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Crop Rotations in the Brazos River Valley

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SUMMARY

The influence of 14 cropping systems on the physical and chemical soil characteristics of Miller clay was studied from 1952 to 1963. Determination of the influence of the rotations on yield also was made. The index crops used were cotton and corn. The soil properties studied were bulk density, field capacity, moisture percentage, permanent wilting percentage, percent available water, noncapillary pore space, capillary pore space, organic matter, aggregation, total nitrogen and available phosphorus.

Yields of cotton and corn were influenced very little by the cropping systems. There were some differences in soil properties after some of the rotations, but these changes were not serious enough to influence the yield of cotton or corn.

If cotton or corn is to be grown on Miller clay it should be grown continuously — not in rotation — with adequate rates of commercial fertilizers for maximum profit.

CONTENTS

Crop Rotations in the Brazos River Valley

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THE ROTATION OF CROPS may be defined as the growth of different crops in recurring sequence as contrasted to continuous culture of one crop on the same land or haphazard sequence of crops. Crop rotations have classically been designed to aid in maintenance or improvement of soil productivity and reduction of insect, disease and weed problems. Changes in modern agriculture, however, warrant a closer look at this classical concept to determine if crop rotations are necessary in all locations.

Maintaining soil productivity is foremost in every farmer's plans. This usually is achieved by finding the best combination of fertilizer practices, crop rotations and other management factors. Rotations unsupported by fertilization will not maintain the high yields demanded by modern agriculture. All products removed from the land contain essential mineral elements. Some or all of these elements probably will be removed by crops or animals at a rate faster than the natural rate of release into available forms in the soil. Thus, the soil must be supplemented with additional nutrients if productivity is to be maintained or improved. Nitrogen-fixing legumes, when properly inoculated, can add nitrogen to the soil but phosphorus, potassium and some minor elements must be returned as fertilizers if productivity is to be maintained.

In recent years many research workers and farmers have questioned the necessity of including a legume in the rotation. The nitrogen supplied by a legume also could be added to the soil in the form of commercial fertilizers which may cost less than nitrogen supplied by legumes. Where livestock are a part of the farm enterprise, legumes may be used as a source of hay or for grazing. This will reduce the cost of nitrogen supplied by the legumes because of the double utility of the plants.

The organic matter produced by grasses and legumes in a rotation is one of their most important products. Many soils with a fairly low clay content can be maintained at a high level of productivity by the use of commercial fertilizers and crop residues.

The effect of deep-rooted legumes on internal drainage in soils with tight subsoils must be considered. Farm observations of improved internal drainage after growing deep-rooted legumes have been frequent but are subject to considerable error. Much work needs to be done on the effect of legumes on aggregation, infiltration and tilth.

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REVIEW OF LITERATURE

Soil scientists and others have conducted experiments on crop rotations for many years and various answers and theories have been developed. Many of these rotation experiments were conducted in the northern United States and on soils very different from Miller clay. A review of the literature discloses findings quite different in some areas and quite similar in others.

Mills (7) made measurements of some physical properties of Miller clay following a 3-year rotation with six cropping systems. He found that sweetclover in rotation with corn increased the percent pore space and permeability and decreased volume weight as compared with winter peas in rotation with corn. There was no improvement in permeability in the 5 to 8-inch zone under any rotation.

Myers and Myers (8) proposed that the favorable effects of legumes upon small grain yields may occur through their effect on soil structure rather than their influence on soil nitrogen.

In a study of rotation and tillage treatments in the Rolling Plains of Texas, Perdomo (14) found a relationship between rotation, tillage practices and soil physical properties. He found that wheat and a forage sorghum in rotation with sub-tillage had a definite beneficial effect on soil physical properties.

Smith et al. (19) found that on Austin clay, water-stable aggregates larger than 2 mm. in diameter were most abundant in soil horizons that contained the most organic matter, but the quantities of smaller aggregates were essentially unchanged in horizons of higher organic matter.

Van Bavel and Schaller (25) showed that a significant positive correlation existed between aggregation and corn yields on Marshall silt loam.

Pillsbury (15) indicated that decayed organic matter can increase the rate of water entry into a Yolo loam. Patrick et al. (13) found that winter cover crops on Commerce loam had a significant influence on organic matter, total nitrogen, aggregation index, bulk density, noncapillary porosity, field capacity and wilting point but had no significant effect on permeability.

Gish and Browning (2) made a study of the factors affecting the stability of soil aggregates and found that soil and crop management practices had a marked effect on the size, distribution and stability of soil aggregates. They also determined that under four rotation systems on Marshall, Belinda and Clarion soils, the best aggregation was achieved with bluegrass. This was followed by rotation meadow and rotation corn, while continuous corn produced the least aggregation.

Laws and Evans (4) investigated the effects of long-period cultivation on some of the physical properties of Houston Black clay and Bell clay. They concluded that: cultivation for 50 to 90 years had decreased the pores drained under tensions of 30 cm. of water in Houston Black clay; Houston Black clay contained a much larger percent of 2 to 5 mm. aggregates under virgin conditions than under cultivation; more total aggregates were observed under virgin soil; and there was a decrease in organic matter in the upper 18 inches of Houston Black clay which had been cultivated for many years.

Olmstead (11) had similar findings under dryland conditions in Kansas. He found that the loss in aggregation was approximately 80 percent after 40 years cultivation. In another portion of the same experiment, however, he showed that cropping systems which included continuous small grains, continuous row crops and rotations including fallow caused no significant differences in aggregation.

Further investigations involving cropping systems and soil properties were made by Page and Willard (12). They made various physical measurements after cropping systems on a Nappanee silty clay loam in Paulding County, Ohio. Of the various physical measurements made, only determinations of the air space porosity and degree of aggregation showed satisfactory correlation with yield levels.

McVickar et al. (6) compared five cropping systems on an Onslow fine sandy loam. The treatments were fallow, rye grass, crimson clover, vetch and Austrian winter peas. After 4 years under these treatments results showed: organic matter content was not increased enough by the different crops to be significant and water holding capacity was not influenced by the cropping systems.

Neher (10) investigated the effect of cropping systems and soil treatments on the water-stable aggregates of a clay pan soil in Kansas. He found that alfalfa apparently caused an increase in the amount of water-stable aggregates in the soil. Also, the residual effect of alfalfa on aggregation appeared to last as long as 8 years after the alfalfa was turned under.

An extensive study on a number of soils in Missouri, Illinois, Ohio, Georgia and California involving the modification of physical properties of soil by crops and management was made by Uhland (22). He reported that (1) plants with deep and well-developed root systems, such as alfalfa and kudzu, may be expected to increase porosity and permeability and to improve soil structure and (2) crop residues which are kept on the soil surface improve the infiltration rate of the surface soil and also improve the soil infiltration rate at lower depths.

In a study of crop rotations on a Lufkin fine sandy loam, Naqvi (9) found no change in soil physical conditions after a 4-year rotation involving cotton and corn in combination with five legumes. Yield data by Reynolds et al. (17) from these same rotations indicated that the effect of legumes and nitrogen on corn production was not enough to be economically important.

An investigation by Raut (16) on a comparison of 5 years of Yellow beardgrass and of continuous cotton on Miller clay showed that: (1) Yellow beardgrass did not increase infiltration capacity and (2) the 4- to 7-inch layer in Miller clay was the limiting factor in water infiltration.

The varying responses of soil properties to cropping systems previously mentioned may need to be studied for each individual area to determine how each soil responds to various crops in cropping systems.

In many cases the cost of obtaining desirable results from crop rotation may cause them to lose their beneficial nature, resulting in a liability rather than an asset. If this is the case, crop rotations could be eliminated and replaced with a sound fertilizer program.

MATERIALS AND METHODS

This study was established on the Texas A&M University Plantation in the Brazos River valley in 1951 on Miller clay. This soil is very fertile and in its natural state is well aggregated. The internal drainage is very slow and crusting is sometimes a problem after heavy rains. The area selected for study was used as pasture from 1935 to 1950, planted to cotton in 1951 and the rotation study was started in the fall of 1951. Grasses and legumes were planted in the fall of 1951, and the index crops – cotton and corn – were planted in the spring of 1952.

