined as "mechanical manipulation that causes the soil to become more dense" (9). Both internal and external forces affect the physical condition of a soil, but compaction of agricultural soils results primarily from externally applied forces (7). Cohron (7) lists tractors and tillage implements as the primary external compaction forces in tilled agricultural soils.

Various systems of minimum and no-tillage have been used for several commercial crops in hopes of creating a more favorable environment for the plant by improving one or more soil physical factors. There have been both favorable and unfavorable results reported for minimum and no-tillage systems. Carter and Colwick (5) compared a normal cotton tillage system with an "optimum" tillage system that was based on the concept of considering the soil in 3 major divisions: root development, water infiltration, and traffic support. The optimum system required fewer mechanical trips through the field and limited traffic compaction to alternate furrows. Their results showed that soil strength and bulk density were less under the optimum system than under the normal system. They concluded that a reduced number of operations could improve the plant root environment and decrease costs as well. Phillips (18) presented experimental data that showed that seed cotton yields with minimum mechanical seedbed preparation on clay and silt loam soils were as great as yields from conventionally prepared seedbeds where the soil was cultivated. Blevins et al. (2) found a decrease in evaporation and a greater ability to store moisture as well as higher yields under no-tillage practices for corn in Kentucky as opposed to conventional corn tillage procedures.

In the tillage and compaction experiments conducted by Taylor and Burnett (21), cotton seedlings died on plots where compacted soils were not disrupted by tillage. Compaction of the soil, if not loosened by tillage, caused a significant reduction in root development and an increase in soil strength. Plant heights were much greater on tilled treatments, whether chiseled, sweep-plowed, or disk-plowed, than on no-till plots. Lint cotton yield was much less on the no-till compacted treatment than on any other treatment.

It is desirable to be able to measure, quantitatively, soil compaction in the field. Several methods have been used in an attempt to establish a quantitative description that corresponded to physical observations. Penetrometers have been used by several workers to measure soil strength, a quantity which is indicative of the degree of compaction. Taylor and Bruce (20) state that, from available evidence, soil strength has been rather well characterized by using penetrometers to make soil strength measurements. However, several researchers (19, 28) feel that there are some discrepancies in measuring soil strength (or resistance to penetration) with a penetrometer and then using these results to predict when plant roots will be unable to enter a soil. Stolzy and Barley (19) found that in comparing the force exerted by a root entering a compacted soil with the point resistance measured with a penetrometer probe, there appeared to be more resistance to the probe than to the root. Waldron and Constantin (28) noted that there was generally a significant difference in root and penetrometer velocities. They point out that there are differences between penetrometers and roots, including shape, rigidity, kinematics of extension, and frictional properties. These might account for roots being able to penetrate a soil in which penetrometer resistance (expressed as the force required to produce a given penetration divided by cross-sectional area of the probe) would be greater than the axial pressure roots are capable of exerting.

Soil strength or penetrometer resistance has been found to be closely related to soil bulk density. Freitag (10) states that the relation of soil strength to soil density is sufficiently well defined for a given water content or a particular compaction effort that it can be used to study the effects of compaction. Chancellor (6) and Camp and Lund (3) point out that penetrometer resistance or strength of a given soil at a given moisture content generally increases as the compactness or density of the soil increases. The major factor affecting the specific relationships between soil strength and density is soil moisture content.

Soil compaction is of interest to the agronomist in that it affects root growth and crop yield. Barley and Greacen's (1) definition of mechanical resistance-"the reaction of the soil to forces exerted by the growing plant"-indicated interest in the way that soil and plants interact. Drew et al. (8) point out that seedling germination is a plant process that is influenced by mechanical impedance of the soil. Work has been done which indicates that soil compaction, as evidenced by high soil strength, is detrimental to normal root growth. In an experiment designed to determine the effect of soil compaction on root penetration in 3 Mississippi River alluvial (medium-textured) soils, Hopkins and Patrick (11) found that compacting the soil had a marked effect on root penetration. There was a pronounced decrease in root development with an increase in compaction up to 10 ft-lb per in^3, with little root penetration occurring above this value. Taylor et al. (24) concluded that excessive soil strength, developed largely as a result of drouth conditions, caused the root-restricting features of many southern Great Plains soils.

The relationship of soil strength to root penetration and growth patterns as well as cotton yield has been the subject of considerable research. Several workers (3, 13, 14, 20, 22, 23, 25, 26) have reported that cotton root penetration was retarded and cotton yields were reduced under conditions of excessive soil strength. Several examples of this work serve to illustrate this point further.

Camp and Lund (3) reported a reduction in rate of cotton root penetration with increases in soil strength. Lowry et al. (13) observed that leaf drop occurred on plants growing in soil-compacted treatments where artificially compacted soil pans were created at varying depths. They concluded that the leaf drop was due to the failure of roots to penetrate the compacted zone. Also, plant height, seed cotton yield, and root penetration were reduced as soil bulk density and/or penetrometer resistance increased and as depth to the pan decreased. Mathers and Welch (14) stated that cotton yields were decreased when taproots were restricted, and yields were decreased by increasing the duration of restriction to more than 2 weeks.

