1963

The Effect of Organic Trenching on Grain Yields, Soil Moisture and Root Penetration on Claypan Soils in South Dakota

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THE EFFECT OF ORGANIC TRENCHING ON GRAIN YIELDS, SOIL MOISTURE AND ROOT PENETRATION ON CLAYPAN SOILS IN SOUTH DAKOTA

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BY

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A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Department of
Agronomy, South Dakota State
College of Agriculture
and Mechanic Arts

June, 1963

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This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

Head of the Major Department

ACKNOWLEDGMENTS

The author wishes to express his appreciation to his family for their understanding and encouragement and to Dr. Fred E. Shubeck, Associate Agronomist, Dr. Lawrence O. Fine, Head of the Agronomy Department, Dr. George Semeniuk, Pathologist, and to Agronomy, Agricultural Engineering and Spink County Agricultural Extension staff members for their supervision and encouragement in conducting this study. The writer also wishes to express his appreciation to Mr. Ray Pederson of Redfield, South Dakota for the use of his land for experimental purposes.

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INTRODUCTION

The impervious nature of claypan soils decreases the rate of water infiltration, air exchange, and root penetration. As a result, these soils are recognized as "problem soils" by farmers and research workers because of the associated tillage difficulties and low crop yields.

Several methods or approaches have been devised in an attempt to overcome this inherent handicap to crop production. The methods presently used are most often centered around the planting of legumes in a crop rotation or the use of a subsoiler to mechanically break up the claypan.

The purpose of this study was to measure the effect of holding open the mechanically fractured claypan with a wedge of organic matter.

REVIEW OF LITERATURE

Impermeability to Water and Air

In nonsaline-alkali soils, the compact layer may be very impervious to water and air. Fireman and Reeve (10) obtained permeabilities of less than 0.01 cm. of water per hour from a soil of this type in Idaho. A permeability of 0.01 cm. per hour is equivalent to only 34 inches per year so the soil would have to be flooded for perhaps five months according to Black (2) before enough water could be absorbed to produce a good crop. Additional evidence of the impervious nature of a compact layer to the movement of water was obtained by Locke *et al*. (21). In field studies with infiltrometers, they found water penetrated the compacted layer at a rate of about 0.2 inches per hour. When this compacted layer was removed, the infiltration rate increased to 9 inches per hour.

Page (27) at Ohio indicated that crop growth in the North Central States frequently is limited because of inadequate soil aeration. This may result from inadequate loosening of the soil in seedbed preparation, from compaction by tillage implements, or from over-working the seedbed.

Kirkham *et al*. (18), working with soils in Belgium, obtained significantly higher yields of sugar beets and wheat in soils with greater air permeability. He concluded that air permeability in the loamy and clay soils studied was a measure of soil structure and was related to crop growth.

Subsoiling

Several attempts have been made to improve or break this impenetrable "hardpan" layer by deep tillage. These attempts have met with varying success.

Osenbrug and Mathews (26) concluded that subsoiling in the clay soils of western South Dakota did not help improve crop yields or reduce the number of failures. Jamison et al. (14) noted variable and relatively small benefits from deep tillage. Considering the expense, it was doubtful if subsoiling treatments in the North Central States could be justified (13).

Long term studies by Hume (12) indicated that yields of corn and wheat were greater from plowing 7 inches deep than from plowing 6 inches deep plus subsoiling 10 inches deep from the bottom of the plow furrow. Russell (33) related crop yield improvement to the time of deep plowing and subsoiling. Brage (4), in a preliminary report on the Claypan Research Farm in the lower James River Basin, obtained no increases in yields of wheat or of corn forage from subsoiling treatment. Larson et al. (20) found subsoiling 16 to 24 inches deep produced no significant yield increases in 12 experiments on seven important soil types in Iowa in 1955 through 1958. In two cases, subsoiling 24 inches deep decreased corn yields significantly. In Illinois (20) corn yields were significantly increased by subsoiling 18 inches deep in one out of eight experiments on five soil types.