The design of the experiment was a randomized block with three replications. The design was such that each crop in each rotation appeared in each replication every year. Thus, in a 4-year rotation, four plots were included in each replication for that rotation. Each plot was eight rows (40-inch) wide and 80 feet long. The rotations used are listed in Table 1. Standard varieties of the crops were used throughout the study. These included Texas 30

TABLE 1. ROTATIONS USED TO STUDY THE EFFECT OF ROTATIONS ON SOIL PRODUCTIVITY AND PHYSICAL PROPERTIES OF MILLER CLAY.

Rotation*	First year	Second year	Third year	Fourth year
C	Cotton	Continuous		
Cr	Corn	Continuous		
C, O	Cotton	Oats		
C, O-sc	Cotton	Oats-sweetclover		
C, O-sc, Sc	Cotton	Oats-sweetclover	Sweetclover	
C, A	Cotton	Alfalfa		
C, O-a	Cotton	Oats-alfalfa		
C, O-a, A	Cotton	Oats-alfalfa	Alfalfa	
C, A-f, A-f	Cotton	Alfalfa-fescue	Alfalfa-fescue	
C, *C*, A-f, A-f	Cotton	*Cotton*	Alfalfa-fescue	Alfalfa-fescue
C, C, A-f, A-f	*Cotton*	Cotton	Alfalfa-fescue	Alfalfa-fescue
Cr, Cr, A-f, A-f	*Corn*	Corn	Alfalfa-fescue	Alfalfa-fescue
Cr, *Cr*, A-f, A-f	Corn	*Corn*	Alfalfa-fescue	Alfalfa-fescue
Cr, O-sc, Sc	Corn	Oats-sweetclover	Sweetclover	

***In these rotations, the italicized symbol represents the crop in question. Preceeding and following symbols represent preceeding and following crops; the sequence remains unchanged.**

corn, Deltapine cotton, Mustang oats, Kentucky 31 fescue, common alfalfa and Madrid sweetclover.

During the first 4 years (one cycle) of the study, the equivalent of 9 pounds of phosphorus (P) per acre per year was applied to the rotation containing legumes. The P was applied at the time of seeding of the legumes as a broadcast application. In a 2-year rotation the plot received 18 pounds of P, while a 4-year rotation received 36 pounds of P. At the end of the first 4 years, the rate of application of P was changed to 13 pounds per acre per annual application.

After 8 years the plots were split and 40 pounds per acre of nitrogen was applied in a band to the corn and cotton plots. The cotton and corn yields were taken from the two center rows of the plots or subplots (after the split). The forage yields were taken from randomly selected areas within the plots.

Standard farming practices were used throughout the study. Regular two or four-row equipment was used to prepare the land, plant and cultivate the crops. The corn was hand harvested. The cotton was hand harvested the first 4 years and machine picked the last 8 years.

During the first 4 years of the study, the forage produced on the grass-legume plots was removed as hay. To return more organic material to the soil, all forage produced was returned to the soil during the last 8 years of the experiment.

All plots were sampled at the beginning of the experiment in 1951. Organic matter determinations were made only on these samples, since the experiment was designed to measure differences between the cropping systems and their effect on the soil as compared with the effects of the index crops in continuous culture.

Soil samples for physical analysis were taken in February 1961. Duplicate samples were taken in copper rings 2 inches in diameter and 3 inches in length. Sampling depths were 0-3, 3-6, 6-9 and 9-12 inches. Samples were trimmed in the field with a cheese cutter and stored in pint ice cream cartons previously coated with paraffin to reduce moisture evaporation. Duplicate samples for chemical analysis were taken with a spade at depths of 0-6 inches and 6-12 inches.

In preparing soil cores for moisture retention characteristics, cheesecloth was placed over the bottom of the ring containing the samples and secured with a rubber band. The samples were then saturated with water.

The saturated samples were allowed to drain briefly and then were weighed. Next, samples were placed in a pressure plate appartus (18) and subjected to a pressure of 1/10 atmosphere. When the samples reached moisture equilibrium at this pressure they were removed, weighed and their water loss recorded. Later, when all determiniations were completed, the samples were ovendried. Calculation of the field capacity then was made by determining the percentage of moisture remaining in the soil at 1/10 atmosphere pressure. (A 1/10 atmosphere percentage was considered as field capacity for this study instead of the usual 1/3 atmosphere percentage.)

Permanent Wilting Percentages

The 15 atmospheres moisture percentage normally is termed the permanent wilting percentage and was determined by the pressure membrane (23). Samples were taken from the pressure plate and placed in the membrane, exposed to a pressure of 15 atmospheres (approximately 221 pounds per square inch) until moisture equilibrium was reached. They were determined to be at equilibrium when their weight remained constant for 3 days. When the samples were at equilibrium, they were removed, weighed and their weights recorded. The percent moisture at 15 atmospheres was determined and termed the permanent wilting percentage.

Noncapillary Pore Space

After weights were recorded from the pressure membrane exposure, the samples again were saturated with water. When saturation was complete, the samples were placed on a tension table (5), and the pores were allowed to drain at 40 cm. water tension for 48 hours. After 48 hours, the samples were removed, weighed and their weights recorded. At the conclusion of the tension table determination, the samples were dried in an oven set at 105° C. for 6 days. Noncapillary pore space was determined by subtracting sample weight at 40 cm. tension from the saturated weight and dividing the difference by the volume of the sample. Noncapillary pore space then was reported as percent by volume.

Capillary Pore Space

Capillary pore space was determined by measuring the moisture lost between 40 cm. water tension and ovendry weight and was expressed as percent by volume as outlined by Baver (1). The calculation is accomplished by subtracting the weight of the ovendry sample from its weight at 40 cm. water tension and dividing the difference by the volume of the sample. It was assumed that the pores not drained at 40 cm. were capillary pores.

Bulk Density and Percent Available Water

Bulk density and percent available water were calculated from data obtained in moisture retention determinations. Bulk density was determined by dividing the ovendry weight of the soil core by the ring volume. Ring volume was 154.4 cubic cm. per ring, and the soil weight was in grams. The resulting weight per volume was in grams per cubic cm.

To determine an approximation of the percent water available to plants, the permanent wilting percentage was subtracted from the field capacity percentage. The difference should have been the amount of water plants can take from this soil.

Organic Matter Determination

Organic matter was determined by the organic carbon content as described by the U. S. Salinity Laboratory (23). This determination was made from the loose soil taken with a spade. Each sample was duplicated, yielding twelve values per treatment. Two grams of ovendry soil were used for this analysis.

Aggregate Analysis

The method used for aggregate analysis was that given by Van Bavel (24). A representative sample of about 500 gm. was passed through an 8-mm. sieve. An air-dry sample of 25 gm. was taken from this and distributed evenly on a 5-mm. sieve with a nest of sieves underneath it descending in screen size. The sizes used were 5 mm., 2 mm., 1 mm., 25 mm. and .125 mm.

The screens were moved in an up and down motion in a container of water for 10 minutes. The soil that remained on each sieve size was ovendried, dispersed until only the primary particles remained and washed through their corresponding screens again. The remaining particles were ovendried and the amount of water-stable aggregates was determined. The degree of aggregation was expressed as a percentage of the ovendry sample.

Infiltration Rates

Infiltration rates were determined on six selected rotations. These measurements were made in the field with cylinder infiltrometers (3).

The heavy metal cylinders ranged from 10 to 12 inches in diameter. The cylinders were driven 6 inches into the soil with a thick, steel-driving plate. Dams were built outside the infiltrometers and filled with water to reduce lateral movement of the water from the cylinders. Water was furnished to the cylinders by a garden hose attached to a water trailer. Before each infiltrometer was filled, a gunny sack was placed on the soil surface to avoid disturbance of topsoil. Water depth in the cylinders was maintained as near as possible to 5 inches. Periodic measurements of water depth were made to determine infiltration rates. Measurements were made for 6 hours after a constant infiltration rate was obtained.

Statistical Analysis

Statistical analysis of this experiment was by analysis of variance as outlined by Snedecor (20) in chapters 11 and 12 and Steel and Torrie (21) in chapter 11.

RESULTS

Cotton Yields

The yields of cotton in the various rotations are presented in Table 2. The (C, O-sc, Sc) rotation produced the most cotton, 1,314 pounds per acre, and the continuous cotton rotation produced the lowest yield, 1,099 pounds per acre. The difference is 215 pounds of seed cotton per acre. (C, C, A-f, A-f and (C, A) produced 171 and 161 more pounds of cotton per acre than continuous cotton. No other rotations produced yields statistically different from each other at 5 percent levels of significance. In view of the economics of cotton production based on yields alone, it would not pay to rotate dryland cotton on Miller clay unless the other crop (s) could be utilized for a profit.