It has been reported (20) for laboratory experiments that the entry of cotton roots into soil pan layers and root elongation through soil pans were reduced as penetrometer resistance was increased. At a penetrometer resistance of about 20 bars, no cotton roots entered the soil layers. Taylor and Gardner (22) found that at a bulk density of 1.65 g/cm^3, there was a 60% reduction in the number of cotton seedling taproots penetrating soil cores at a soil-water tension of 2/3 bar as compared to a soil-water tension of 1/5 bar. Thus, at a given bulk density, taproots had a greater probability of penetrating the cores with a lower soil-water tension. Also, they showed that an increase in soil strength not only reduced the percentage of roots penetrating the soil, but decreased the rate of root growth through the soil. It was shown by Taylor et al. (26) that four soils, ranging in texture from a loam to a loamy fine sand, exhibited similar patterns in that the percentage of cotton taproots that penetrated the soil cores decreases as soil strength increased. A sharp decline in root penetration occurred as soil strength increased from 3 to 15 bars followed by a more gradual decline out to about 25 bars. No taproots penetrated any core with soil strengths of 25 bars or more, regardless of soil.

In experiments by Taylor and Ratliff (25), root elongation rates of cotton and peanuts were decreased as soil strengths (measured with a penetrometer) increased. Taylor et al. (23) conducted experiments to determine the effects of soil pan strengths on yield of cotton and grain sorghum at 3 locations in the southern Great Plains. They reported that growth rate and yield of both cotton and grain sorghum were drastically reduced as soil pan strengths increased to 25 bars. They found that yields were reduced approximately 50% under high strength conditions as compared with low strengths.

Research conducted with other crops has shown that high soil strength is as damaging to them as it is to cotton. Parker and Taylor (16) have shown that sorghum seedlings ceased to emerge from several sandy soils with soil strengths ranging from 13 bars to 18 bars. Also, an increase in soil-water tension decreased seedling emergence. Meredith and Patrick (15) found that for sudangrass grown on silt loam and clay loam soils, root penetration decreased as the compactive effort on each soil was increased (i.e., as the soil strength became higher). Kar and Varade (12) also report that rice root growth decreased as the soil density increased. Veihmeyer and Hendrickson (27) reported that sunflowers did not penetrate soils compacted to high densities.

Soil compaction has also been shown to have an effect on the heat content of soils, and therefore on soil temperature. Willis and Raney (29) state that compaction affects heat content and transmission in soil by changing soil density, soil-water relations, and plant growth. They point out that compaction causes an increase in density with a resultant increase in thermal conductivity and a probable increase in thermal diffusivity. In an experiment to determine cotton root length under varying conditions of soil temperature and penetrometer resistance, Pearson et al. (17) found that for low soil densities growth was primarily governed by temperature with maximum root elongation occurring at approximately 32^{o}C. The first significant increase in penetrometer resistance resulted in a sharp decrease in elongation at all temperatures. At higher levels of resistance, they found that the effect of temperature was overshadowed by soil strength. When resistance was greater than 13.7 bars, roots penetrated the compact zone a distance of only about 2 mm regardless of temperature. At high soil strength only 7% of the variation in root length was accounted for by temperature, whereas 80% was accounted for by strength.

No-tillage and minimum tillage practices are being used in several parts of the United States in the production of various crops. Soil physical properties and cotton plant responses have been studied together previously. This research, however, attempted to use these variables in evaluating the feasibility of minimum and no-tillage systems for dry-land cotton production on the medium-textured soils of the South-Central United States.

CHAPTER III

MATERIALS AND METHODS

The research area for this study was located on the Agronomy Research Station near Perkins, Oklahoma. The soil is mapped as a Teller loam. The total project consists of eleven different tillage systems, but only five were sampled in detail during this study. These five represent the extremes as well as the average of the eleven treatments. Each treatment was replicated four times using a randomized block design.

Tillage systems studied are as follows:

Treatment 1. (Conventional tillage) Seedbed preparation consisted of plowing and disking, cotton was planted with a conventional profile cotton planter, and cultivated as needed for weed control. Plowing was done March 22, 1972.

Treatment 2. (Zone tillage + chemical) Weeds were controlled from harvest to planting with 1,1′-dimethyl-4,4′bipyridinium ion (paraquat). The planting zone was tilled with a sweep-type implement which worked an area approximately 14 inches wide and 6 inches deep. The tillage and cotton planting were done in one operation (planted with conventional profile cotton planter). 1,1-dimethyl-3-(α,α,α-trifluoro-m-tolyl) urea (fluometuron) was applied for weed control immediately following planting and as needed thereafter.

Treatment 3. (Zone tillage + mechanical) Weeds were controlled from harvest to planting with paraquat. The planting zone was tilled with a sweep-type implement which worked an area about 14 inches wide and 6 inches deep. The tillage and planting were done in one operation (planted with conventional-type planter). Fluometuron was applied for weed control immediately after planting. Mechanical cultivation was used as needed thereafter for weed control.