On the other hand, Jones (15) obtained favorable results from subsoiling and he advocated depth of subsoiling should depend on the type of crop to be planted; for example, deeper subsoiling for corn than for small grain or beans. He suggested optimum spacings between "rips" should depend on the soil structure and the moisture content of the soil. Hovland et al. (11) in 1962 summarized four years of deep tillage work at the South Dakota Claypan Research Farm. He obtained small increases in corn yields due to subsoiling but they were just enough to pay for the additional costs of the subsoiling operation. The small grain crops - oats, winter wheat, and spring wheat - did not respond sufficiently to pay for the added cost of operations.

Vertical Mulching

As a result of the generally unfavorable results of subsoiling (4, 11, 12, 13, 14, 20, 26) a different approach to the problem was attempted. A wedge of organic matter was forced down in the claypan to prevent the clays from flowing together again when they became wet. Jones (15) of Ohio suggested organic trenching at a meeting in 1938 and expected to develop it a year later. Spain et al. (35) devised a method of utilizing a subsoiler and attaching wings to the chisel to hold the furrow open long enough to blow chopped organic material into the trench. The trench was about 20 inches deep, 2 1/2 inches wide at the bottom, 6 inches wide at the top, and contained approximately 2 tons of material per acre. The trenches permitted fairly rapid lateral movement of water. A study conducted by Parr (28) denoted stabilization of the trench walls by addition of organic matter. Bulk density differences were noticed near the trench. In most cases soil moisture values for vertical mulching were higher and bulk density values lower than for subsoiling. Swartzendruber (37) indicated that moisture intake by the channel is ideal, but moisture must penetrate to a more permeable layer immediately beneath. Another benefit of the channel is the lateral movement of water in saturated areas.

Fertilizer Application Methods

The placement of fertilizer is a perplexing and much studied subject. Many researchers advocate deep placement of fertilizer, but others are as definitely opposed to this method. Weaver et al. (40) demonstrated the important role played by the subsoil in supplying water and nutrients to the plant. They found that both the yield and quality of barley were improved more by the addition of fertilizer to the subsoil than when usually adequate amounts had been added to the surface soil. Nissley (25) devised a machine for deep application of fertilizer in varying amounts. The yields on poorly-drained claypan soil were greater than on check plots; they were not always greater in comparison to well-drained soils. Kohnke et al. (19) predicted great benefits on half the crop acres of Indiana from deep fertilization. This method aids the downward movement of roots and forms an organic mass in the loosened rip marks, keeping the soil separated. Patrick (29) conducted research in Louisiana on four soil types, using deep fertilization. He found that increased root development and yield may be expected from deep fertilization. The increased yields were evident during periods of low moisture. Fehrenbacker (8) of Illinois accomplished deep fertilization by removing the soil to various depths and adding fertilizer to the bottom of the furrow and returning the mixed soil on top of it. Yield increases were obtained with this technique by placement at the 9- and 18-inch level.

In contrast to the data favoring deep application of fertilizer, Bower at al. (3) of Iowa show an increase in yield by plowing in the fertilizer over deep placement of fertilizer. Puhr et al. (31) disclosed some evidence that in Spink County on two soil types, yield increases were due more to rate of nitrogen application than to depth of placement. Shubeck (34) found conditions much the same at the Southeast Research Farm. Jamison et al. (13, 14) of Missouri indicate that the benefits, when they occur from deep tillage and deep fertilization, are both variable and relatively small in the Midwest. Much the same results were reported by Larson et al. (20) from work conducted in Iowa and Illinois. The plow under method of fertilizer application appeared to have the greatest effect on yields.

Residual Effect of Fertilizer

Over years that commercial fertilizer has been used, much thought has been given to residual effects that may arise from previous applications. Residual fertilizer experiments conducted under South Dakota conditions by Puhr et al. (31) indicate a considerable carry over of nitrogen from an application of 80 pounds per acre. The carry over increased the oats yield in one experiment about 10 bushel per acre, but applications under 80 pounds were not as effective. These experiments were carried out in Clay, Codington and Spink Counties. Results of the Northeast Farm at Watertown, South Dakota (17) show an advantage to applying small amounts each year rather than an equivalent large amount once in four years. Under Iowa conditions Pesek (30) found the average residual effect of moderate amounts of nitrogen applied to corn is about 25 per cent when measured with oats the next year. Following dry years, the average residual is nearer 30 per cent, but following wet years it is below 20 per cent. The response varied from 4 to 8 bushels of oats per acre. These figures are for silt loams or soils of fine texture. Cook et al. (5) of Michigan are basically in agreement with these results. Struchtemeyer (36) working with potatoes in Maine, found that the carry over of a complete application of 120 pounds of nitrogen, 180 pounds of P_2O_5 and 180 pounds of K_2O in one year produced enough residual effect to maintain a potato crop the following year. Munson et al. (24) at Iowa stated that apparently there were relatively large quantities of inorganic nitrogen existing in the unleached soil following the corn crop and prior to planting the oats crop.