In 1960 the plots were split, and nitrogen was added at the rate of 40 pounds per acre per year to half of each plot. Yields are shown in Table 3. The yield of the rotations receiving nitrogen was significantly higher than the rotations not receiving nitrogen. The 4-year period during which additional nitrogen was applied to the plots was sufficient to establish a trend showing an increase in cotton yields. (C, A) and (*C*, C, A-f, A-f) had the highest yields from 1960 to 1963 and continuous cotton and (C, O) had the lowest yields.

All rotated cotton produced higher yields than continuous cotton when all plots were averaged over all years. There was a greater difference between years than between rotations.

Corn Yields

Corn yields were erratic during this 12-year study. Averages varied from a high of 67.7 bushels per acre in 1955 to a low 11.8 bushels per acre in 1956. (Cr,

TABLE 2. COTTON YIELDS IN POUNDS OF SEED COTTON PER ACRE, 1952-1963
Lint = 37.5 percent
Year

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	Average
	—	—	—	—	—	—	Pounds	—	—	—	—	—	—
C, O-sc, Ss	1,547	2,017	1,200	2,230	798	557	1,562	1,430	1,732	1,320	476	907	1,314a*
C, C, A-f, A-f	1,360	2,240	1,387	2,465	857	452	1,198	1,222	1,582	1,133	300	1,040	1,270a
C, A	1,270	1,947	1,253	2,023	760	355	1,584	1,247	2,335	880	695	800	1,260a
C, O-a, A	1,013	2,128	1,227	2,543	507	402	1,322	1,575	1,505	960	560	907	1,221ab
C, O-a	1,147	2,415	1,227	2,050	545	753	1,240	1,428	1,555	733	507	907	1,209ab
C, O	987	1,973	1,413	2,230	758	447	1,358	1,505	1,358	1,000	405	880	1,193ab
C, O-sc	1,147	1,680	1,253	1,997	760	570	1,220	1,453	1,658	880	530	1,013	1,180ab
C, *C*, A-f, A-f	960	1,760	1,147	2,358	508	455	1,058	1,505	2,133	693	543	933	1,171ab
C, A-f, A-f	1,120	2,133	1,013	1,972	527	435	1,512	1,298	1,455	1,080	555	853	1,163ab
C	1,173	2,338	1,120	2,022	603	493	1,138	1,090	1,482	653	230	847	1,099 b
Average	1,168	2,063	1,224	2,189	662	493	1,319	1,375	1,680	933	479	909	
	d	a	cd	a	f	g	cd	c	b	e	g	e	

*Means followed by different letters are significantly different from each other at the 0.05 level according to Duncan's Multiple Range Test.

O-sc, Sc) and (*Cr*, Cr, A-f, A-f) were significantly higher than (Cr, *Cr*, A-f, A-f) and continuous corn. However, (Cr, *Cr*, A-f, A-f) was significantly higher than continuous corn. These data are presented in Table 4. The corn in rotations (Cr, O-sc, Sc) and (*Cr*, Cr, A-f, A-f) followed 2 years of a grass-legume mixture and would be expected to yield more than continuous corn or corn following corn in a rotation.

Corn gave good yields in only 2 of the 12 years. In 1955 and 1962 the yields of some plots were approximately 70 bushels per acre.

When the plots were split in 1960, the addition of 40 pounds of nitrogen per acre increased the yields of the fertilized rotations over the nonfertilized rotations. Table 5 shows the influence of 40 pounds of nitrogen on corn yields. (C, O-sc, Sc) and (*Cr*, Cr, A-f, A-f) were significantly higher than (Cr, *Cr*, A-f, A-f) and continuous corn. Corn yields from (Cr, Cr, A-f, A-f) were significantly higher than yields from continuous corn.

A comparison of yields from nonfertilized plots of (*Cr*, Cr, A-f, A-f) and (Cr, *Cr*, A-f, A-f) shows that the (*Cr*, Cr, A-f, A-f) rotation yielded more than (Cr, *Cr*, A-f, A-f) in every year after 1955. The only difference between these rotations is that the corn in (*Cr*, Cr, A-f, A-f) followed 2 years of alfalfa-fescue while the corn in (Cr, *Cr*, A-f, A-f) followed corn in the same sequence of crops. All rotations re-

TABLE 3. COTTON YIELDS FROM THE ROTATION PLOTS THAT RECEIVED NO NITROGEN AND THE ROTATION PLOTS THAT RECEIVED 40 POUNDS NITROGEN PER ACRE FOR THE PERIOD 1960-63

	No nitrogen					40 pounds nitrogen per acre					
	1960	1961	1962	1963	Average	1960	1961	1962	1963	Average	Mean
						Pounds					
C, A	2,335	880	695	800	1,178	2,238	800	650	720	1,102	1,104a*
C, *C*, A-f, A-f	2,133	693	543	933	1,076	2,112	1,053	538	933	1,159	1,118a
C, O-sc, Sc	1,732	1,320	425	970	1,096	1,857	1,227	577	773	1,108	1,102a
C, O-sc	1,658	880	530	1,013	1,020	2,085	1,160	667	800	1,178	1,099a
C, C, A-f, A-f	1,582	1,133	300	1,040	1,014	1,935	1,093	340	1,013	1,095	1,055ab
C, O-a, A	1,505	960	560	907	983	1,653	1,240	550	773	1,054	1,020abc
C, O-a	1,555	733	507	907	925	1,778	760	523	907	992	959 bc
C, O	1,358	1,000	405	880	911	1,550	987	447	747	933	921 c
C	1,482	653	230	847	803	1,985	813	357	800	989	896 c
Average	1,680	933	475	909	999b	1,885	1,016	522	837	1,065a	

*Means having different letters beside them differ at the 5 percent level of significance.

TABLE 4. CORN YIELD IN BUSHELS PER ACRE OF EAR CORN FOR THE ROTATION PLOTS THAT RECEIVED NO NITROGEN FROM 1952 TO 1963

Rotation	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	Mean
							Bushels						
Cr, O-sc, Sc	42.6	38.1	30.2	67.6	9.0	34.2	30.3	37.7	39.7	48.3	72.5	24.6	39.6a*
Cr, Cr, A-f, A-f	35.6	27.7	27.4	56.5	8.3	35.5	32.8	42.0	37.1	34.5	77.5	31.7	37.2a
Cr, *Cr*, A-f, A-f	41.6	32.4	25.6	70.8	7.6	30.7	27.8	37.3	35.7	15.6	39.1	21.8	32.2 b
Cr	46.2	33.8	23.1	75.7	22.5	30.7	17.8	22.4	19.3	13.1	10.3	18.9	27.8 c
Average	41.5	33.0	26.6	67.7	11.8	32.8	27.4	34.9	33.0	27.9	49.9	24.2	

*Means having different letters beside them differ at the 5 percent level of significance.

TABLE 5. CORN YIELD IN BUSHELS PER ACRE OF EAR CORN FOR THE ROTATION PLOTS THAT RECEIVED NO NITROGEN AND THE PLOTS THAT RECEIVED 40 POUNDS PER ACRE OF NITROGEN FROM 1960 TO 1963

Rotation	No nitrogen					40 pounds nitrogen per acre					
	1960	1961	1962	1963	Average	1960	1961	1962	1963	Average	Mean
						Bushels					
Cr, O-sc, Sc	39.7	48.3	72.5	24.6	46.3	44.1	53.9	67.7	30.7	49.6	47.9a*
Cr, Cr, A-f, A-f	37.1	34.5	77.5	31.7	45.2	37.5	34.1	72.5	32.1	44.1	44.7a
Cr, *Cr*, A-f, A-f	35.7	15.6	39.1	21.8	28.1	38.6	24.2	53.0	33.5	37.3	32.7 b
Cr	19.3	10.3	17.1	12.8	14.9	13.1	18.9	45.2	30.3	26.9	20.9 c
Average	33.0	27.2	51.6	22.7	33.6	33.3	32.8	60.1	31.7	39.5	

*Means having different letters beside them differ at the 5 percent level of significance.