Treatment 4. (No-tillage + chemical) Weeds were controlled with paraquat between harvest and planting. The cotton was planted near the previous year's cotton rows in unprepared ground. A special planter equipped with a coulter wheel ahead of double disk openers made it possible to plant in non-tilled soil. Fluometuron was used immediately after planting and as needed for weed control until harvest.

Treatment 5. (No-tillage + mechanical) Same as treatment 4 except that the second weed control operation required after planting was mechanical. All others were chemical.

The cotton was planted in 40-inch rows. Each plot consisted of 6 rows except treatment 1 where 12 rows were used. Twelve rows were used in treatment 1 since the seedbed preparation and weed control were entirely mechanical and a larger area was required for adequate machinery maneuverability. Planting was done on May 25, 1972, for the growing season during which this thesis study was conducted. This was the fourth year for the entire project to be conducted on the same plots; thus, the results obtained in the present study were affected by cumulative effects of these treatments from past seasons. Treatments 1 and 5 were cultivated June 19, and treatments 1 and 3 were cultivated July 25, 1972. Cultivation was done with a 2-row tractor mounted row crop cultivator.

Soil Strength and Bulk Density

Soil strength and bulk density were determined from cylindrical soil samples 3 inches high by 3 inches in diameter. The cores were undisturbed and were taken in the plant row from the 2 to 5-inch depth.

One set of core samples was taken each month, June through October. Cores were taken on each of the following dates: June 12, July 10, August 16, September 16, and October 25, 1972. Two core samples were taken from each replication of the five treatments; samples were removed from within the second and fifth rows of the plot. Samples were taken from the northeast corner of the second row of the plot, while those from the fifth row were taken from the southwest corner. In the 12-row treatment, treatment 1, cores were taken from the second and eleventh rows.

Core samples were brought to the laboratory, trimmed to 3 by 3 inches, and placed on a ceramic plate in a "pressure cooker" extractor. Water was applied to the plate until the cores had become saturated, a process requiring 2 to 4 days. Following saturation, a pressure of 1/3-atm. was applied to the cores for 48 hours. Soil strength measurements from each core were made using a static penetrometer (Figure 1) with a single proving ring with a 0-220 newton range. The penetrometer shaft had a 0.95 cm diameter blunt tip and was forced into the soil to a depth of 0.65 cm by turning the driving wheel at a rate of 6 rev/min. The unloaded penetration rate for the shaft was 0.90 cm/min. Three penetrations were made at the 2-inch depth, and three penetrations were made at the 5-inch depth. It is pointed out by Barley et al. (1) that accuracy may be reduced for depths less than 3 times the shaft