TABLE 6. FORAGE YIELDS, 1956 TO 1963. YIELDS ARE IN POUNDS PER ACRE ON AN OVENDRY BASIS

Rotation	1956	1957[2]	1958	1959	1960	1961	1962	1963	Mean
C, O-sc	3,310		3,300	8,800	9,880	7,573	6,623	4,445	6,276a[1]
Cr, O-sc, Sc	3,710		2,965	11,293	5,538	6,984	5,015	4,361	5,695ab
C, O-sc, Sc	2,988		2,650	9,178	6,713	5,490	5,822	4,175	5,288 bc
Cr, *Cr*, A-f, A-f	3,070		3,247	7,240	7,602	9,968	3,102	1,985	5,173 bc
C, O-a	3,990		3,830	6,580	8,705	4,360	4,512	3,274	5,036 bc
C, O-a, A	3,143		2,603	6,368	9,028	6,250	4,219	3,107	4,960 c
C, A-f, A-f	2,793		2,893	8,233	7,423	6,612	2,020	4,583	4,937 c
C, C, A-f, A-f	3,460		3,070	8,430	8,122	5,218	2,015	2,787	4,727 cd
C, A-f, A-f	2,577		2,663	9,222	7,551	5,422	2,765	2,423	4,665 cd
C, *C*, A-f, A-f	3,280		3,200	8,847	5,487	3,005	2,915	2,443	4,168 d
Cr, Cr, A-f, A-f	3,580		3,867	6,463	6,708	3,918	2,895	1,398	4,119 d
C, O	3,240		3,222	1,860	3,355	2,765	3,492	2,277	2,887 e
Average	3,262		3,125	7,710	7,176	5,633	3,782	3,105	

[1]Means having different letters beside them differ at the 5 percent level of significance.
[2]No yields due to floods.

ceiving nitrogen yielded more than the rotations not receiving nitrogen except (*Cr*, Cr, A-f, A-f).

Forage Yields

The forage yields are shown in Table 6. This is the amount of ovendry material returned to the soil per acre each year except 1957. That year the Brazos river backed water on the plots; all forage plants were killed and no data were taken. The plots were reseeded in the fall of 1957. In the rotations (C, O-sc, Sc), (C, O-a, A), (C, A-f, A-f) and (Cr, O-sc, Sc) the yields in Table 6 are averages of the forage production for the 2 years that the forage was returned to the soil.

(C, O-sc) produced the greatest amount of material to be returned to the soil. This rotation produced an average of 6,276 pounds of ovendry material each year. The (C, O-sc, Sc) rotation produced the second largest amount, 5,695 pounds per acre per year. The lowest production was in (C, O) and it was significantly lower than all other rotations. The alfalfa-fescue mixture did not produce as much forage as expected. It was difficult to maintain a uniform mixture of the grass and legume. In most years it tended to be mostly alfalfa or fescue. However, no difficulty was encountered in establishing these crops.

Soil Organic Matter

The percent organic matter in the 0-6 inch depth of the soil is shown in Table 7. The organic matter decreased under every rotation. The amount of organic matter in the soil at the start of the experiment was relatively high for soils in this area of Texas. However, it decreased rapidly in the 12 years of the study. The smallest decrease occurred in the (C, A-f, A-f) rotation, and the largest occurred in (C, O-sc). This decrease is quite interesting when the forage yields are considered. (C, O-sc) had the highest average forage yield (Table 6) and (C, A-f, A-f) produced about a ton less. The greatest decrease in organic matter occurred under the rotation producing the largest amount of ovendry forage. In the (C, A-f, A-f) rotation the soil was cultivated in a row crop 1 year out of 3, while in (C, O-sc) the soil was cultivated in a row crop 1 year out of 2. This is believed to be one reason for the decrease in organic matter in the soil under the (C, O-sc) rotation. More cultivation in combination with high temperatures increased the rate of decomposition under (C, O-sc) which was much greater than that under (C, A-f, A-f), and although more material was re-

TABLE 7. SOIL ORGANIC MATTER CONTENT IN THE TOP 6 INCHES OF SOIL IN THE BEGINNING AND AT THE END OF THE ROTATION STUDY

	Percent organic matter		
	Start 1952	End 1963	Amount of decrease
Cotton, Alfalfa-fescue, alfalfa-fescue	2.46	2.18a*	0.28
Cotton, alfalfa-fescue, alfalfa-fescue, cotton	2.49	2.09b	0.40
Cotton, oats-sweetclover, sweetclover	2.50	2.08bc	0.42
Corn, oats-sweetclover, sweetclover	2.46	2.07c	0.39
Cotton, oats	2.42	2.07c	0.39
Cotton, alfalfa	2.47	2.06c	0.41
Corn, corn, alfalfa-fescue, alfalfa-fescue	2.38	2.05c	0.33
Cotton, oats-alfalfa, alfalfa	2.44	2.05c	0.39
Cotton, oats-alfalfa	2.43	2.01c	0.42
corn, alfalfa-fescue, alfalfa-fescue, corn	2.38	2.00c	0.38
Cotton, cotton, alfalfa-fescue, alfalfa-fescue	2.39	2.00c	0.39
corn continuous	2.36	1.90de	0.46
cotton, oats-sweetclover	2.47	1.89e	0.58
Cotton continuous	2.18	1.88e	0.30
Average	2.42	2.02	0.40

*Means not having the same letter beside them differ significantly at the 5 percent level.

TABLE 8. PERCENT TOTAL NITROGEN IN MILLER CLAY AFTER VARIOUS CROP ROTATIONS

Rotation	0-6 inch	6-12 inch	Average	
C, A	0.16	0.161	0.161	a*
C, O-sc, Sc	0.190	0.122	0.156	ab
Cr, Cr, A-f, A-f	0.147	0.137	0.142	abc
C, O-a	0.164	0.119	0.142	abc
C, A-f, A-f	0.142	0.139	0.141	bc
C, C, A-f, A-f	0.159	0.118	0.138	bc
C	0.164	0.110	0.137	bc
C, *C*, A-f, A-f	0.151	0.122	0.136	bc
Cr, O-sc, Sc	0.143	0.124	0.134	c
C, O	0.143	0.123	0.133	c
Cr, Cr, A-f, A-f	0.146	0.120	0.132	c
C, O-sc	0.136	0.119	0.127	c
Cr	0.134	0.118	0.126	c
C, O-a, A	0.140	0.109	0.124	c
Average	0.151a	0.124b		

*Means not having the same letter beside them differ significantly at the 5 percent level.

turned to the soil, the organic matter decreased more rapidly and was reduced to a lower level in the (C, O-sc).

The rotations (C, O), (C, A) and (C, O-a) also were cultivated 1 year out of 2. The decrease in organic matter was 0.35, 0.41 and 0.42 percent, respectively. The rotations involving 2 years of cultivated crops and 2 years of sod crops followed the same pattern as the rotations with a 1:1 ratio of cultivated to sod crops. The percent decrease in organic matter varied from 0.33 to 0.40 percent. This indicates that it is somewhat fruitless to try to maintain a high organic matter content in these soils.

Total Nitrogen

The total nitrogen in the soil under the various rotations is shown in Table 8. Total nitrogen was significantly higher in the 0-6-inch depth than in the 6-12-inch depth. The total nitrogen varied from 0.161 to 0.124 percent.

TABLE 9. PARTS PER MILLION PHOSPHORUS EXTRACTED FROM MILLER CLAY AFTER VARIOUS CROPPING SYSTEMS

Rotation	0-6 inch	6-12 inch	Mean	
Cr	34.05	16.2	25.3	a*
C, O	32.5	13.3	22.9	ab
Cr, Cr, A-f, A-f	31.7	13.0	22.3	abc
C, C, A-f, A-f	31.0	13.7	22.3	abc
C	29.8	14.2	22.0	abc
C, O-a	29.8	13.7	21.8	abc
C, O-a, A	26.5	15.2	20.8	abcd
C, A	29.0	11.8	20.4	bcd
Cr, *Cr*, A-f, A-f	25.8	12.2	19.0	bcde
C, O-sc	25.3	12.0	18.7	bcde
C, O-sc, Sc	25.8	10.5	18.2	cdef
C, A-f, A-f	22.7	11.0	16.8	def
Cr, O-sc, Sc	19.7	10.2	14.9	ef
C, *C*, A-f, A-f	15.8	12.3	14.2	f
Average	27.1 a	12.8 b		

*Means not having the same letter beside them differ significantly at the 5 percent level.

Phosphorus

The available P in the soil at two depths is shown in Table 9. There was a significant difference between depths. The 0-6-inch depth was significantly higher in available P than the 6-12-inch depth. This was to be expected, since all P was applied as a broadcast application to the surface and then disked into the top 6 inches of soil.

Soil Physical Properties

When all four depths were combined (C, O-sc) had a significantly less noncapillary pore space than all other rotations. All rotations involving corn produced a greater percentage of noncapillary pores than the other rotations. Row crops seemed to have influenced the noncapillary pore space more than close-growing crops such as alfalfa, oats and sweetclover. The range in noncapillary pore space was from 6.23 percent for (C, O-sc) to 12.49 percent for the (*Cr*, Cr, A-f, A-f) rotation, Table 10.

The 0-3-inch depth showed effects of rotation on noncapillary pore space similar to the 0-6-inch profile discussed previously. The corn rotations again had larger amounts of pore space, and the (C, O-sc) rotation had the least amount of noncapillary pore space. This low value for (C, O-sc) may have been caused by the decrease in organic matter under this rotation, Table 7.

A difference in the effect of 2 years of cotton versus 1 year of cotton following 2 years of alfalfa-fescue was found at this depth. The second-year cotton had 13.00 percent noncapillary pore space,

TABLE 10. NONCAPILLARY PORE SPACE IN MILLER CLAY AFTER VARIOUS ROTATIONS

Rotation	Mean (percent by volume)
C, O-sc	6.23a*
C, C, A-f, A-f	8.20 b
C, A-f, A-f	8.23 b
C, O-sc, Sc	8.79 bc
C, O-a	8.80 bc
C, O	8.98 bc
C, A	9.24 bc
C, O-a, A	9.48 bc
C, C, A-f, A-f	10.14 bcd
C	10.36 cd
Cr, *Cr*, A-f, A-f	10.50 cd
Cr, O-sc, Sc	11.44 de
Cr	11.79 de
Cr, Cr, A-f, A-f	12.49 e

*Means not having the same letter beside them differ significantly at the 5 percent level.

while first-year cotton had 22.68 percent noncapillary pore space.

Continuous cotton was midway between these two rotations. This was thought to be caused by the effect of both aggregation and root channels. Many large root channels may have been produced through several years of continuous cotton which increased noncapillary pore space in that rotation. Apparently, the formation of large aggregates was induced by alfalfa-fescue which increased the noncapillary pore space under first-year cotton. In the second-year cotton, aggregation may have been reduced by natural deterioration; furthermore, a large number of root channels had not had time to develop from only 2 years of cotton, resulting in a small amount of noncapillary pore space for the (C, C, A-f, A-f) rotation.

Corn also increased the amount of noncapillary pore space at 3-6 inches and 9-12 inches, but there was no difference in noncapillary pore space due to rotation at the 6-9-inch depth. This effect was thought to be caused by the many root channels produced by corn in the 3-6-inch and 9-12-inch zones. The lack of increase in noncapillary pore space at 6-9 inches may have been caused by the poor root growth in that zone because of a compacted layer at 6-9 inches. Evidence of this compacted layer will be presented later.

The increase in noncapillary pore space brought about by corn was attributed to the intensive root system of corn in the top 12 inches of the soil. Less intensive cultivation also was a possible factor in increased pore space as a result of corn rotations. There was a significant difference in noncapillary pore space at each of the four depths from all rotations combined (Table 11).

In a simple correlation of all variables at the 0-6-inch depth, noncapillary pore space was found to have r values of .403 with field capacity, -.827 with bulk density, -.711 with capillary pore space and -.349 with aggregates 2-5 mm. in diameter. An r value of .325 was required for significance at the 5 percent level. Correlation with all other variables not listed was not significant at the 5 percent level.

An analysis of the effects of cotton versus corn was made concerning noncapillary pore space. This analysis was based on 1 degree of freedom.

Comparison of cotton and corn indicated that corn produced significantly more noncapillary pore space than cotton at 3-6 and 9-12-inch depths. F values obtained were 19.08 and 4.15, respectively. An F value of only 3.91 was required for significance at the 5 percent level. This noncapillary-pore-space increase, brought about by cropping systems con-

TABLE 11. PERCENT NONCAPILLARY PORE SPACE MEANS FROM 14 ROTATIONS AT FOUR DEPTHS

Depth	Mean
0-4 inches	16.66a*
3-6 inches	6.98c
6-9 inches	4.47d
9-12 inches	10.38b

*Means having different letters differ significantly at the 5 percent level of significance.

taining corn, was thought to be caused by the intensive fibrous root system of corn. This root system makes many channels, allowing passage of water, whereas the cotton taproot has fewer roots in the top 12 inches of soil. Consequently, fewer channels are produced.

Capillary Pore Space

Corn tended to promote smaller amounts of capillary pore space than did rotations involving cotton. The (C, O-sc) rotation had consistently more caapillary pores than all other rotations. This effect was obviously again caused by the lack of organic matter under this rotation. Although corn and oats have similar root systems, the oats did not seem to prevent compaction as well as corn. Compaction was highly correlated with capillary pore space; therefore, capillary pore space also increased under the (C, O-sc) rotation.

The rotations involving corn had consistently less capillary pore space at all depths but were not significantly less at the 6-9 inch depth. There were no significant differences in capillary pore space in the 6-9-inch zone (Table 12).

These changes in capillary and noncapillary pore space due to a certain rotation were balanced by each other, so that the total pore space remained practically constant. When capillary pore space and noncapillary pore space were added together for each rotation, the range of total was from 55.50 to 58.28 percent. The extreme rotations were (C, O-a), and (C), respectively. This indicated a difference of only 2.71 percent in total pore space. It appears that either of these two types of pore space was increased only at the expense of the other, Figure 1.

TABLE 12. PERCENT CAPILLARY PORE SPACE MEANS FROM 14 ROTATIONS AT FOUR DEPTHS

Depth	Mean
0-3 inches	41.15a*
3-6 inches	47.72 b
6-9 inches	51.89 c
9-12 inches	50.26 d

*Means having different letters differ at the 5 percent levels of significance.

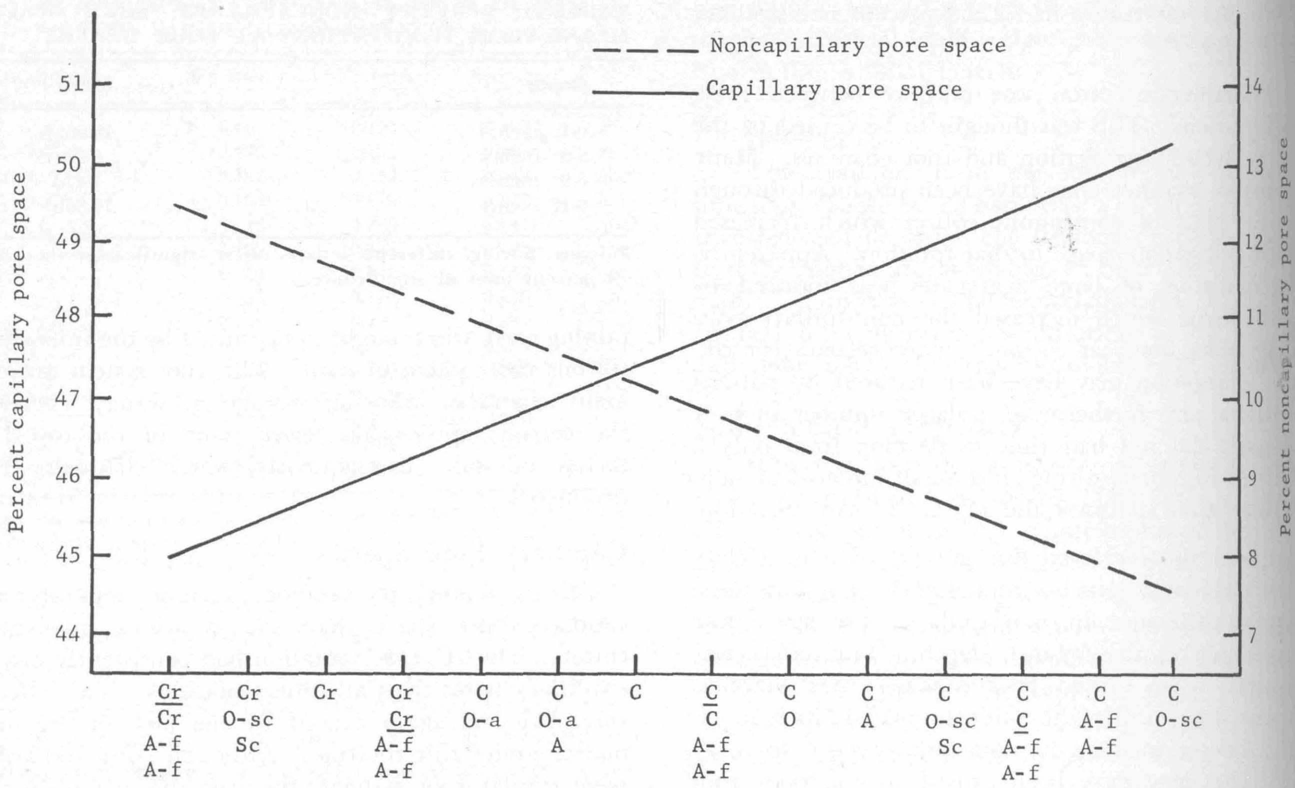

Figure 1. Capillary and noncapillary pore space as influenced by crop rotation.