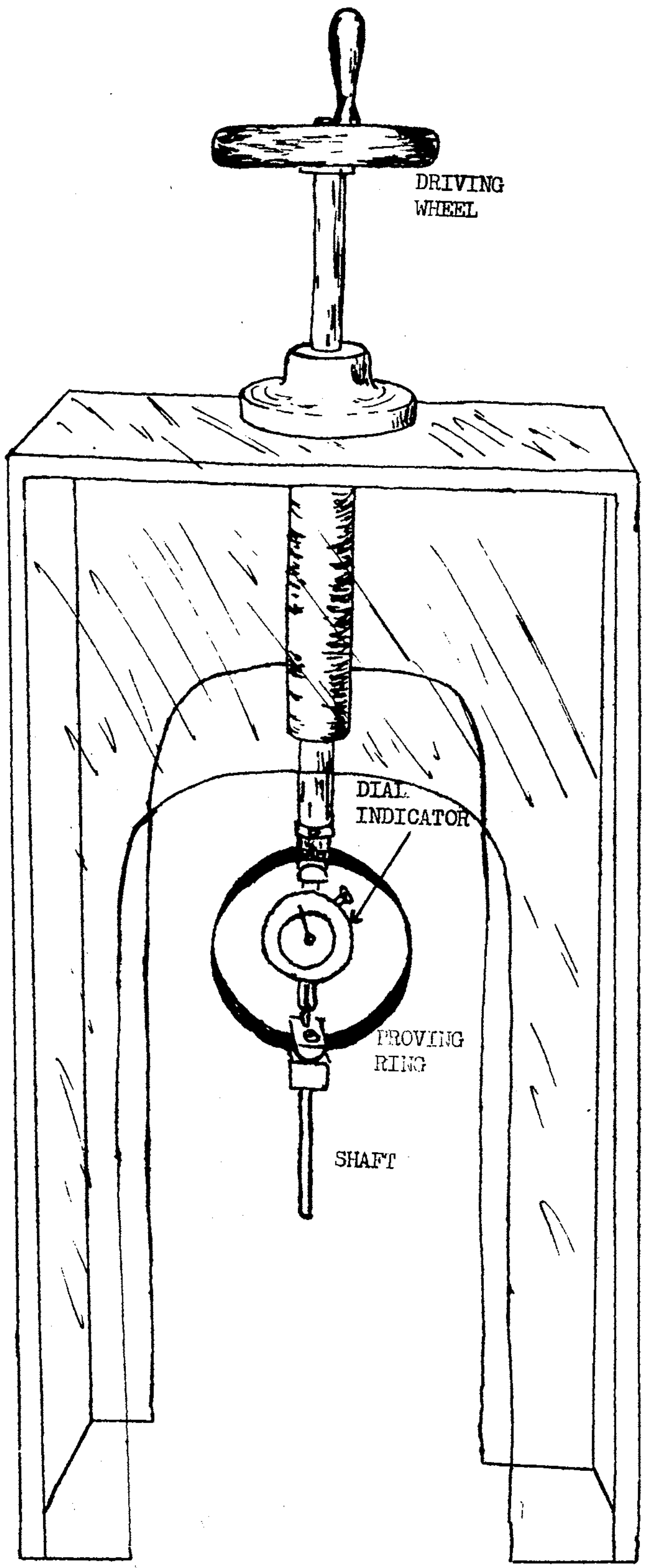

Figure 1. Penetrometer

diameter owing to the rapid increase in pressure for small increase in penetration depth. A shallow depth of penetration was used in this study, however, since penetrations on both ends of the core were desired, and deep penetrations on one end could influence the readings on the opposite end.

After the soil strength measurements were completed, the core was weighed and placed in a drying oven (approx. $105^{o}C$) for a minimum of 48 hours. The cores were removed from the oven and reweighed after they had dried. The penetrometer readings were converted to soil strength (bars) using a calibration for this particular proving ring. The dial indicator had a calibration capable of reading deflections in the proving ring to $\pm$ 0.0003 cm.

Bulk densities were calculated by dividing the oven dry soil weight by the total volume of the cylinder.

Water Content

The water percent by weight in the field at each sampling time was also determined. A disturbed soil sample was taken in the vicinity of each core sample. These samples were weighed, allowed to dry in the oven, and reweighed. The water content was calculated by dividing the weight of water in the sample by the weight of oven dry soil.

Another soil-water content of interest was the amount of water retained in the soil at 1/3 atmospheric pressure. The soil cores were weighed after the soil strength test had been completed, placed in an oven to dry, and reweighed. The water content was then determined by the procedure described above.

Soil Temperature

Soil temperature readings were made in 2 of the 4 replicates of the 5 treatments. Readings were taken to determine if temperature differences existed among treatments. The readings were taken at selected times during June, July, and August. Readings were taken every 30 minutes for a 6-hour period one day during August from the middle of the afternoon into late evening. Two thermisters were placed at a depth of 2 inches and 6 inches in each plot. A total of 40 thermisters was used in determining soil temperature. A digital voltmeter was used to measure voltage, and this was converted to temperature (^{o}C) through a previous calibration.

Plant Observations

The average height of cotton plants in the various treatments was recorded at monthly intervals with measurements being made June 14, July 17, and August 15, 1972. During August taproot lengths were measured and root growth shapes were observed. The roots were obtained by hand pulling several cotton plants at random throughout a particular treatment. Then the average taproot length was determined, and typical growth shapes of the roots in the treatment were recorded. Later in the fall, photographic slides were taken to show typical taproots in the various treatments. The observations pertaining to root characteristics and plant heights were studied to determine if measured differences in soil properties between treatments were exhibited in the plants and roots.

Also, overall plant size and vigor were noted throughout the season. A 10 ft section of the two middle rows in each treatment was harvested by hand picking every boll for yield. The cotton was harvested November 11, 1972.

Analysis of Results

Analysis of variance was calculated with the SAS (Statistical Analysis System) program for the following data: soil strength, bulk density, field and 1/3 bar soil-water contents, soil temperature, and seed cotton yield. F-tests were performed at the 5% level to indicate whether or not there were significant differences in a set of data due to treatment differences. If significant F values were obtained for most data sets of a given type of measurement, least significant differences were computed to test treatment means for differences at the 5% level. If the LSD obtained was too large to show a significant difference between any of the treatment means, LSD's were calculated at the 10% level. However, when most F values in a given type of data were not significant, LSD values were not calculated. This range test was patterned after the results of Carmer and Swanson (4).

CHAPTER IV

RESULTS AND DISCUSSION

Soil strength measurements obtained during the study showed more differences between treatment means than did any other type of data. The treatment means for soil strength at the 2-inch depth and at the 5-inch depth, along with the LSD values, are reported in Tables I and II, respectively. The F-tests for the soil strength data showed more significant differences at the 2-inch depth than at the 5-inch depth.

The treatment means for both depths indicated similar patterns. At the 2-inch depth, treatment 1 (conventional tillage) and treatment 3 (zone tillage + mechanical) usually had the lowest soil strength values. Treatment 5 (no-tillage + mechanical) generally exhibited the highest soil strengths. Treatment 2 (zone tillage + chemical) and treatment 4 (no-tillage + chemical), while producing high soil strength values, were generally somewhat below treatment 5. The results for the 5-inch depth are very much like those reported for the 2-inch depth. Treatments 1 and 3 had the lowest values of soil strength, treatment 5 tended to have the highest, and treatments 2 and 4 were high but not quite as high as treatment 5 during most of the study.