This could well be caused by differences in sizes of aggregates dominant in each rotation. In all rotations combined, there was a difference in the amount of capillary pores at each of the four depths. Table 12 shows these differences at four depths. The two values at 6-9 and 9-12 inches were higher than those at the 0-3 and 3-6-inch layer. This indicates that cultivation practices, which normally do not exceed a depth of 6 inches, tend to keep the particles separated and prevent reorientation, so that pore spaces remain larger in the surface 6 inches than in the next 6 inches.

Simple correlation with other measured variables shows that capillary pore space was significantly correlated with percent available water (r = -.579) and bulk density (r = -.907).

Percent Available Water

The (C) rotation had the least amount of available water (7.75 percent) and (C, O-sc) had the second least amount (7.91 percent) (Table 13). The low amounts of available water in these two rotations was due to their high percentage of capillary pores. Evidently, the pores were small enough that water could not be removed as readily as from soils that had high amounts of large pore spaces. Another possibility for the low amount of available water in these two rotations is the "sealing off" of the routes of water removal by the large number of tiny aggregates present under these rotation systems. The (C, C, A-f, A-f) rotation had the highest amount of available water (8.97 percent) for the entire 0-12-inch depth. The remainder of the rotations were very similar to each other in amounts of available water for all depths combined.

At the 0-3-inch depth, the (C) rotation had an exceptionally small amount of available water, 4.64 percent, which was significantly less than all other rotations. Rotations involving corn had more available water than the other cropping systems. There was a difference of 4.13 percent available water between continuous cotton and continuous corn. This is an approximate amount of water equal to .37 acre-inches.

Rotation systems seemed to react differently at the 6-9-inch depth in this phase of the experiment as well as some of the other phases. At this depth the corn rotations had the least available water. Apparently, the corn roots did not penetrate or affect this zone. Alfalfa-fescue seemed to be less effective in disturbing the compacted layer than sweetclover because (C, O-sc, Sc) and (Cr, O-sc, Sc), both containing sweetclover, increased the amount of available water. Apparently, the roots from sweetclover disturbed this compacted layer and gave it the ability to release more water when subjected to pressures from .10 to 15 atmospheres.

TABLE 13. PERCENT AVAILABLE WATER IN MILLER CLAY FOLLOWING VARIOUS CROPS IN ROTATION

Rotation	Percent available water
C	7.75a*
C, O-sc	7.91ab
Cr, Cr, A-f, A-f	8.02abc
C, C, A-f, A-f	8.14abcd
C, O	8.18abcd
C, A	8.20abcd
Cr	8.32abcde
C, A-f, A-f	8.32abcde
Cr, *Cr*, A-f, A-f	8.36abcde
C, O-sc, Sc	8.56 bcde
Cr, O-sc, Sc	8.72 cde
C, O-a	8.76 de
C, O-a, A	8.78 de
C, *C*, A-f, A-f	8.97 f

*Means not having the same letter beside them differ significantly at the 5 percent level.

It is possible that the increase in release of water by some rotations is due to the size of pores and aggregates created by certain cropping systems. Those rotations causing large pore spaces tend to release more water to plants than rotations with large amounts of capillary pore space. The very small aggregates which contribute to capillary pore space have a shell of water around them not removed at 15 atmospheres pressure, and the water inside the small pore space is a limited amount; therefore, the available water is decreased.

Bulk Density

Corn decreased bulk density more than any other crop. Over the entire 0-12-inch depth the bulk density of corn rotations ranged from 1.14 for continuous corn to 1.18 for (Cr, *Cr*, A-f, A-f), and the cotton ranges were from 1.21 for continuous cotton to 1.28 for (C, O-sc), Table 14.

TABLE 14. BULK DENSITY OF MILLER CLAY FOLLOWING VARIOUS ROTATIONS

Rotation	Mean (grams per cc.) (0-12 inch depth)
Cr	1.14a*
Cr, Cr, A-f, A-f	1.16ab
Cr, O-sc, Sc	1.18abc
Cr, *Cr*, A-f, A-f	1.18abc
C	1.21 bcd
C, O-a, A	1.21 bcd
C, C, A-f, A-f	1.22 cde
C, O-a	1.23 cde
C, A	1.24 de
C, A-f, A-f	1.24 de
C, O	1.25 de
C, *C*, A-f, A-f	1.25 de
C, O-sc, Sc	1.25 de
C, O-sc	1.28 e

*Means not having the same letter beside them differ significantly at the 5 percent level.

TABLE 15. BULK DENSITY AT FOUR DEPTHS AND 14 COMPOSITED ROTATIONS

Depth, inches	Mean in gms/cc
0.3	1.02a*
3-6	1.276 b
6-9	1.339 c
9-12	1.257 b

*Means not having the same letter differ significantly at the 5 percent level.

At the 0-3 and 3-6-inch depths, the corn rotations had the lowest bulk densities, but there was little difference in the cotton rotations at 0-3 inches. At 6-9 inches, continuous corn had the least bulk density but there was no difference in the other rotations. Apparently, a compacted layer is developing at 6-9 inches under all rotations. Bulk density values are higher at this depth than either of the other three depths, Table 15.

Simple correlation shows that the bulk density values determined coincide with capillary and noncapillary pore space. High bulk density samples had high percentages of capillary pore space and low bulk density samples had high noncapillary pore space percentages. Table 16 indicates these correlations. When a linear contrast of cotton and corn was made, F values obtained were 15.37, 4.38, .13 and 1.00 for the 0-3, 3-6, 6-9 and 9-12-inch depths, respectively. The required significant F value is 3.91.

In a comparison of cotton and corn, corn was found to cause a much lower bulk density than cotton, especially in the surface 6 inches. This difference probably was due to the difference in root growth and tillage practices on cotton and corn. It appears that there has been little alteration of the soil physical properties accomplished in the 6-12-inch zone.

Field Capacity

The 14 cropping systems used in this study had no significant effect on the amount of water retained by the soil at field capacity; however, field capacity was correlated with bulk density and noncapillary pore space as shown previously.

TABLE 16. A SIMPLE CORRELATION OF VARIABLES THAT WERE SIGNIFICANTLY CORRELATED WITH BULK DENSITY

Measured variable	r value found	least significant r value at 5 percent level
Field capacity	—.561	.325
Percent available water	—.521	.325
Noncapillary pore space	—.827	.325
Capillary pore space	.907	.325

TABLE 17. PERCENT WATER IN MILLER CLAY AT PERMANENT WILTING FOLLOWING VARIOUS ROTATIONS

Rotation	Mean (Percent water)
Cr, O-sc, Sc	30.02 a*
C, *C*, A-f, A-f	30.02 a
C, O	30.35 ab
C, O-sc, Sc	30.38 ab
C, O-a, A	30.48 ab
C, O-a	30.52 ab
Cr, *Cr*, A-f, A-f	30.60 ab
Cr, Cr, A-f, A-f	30.73 ab
C, A	30.74 ab
Cr	30.76 ab
C, A-f, A-f	30.99 ab
C, O-sc	31.16 ab
C, C, A-f, A-f	31.19 ab
C	31.32 b

*Means not having the same letter beside them differ significantly at the 5 percent level.

Permanent Wilting Percentage

There was little difference in wilting percentage as a result of rotation.

Continuous cotton had a significantly higher permanent wilting percentage than (C, *C*, A-f, A-f) and (Cr, O-sc, Sc), both of which contained legumes. The 15 atmospheres percentage (permanent wilting point) for the (C) rotation was 31.32 percent, and was 30.02 percent for both (C, *C*, A-f, A-f) and (Cr, O-sc, Sc), Table 17.

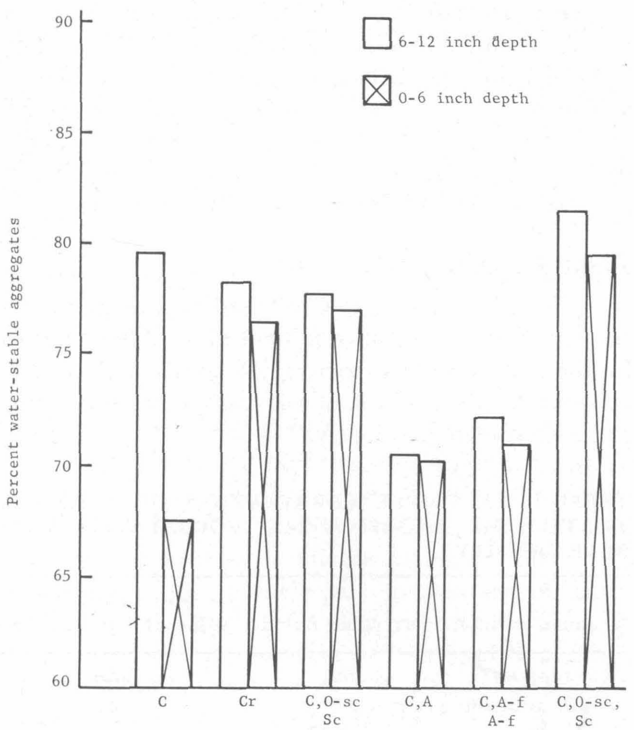

Figure 2. Effect of cropping systems on total water-stable aggregates.

At the 3-inch depth increments, the differences in rotations were minor. Rotations involving sweetclover or alfalfa had consistently lower values except in the 0-3 inch depth where continuous corn had the lowest value. The (Cr) rotation had a high amount of noncapillary pore space which made water easily removed from its large pores when subjected to 15 atmospheres pressure.

Aggregate Analysis

Total aggregation was increased by (C, O-sc, Sc) and (Cr, O-sc, Sc) at the 0-6-inch depth, Figure 2. There was very little effect on total aggregation from any of the cropping systems at the 6-12-inch depth.

Linear comparison shows that rotations involving sweetclover increased total aggregation significantly more at 0-6 inches than the other crops used in these rotations; however, the effect of sweetclover at 6-12 inches was not statistically significant.

Cropping systems did affect the amount of 2-5 mm. aggregates. Continuous cotton had the least amount of 2-5 mm. aggregates, Figure 3, and (C, O-sc, Sc) and (Cr, O-sc, Sc) had the largest amounts of this diameter aggregates in the 0-12 inch profile.

Rotations involving sweetclover increased the percentage of 2-5 mm. aggregates at 0-6 inches but did not increase them significantly at 6-12 inches. At the 0-6 inch depth (Cr, O-sc, Sc) and (C, O-sc, Sc), both of which included sweetclover, had 11.88 and 15.88 percent, respectively, Figure 4, and (C) and (C, A), which did not include sweetclover, had the least amounts, 1.65 and 3.75 percent, respectively.

(C, O-sc, Sc, and (Cr, O-sc, Sc), both containing sweetclover, had the largest amount of 1-2 mm. aggregates at the 0-6 inch depth. They had 21.63 and 22.12 percent, respectively. Continuous cotton had the least number of 1-2 mm. aggregates with 11.10 percent.

There was very little difference in effect of cropping system on the amount of .25-1 mm. and .125-.25 mm. aggregates at any of the depths measured. However, continuous cotton did tend to have a larger number of small aggregates at all depths. The large number of small aggregates under continuous cotton rotations was due to the large number of small basic soil particles that did not stick together to form larger aggregates. It was also noticed that the rotations with a high degree of large aggregates had fewer small aggregates. This would indicate that the rotations causing large aggregates did so at the expense of the small aggregates.

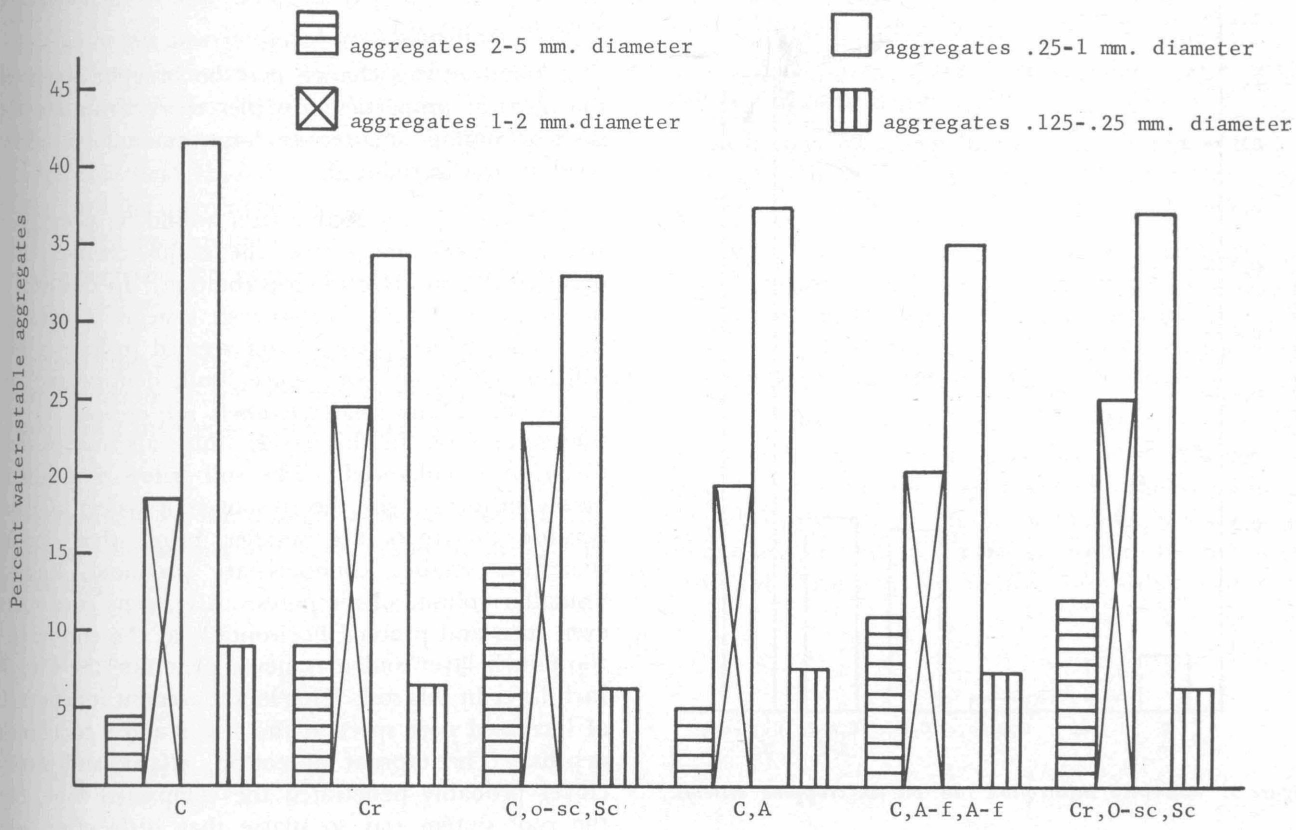

Figure 3. Effect of cropping systems on water-stable aggregates at a depth of 0-12 inches.