In comparing the treatment means at the 2-inch depth, the LSD values showed that in most months the means for treatments 1 and 3 were significantly lower than the means for treatment 5. Also, treatment 3 means usually differed significantly from treatment 2 means. At

TABLE I

TREATMENT MEANS AND LSD VALUES FOR SOIL STRENGTH AT THE 2-INCH DEPTH

Treatment	Soil Strength (bars)				
	June 12	July 10	August 16	September 16	October 25
1	8.72	8.75	6.89	8.47	9.24
2	14.49	11.82	12.00	11.54	8.50
3	8.59	6.42	5.45	5.03	9.16
4	10.31	13.14	10.78	9.92	9.68
5	12.71	14.51	14.21	11.17	13.14
LSD 5% level	6.6	5.3	5.5	5.4	2.6
LSD 10% level	5.4				

TABLE II

TREATMENT MEANS AND LSD VALUES FOR SOIL STRENGTH AT THE 5-INCH DEPTH

Treatment	Soil Strength (bars)				
	June 12	July 10	August 16	September 16	October 25
1	8.70	7.63	7.19	7.56	9.36
2	12.50	10.09	10.32	9.05	9.31
3	9.65	9.20	6.25	7.02	10.85
4	10.25	12.29	10.75	9.75	11.32
5	11.34	11.88	11.75	10.59	11.37
LSD 5% level	4.5	3.7	3.2	4.4	2.2
LSD 10% level	3.7			3.6	1.8

the 5-inch depth the LSD values showed that treatment 1 means usually differed significantly from treatment 4 and 5 means.

Treatment means for bulk density are reported in Table III. There is a trend in the bulk density means similar to that noted in soil strength means; however, none of the F-tests for bulk density indicated significance. Treatments 1 and 3 were generally lower in bulk density than the other treatments. Treatment 5 usually showed the highest means, and treatments 2 and 4, while having high densities, were usually not quite as high as treatment 5.

Treatment means for water content samples which were taken in the field at the time of taking soil cores are reported in Table IV. The F-tests did not indicate significance. Water contents for August are low in all treatments, reflecting the dryness of that month. The October means are high throughout the various tillage treatments, and this is indicative of the wet field conditions existing during that month.

In graphs relating soil-water content to soil strength and bulk density to soil strength in a study done by Stone[1] on the same soil type as was used in this study, it was observed that for a given change in soil-water content or bulk density a corresponding change in soil strength, about 1/5 the changes seen in soil strength in the present study, occurred. Therefore, it is evident that the large differences in soil strength must have resulted from sources other than the two factors usually determining strength-bulk density and soil-water

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[1]Loyd R. Stone, "Soil Strength and Bulk Density Conditions Following an Imposed Metal to Soil Sliding Action" (Unpublished M.S. thesis, Oklahoma State University, 1969), p. 29, 34.

TABLE III

TREATMENT MEANS FOR BULK DENSITY

Treatment	Bulk Density (g/cm^3)				
	June 12	July 10	August 16	September 16	October 25
1	1.55	1.54	1.49	1.53	1.63
2	1.62	1.59	1.57	1.57	1.61
3	1.55	1.53	1.49	1.49	1.63
4	1.56	1.60	1.55	1.55	1.60
5	1.59	1.60	1.59	1.57	1.64

TABLE IV

TREATMENT MEANS FOR SOIL-WATER CONTENT IN FIELD

Treatment	Water Content in Field (% by weight)				
	June 12	July 10	August 16	September 16	October 25
1	8.7	7.9	6.7	8.4	12.3
2	8.1	8.6	6.7	7.6	12.1
3	7.5	7.5	6.3	6.8	11.6
4	8.6	8.1	6.8	7.0	11.2
5	9.4	6.1	6.2	7.3	11.6

content. These mean differences in soil strength were evidently caused by treatment differences or by micro-structural non-homogeneity. The latter would not be detected in the present study since it was not conducted on that scale.

The treatment means for water content of the soil cores after equilibration with 1/3 bar pressure are given in Table V. The F-tests for this data generally indicated non-significance.

Out of 30 separate sets of temperature data for the 2-inch and 6-inch depths each, only 1 set of readings was significantly influenced by treatment. It is, therefore, obvious from the results of the F-tests that differences in tillage treatments did not produce significant temperature differences. Also, no trends in the temperature data were noted. Soil temperatures at the 2-inch and 6-inch depths for selected reading dates during the 3-month period are shown in Tables VI and VII, respectively. The treatment means in the two tables show very little variation among the treatments in temperature; this pattern is typical of the treatment means for most reading dates during the 3 months.