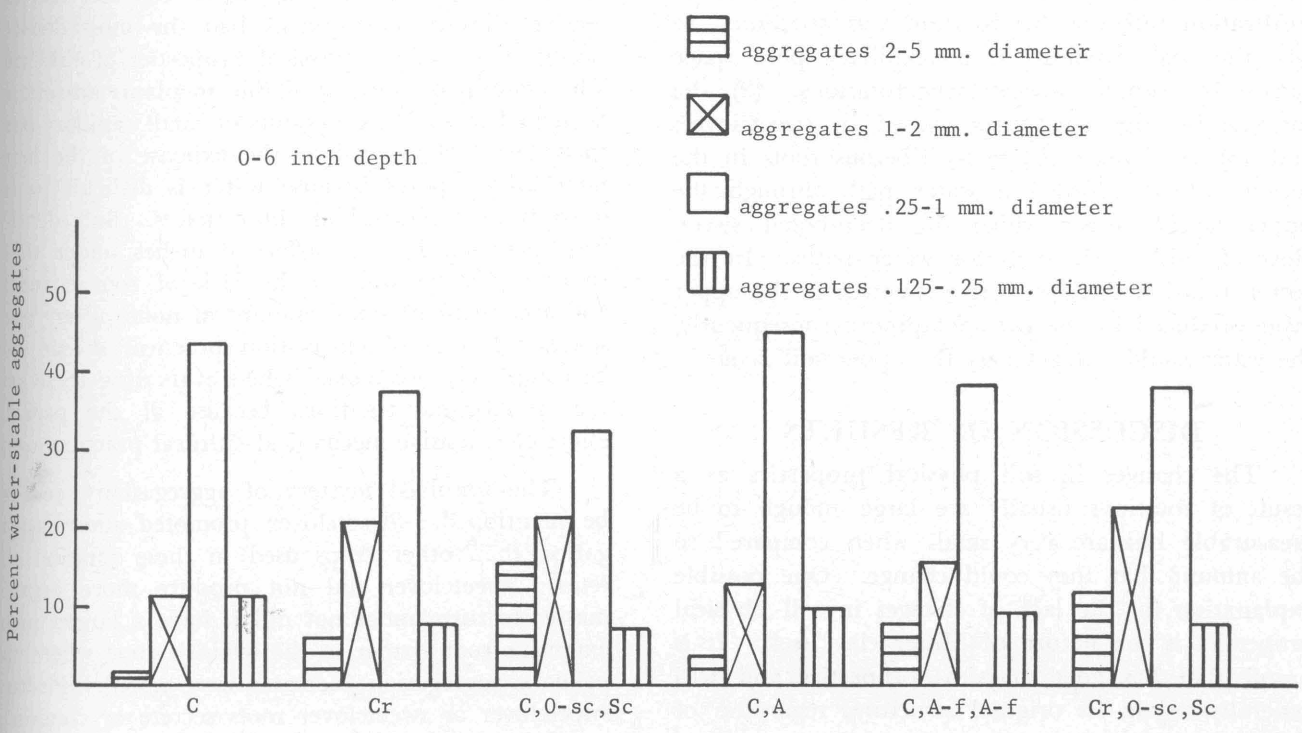

Figure 4. Effect of cropping systems on water-stable aggregates at 0-6 inch depth.

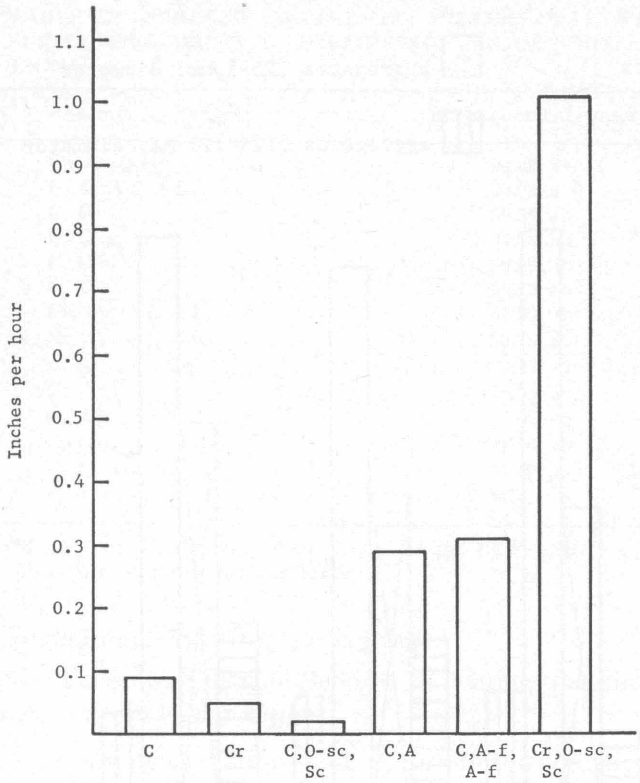

Figure 5. Sustained infiltration rate on six cropping systems.

Infiltration

There was a highly significant increase over all other rotations in sustained rate of infiltration on the (Cr, O-sc, Sc) rotation, Figure 5. The high infiltration rate on this rotation was attributed to (1) the high amount of noncapillary pore space caused by corn, oats-sweetclover rotations; (2) the increase in large aggregates caused by sweetclover; and (3) corn produced many fiberous roots in the topsoil which afforded a water path through the upper layers, under which the deeprooted sweetclover furnished channels for water paths. In the cotton rotation there were few channels in the upper layer produced by the cotton taproot; consequently, the water could not get past the upper soil layers.

DISCUSSION OF RESULTS

The changes in soil physical properties as a result of rotations usually are large enough to be measurable but are very small when compared to the amount that they could change. One possible explanation for the lack of changes in soil physical properties is the nature of Miller clay itself. It is a soil that has good physical properties and will generally regain its original structure, regardless of treatment. This is evident when tillage practices are carried on and aggregates are broken and crushed; in a short time they seem to be back to their original state of aggregation.

Apparently a change may be brought about in the physical properties of Miller clay when materials such as organic matter or large amounts of plant residue are introduced.

Another introduced matter would be plant root systems. This may cause the major changes that occur in this soil due to crop rotation. In this experiment the extensive fibrous root systems of corn in the upper 6-inch layer of soil seemed to have a significant effect on pore space, bulk density and infiltration. Many small channels are created by the numerous roots in this layer; thus, air and oxygen diffusion is enhanced. The soil below 6 inches is barely influenced by the fibrous root system of corn because the roots are smaller below that depth; therefore, smaller channels are produced, leaving a smaller volume of air pores. Also, some corn roots even turn and proceed horizontally at the end of the top 6-inch layer and may never penetrate the 6 to 9-inch layer in this soil. This might account for the lack of increased pore space at the 6 to 9 and 9 to 12-inch depths. The taproot of cotton, alfalfa and sweetclover probably penetrated the compacted zone, but the root system was so sparse that little effect was measured.

Continuous cotton, cotton-oats and other similar rotations that produced neither large amounts of organic matter to be returned to the soil nor extensive fibrous root systems had the most deteriorating effect on the physical properties of this soil. The amount of water available to plants apparently decreased when large amounts of small capillary pore spaces were developed at the expense of the large noncapillary pores because water is difficult to remove from small capillary pore spaces. Bulk density was increased in the surface 6 inches under these rotation systems due to the lack of root channels and a consequent small amount of noncapillary pore spaces. Effects of cultivation practices should not be completely overlooked when evaluating these cotton, nonlegume rotations because of the packing effect of extensive mechanical cultural practices used.

The unsolved mystery of aggregation needs to be mentioned. Sweetclover promoted more aggregation than other crops used in these rotation systems. Sweetclover did not produce more organic matter to turn under nor did it have a larger, more extensive root system in the 0-6-inch zone where the primary aggregation increases were noted. Perhaps sweetclover or sweetclover roots secrete or contain a substance conducive to aggregation, either by itself or through microbial stimulation.

SUMMARY AND CONCLUSION

This study was designed to determine the influence of crop rotation on the physical and chemical properties of Miller clay after 12 years of cropping systems and 14 crop rotations. The soil properties studied were field capacity moisture percentage, permanent wilting percentage, percent available water, bulk density, noncapillary pore space, capillary pore space, organic matter, aggregation and total nitrogen and available P.

The experiment was conducted on the Texas A&M Planation in the Brazos River bottom. The cropping systems were started in 1952 and concluded in 1963.

Results from the foregoing data warrant the following conclusions regarding crop rotations on Miller clay.

Rotations involving corn tended to result in more noncapillary pore space, less capillary pore space and lower bulk density.

Rotations which included 2 continuous years of sweetclover increased the percent of large, water-stable aggregates.

Yield was significantly correlated with only one soil physical property — total aggregation — and this correlation value was very low; however, if the present trend continues, yield may be critically influenced by more than one physical property.

A rotation system containing the so-called soil-building crops used in this study would not be feasible. Instead of crop rotations, the continuous cropping of corn or cotton with adequate rates of commercial fertilizers probably would be the most profitable cropping alternative on Miller clay soil.

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