There were some visual plant differences observed between treatments. The average cotton plant heights in the various treatments on specific dates are reported in Table VIII. The plants in treatments 1 and 2 were tallest, the plants in treatments 4 and 5 were shortest, and the plants in treatment 3 were intermediate between the two extremes. Also, it was observed during the growing season that the plants in the conventional tillage treatment (treatment 1) and zone tillage treatments (treatments 2 and 3) were generally larger and more vigorous than the plants in the no-tillage treatments. This same

TABLE V

TREATMENT MEANS FOR 1/3 BAR SOIL-WATER CONTENT

Treatment	1/3 Bar Water Content (% by weight)				
	June 12	July 10	August 16	September 16	October 25
1	7.7	8.0	7.8	7.5	9.1
2	8.2	8.8	7.7	8.4	9.7
3	8.8	8.1	8.8	9.3	8.6
4	9.1	9.1	9.0	9.4	9.4
5	7.4	7.3	6.9	7.2	8.8

TABLE VI

TREATMENT MEANS FOR SOIL TEMPERATURE AT THE 2-INCH DEPTH (FOR SELECTED READING DATES)

Treatment	Soil Temperature (^{o}C)		
	June 12	July 11	August 11
1	27.7	31.7	32.3
2	28.1	31.3	30.2
3	28.1	31.4	29.9
4	28.1	31.5	29.6
5	28.6	32.5	29.1

TABLE VII

TREATMENT MEANS FOR SOIL TEMPERATURE AT THE 6-INCH DEPTH (FOR SELECTED READING DATES)

Treatment	Soil Temperature (^{o}C)		
	June 12	July 11	August 11
1	26.9	30.1	28.3
2	26.9	30.5	28.9
3	26.4	30.8	28.9
4	27.3	30.8	30.3
5	27.2	31.2	29.0

TABLE VIII

AVERAGE COTTON PLANT HEIGHTS

Treatment	Cotton Plant Heights (cm)		
	June 14	July 17	August 15
1	7.5	48	65
2	8.0	52	65
3	7.0	43	60
4	6.0	37	52
5	5.5	39	56

trend was observed by Taylor and Burnett (21) in their tillage and compaction experiments. They also found that plant heights were much greater on tilled treatments than on no-till plots.

Cotton taproot lengths and root growth shapes in the various treatments indicated a more favorable response to tillage as opposed to no-tillage. The average cotton taproot lengths and shapes as observed in August are reported in Table IX. These results show that roots were longest in the conventional tillage treatment and shortest in the no-tillage + chemical treatment, with the zone tillage treatments and the no-tillage + mechanical treatment showing intermediate results. The roots were generally straight in the conventional tillage treatment, but exhibited some bending in the zone tillage treatments. Roots showed severe bending in the no-tillage treatments. Sketches made from photographic slides showing typical taproots in treatment 1 are shown in Figure 2. Typical taproots from treatments 4 and 5 are illustrated in Figures 3 and 4, respectively. Some relationships exist between the taproot lengths and shapes observed in certain treatments and the soil strengths reported for those treatments. The roots tended to be longer and straighter in the conventional treatment (which had lower soil strength), and they were shorter and exhibited abnormal shapes in no-till treatments (which had higher soil strengths). These results are similar to those of Taylor and Burnett (21) who found that on compacted no-tillage plots there was increased soil strength and a marked reduction in root development.

Average cotton yields, reported in pounds of clean seedcotton, are listed in Table X. A significant F value was obtained for this data. The LSD value at the 10% level indicates that the yield from

TABLE IX

AVERAGE COTTON TAPROOT LENGTHS AND TYPICAL GROWTH SHAPES AS OBSERVED IN AUGUST

Treatment	Cotton Taproot Lengths (cm)	Comments on Taproot Shapes
1	27	taproots generally straight
2	20	most taproots fairly straight; some bending observed
3	20	taproots tended to be fairly straight; some bending observed
4	17	most taproots exhibited considerable bending; little vertical elongation but a great deal of lateral expansion was seen in these taproots
5	20	most taproots exhibited considerable bending; many taproots had become bent to the point that they approached or actually were perpendicular to the original vertical direction of growth

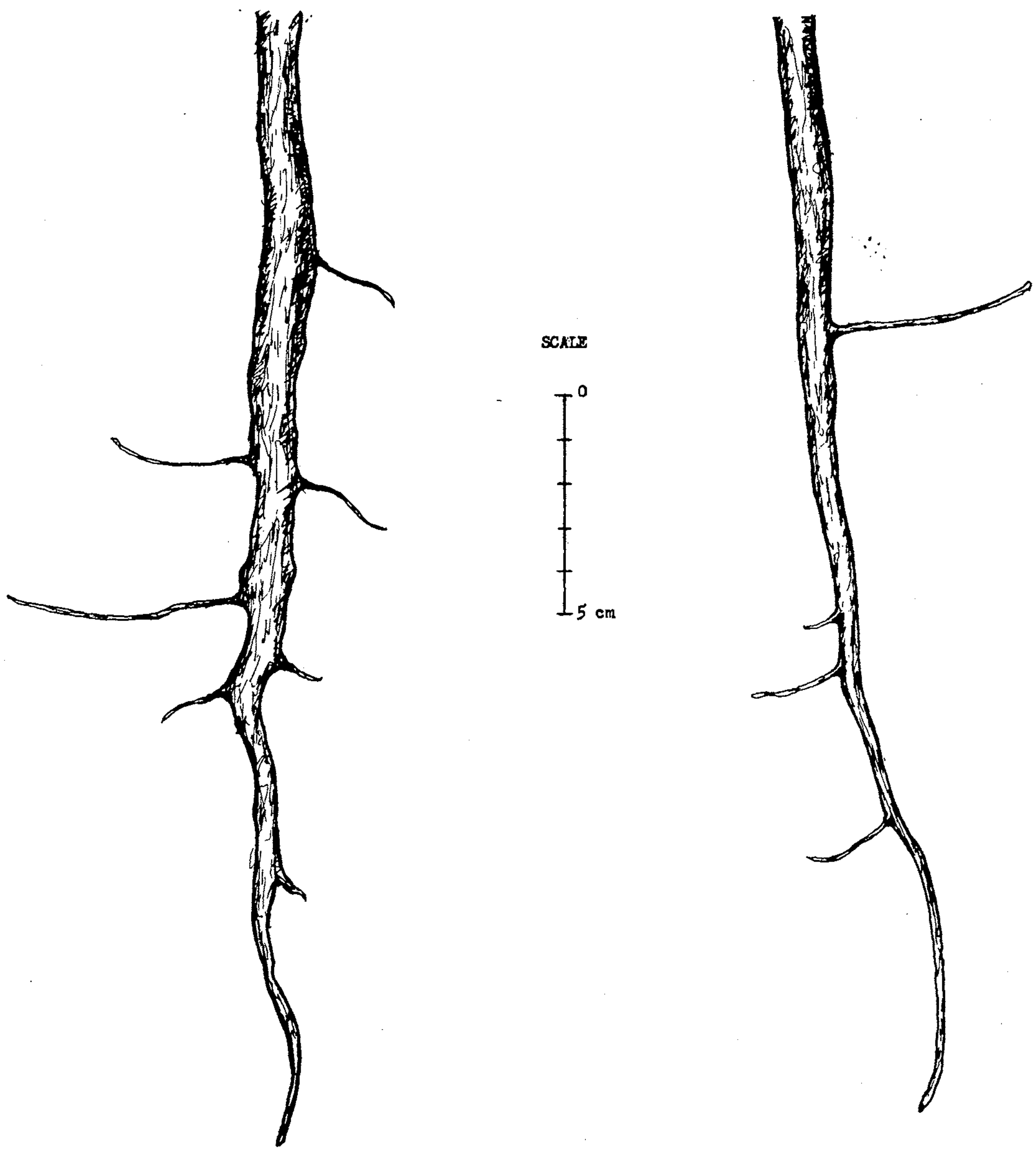

Figure 2. Typical Taproots from Treatment 1

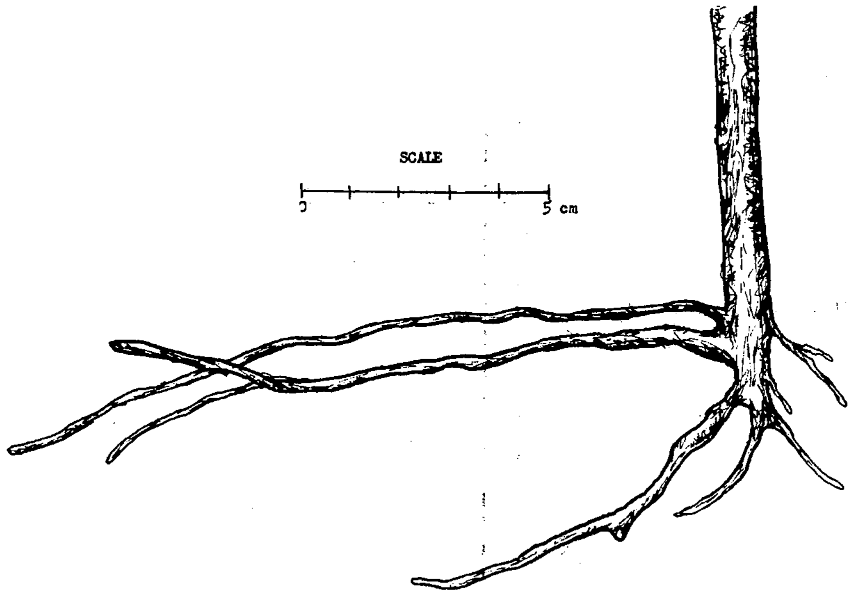

Figure 3. Typical Taproot from Treatment 4

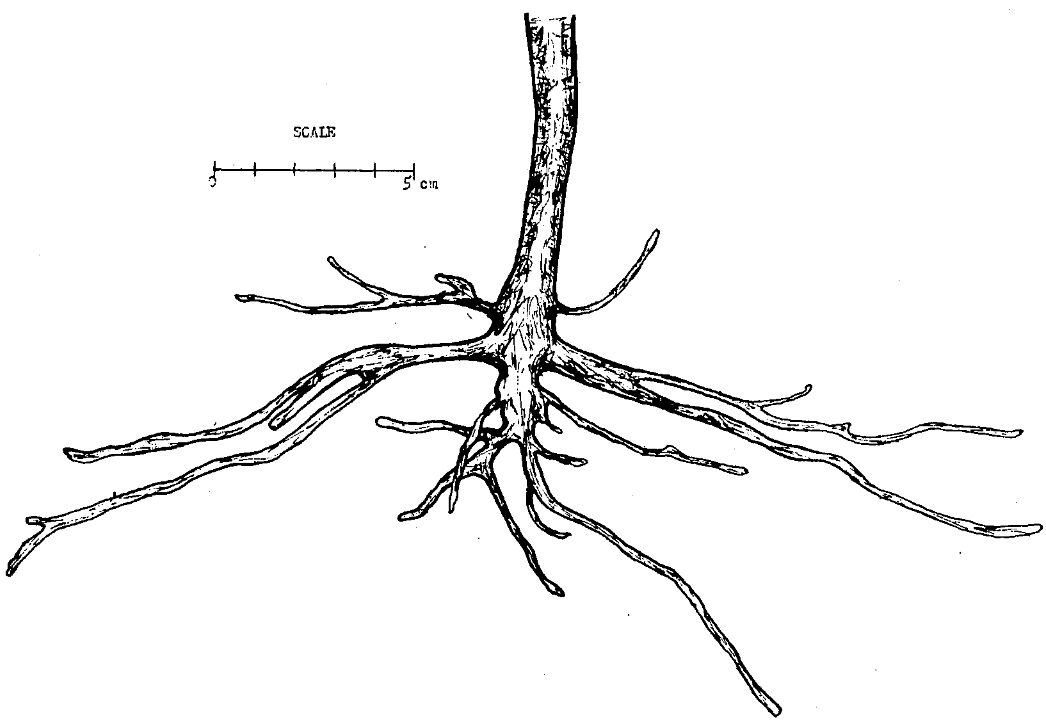

Figure 4. Typical Taproot from Treatment 5

TABLE X

TREATMENT MEANS AND LSD VALUES FOR YIELDS OF CLEAN SEEDCOTTON FOR A 10 FT SECTION OF ROW

Treatment	Pounds of Clean Seedcotton
1	1.59
2	1.49
3	1.34
4	1.09
5	1.31
LSD 5% level	0.32
LSD 10% level	0.26

treatment 4 was significantly lower than the yields of treatments 1 and 2. Also, it is apparent that treatment 1 is significantly different to treatment 5. The highest yields came from treatments 1 and 2, while the lowest came from treatments 4 and 5. Yield was high in the conventional tillage treatment (which had low soil strength) and low in the high strength, no-tillage treatments. Taylor et al. (23) found that yields of cotton and grain sorghum were adversely affected by high soil strength-yields were reduced approximately 50% under high strength conditions as compared with low. Taylor and Burnett (21) reported that cotton yield was much less on the no-tillage compacted treatment than on any other treatment they studied.

The results obtained for treatment 2 are particularly surprising. The treatment exhibited high values for soil strength, and this would normally be thought to contribute to poor plant and root response and poor yield. However, treatment 2 plants were tall and vigorous, the treatment produced a good yield, and it exhibited acceptable root characteristics. These results seem to indicate some success for a modified tillage system (zone tillage + chemical).

CHAPTER V

SUMMARY AND CONCLUSIONS

Five tillage systems, including 2 no-tillage, 2 zone tillage, and 1 conventional tillage system, were studied to determine the desirability of each for dry-land cotton production in Oklahoma. The tillage systems were evaluated by measuring their effects on certain soil physical properties and cotton plant responses. The soil properties measured included soil strength, bulk density, soil-water content in the field, 1/3 bar soil-water content, and soil temperature. The plant responses measured included plant height, taproot length and shape, and cotton yield.

The conventional tillage system (treatment 1), with its low soil strength and bulk density, good plant and root growth characteristics, and high yield, appeared to be a better system by looking at these results than any of the others. However, treatment 2 (zone tillage + chemical) had a very good yield even though it consistently exhibited high soil strength. Therefore, this is a tillage system which might prove to be a profitable one, and it probably merits further study. Treatment 3 (zone tillage + mechanical) possessed low soil strength but had a fairly low yield. The 2 no-tillage treatments, 4 and 5, generally possessed high soil strength, had poor plant growth response and poor taproot lengths and shapes, and low yields. Therefore, the no-tillage treatments, which produced the least desirable measurements and observations among the treatments, were evidently the poorest.

Thus, from the experimental results, it appears that conventional tillage is probably the optimum system for dry-land cotton production on medium-textured Oklahoma soil. However, zone tillage systems, as evidenced by treatment 2 effects, will be worthy of additional investigation.

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