Root Studies

Restrictions to Root Growth

There is considerable evidence to indicate the seriousness of the problem of impervious B horizons to root growth in claypan soils. Weaver et al. (39) working with distribution of grass roots, found large accumulations of roots in the 0 to 6 inch layer with a severe restriction of growth in the B horizon. Root growth again became more abundant in the C horizon.

De Roo (6) in Connecticut working with tobacco roots noted that where the subsoiler had fractured the compacted area (Ap3 + B21 horizons) the structure was open (bulk density 1.40) and filled with well branched roots which penetrated into the B22 and B3 horizons. Between the subsoiler grooves, the soil was still compact (bulk density 1.64) and only a few roots were able to penetrate these dense areas. Bulk density work conducted in Pennsylvania by Zimmerman et al. (42) in conjunction with root growth indicates that as bulk density increases the amount of roots decreases. They also found that sudangrass roots penetrate compacted soils more readily than did soybeans, and bulk densities of 1.80 and higher virtually exclude root penetration. Taylor et al. (38) of Texas used a wax substrate of varying degrees of hardness to test legume and nonlegume root penetration. These men found that root penetrating abilities varied with species of plants, but those of legumes were not significantly greater than nonlegumes.

Research work conducted by Locke et al. (21) in Oklahoma and North Dakota concentrated mainly in the plowpan area in the profile. The roots in and below the plowpan zone were less than in the area above, and in their opinion this was responsible for decreased yields, increased runoff, and soil erosion losses. In addition, the plowpan reduced infiltration and hindered root penetration.

Root Sampling Technique

Baxter and Fine (1) studied the root distribution of corn to the 4-foot depth. The root distribution was determined by excavating to expose the soil profile, cutting a section of soil 6 inches thick, 40 inches wide, and 48 inches deep, enclosing it in a rectangular frame, moving the frame to a water supply, and washing the soil away until the roots could be separated and weighed. Fehrenbacker et al. (9) used a method of sampling roots in concentric rings around a corn hill with the Kelly soil-core sampling machine (16). With this machine, 4-inch diameter cores were taken to a depth of 6 feet. A shaker type washer was used to remove most of the soil from the roots, and final separation was made with fine screen and tweezers. He states that root weights per acre determined in this way appear to be in line with those obtained by taking large soil-root monoliths. The core sampling method eliminates the pits and gives more complete sampling at various distances from the corn plant in less time.

METHODS AND PROCEDURE

Field Experiments

The field experiments were designed to measure the yield effects of organic trenching and other tillage methods on corn and small grain.

Organic trenching may be defined as the practice of placing a continuous wedge of organic material in a vertical fracture extending from the soil surface to a depth of 18 to 20 inches. Both trenching and subsoiling were performed at 84-inch intervals, allowing two corn rows between each pair of fractures. Four different field experiments involving organic trenching were completed for each of the years 1958 through 1960. No crop yields were obtained for 1959 because of severe hail damage. These experiments with their plans and treatments are listed below.

1. Comparison of several organic materials placed in the trench and root penetration studies in claypan soils.

The object of this experiment was to compare the effect on grain yields of several materials placed in the trench and to measure the lasting effect of these materials.

Materials compared were: corn cobs, flax straw, wheat straw and sweet clover.

A cropping sequence was followed with corn in 1958, wheat in 1959 and corn in 1960. The trenching was parallel to the long axis of the plots. The seedbed between the trenches, was prepared with a rear-mounted field cultivator with spike tooth shovels as illustrated in Figure I. Maximum penetration of the shovels was 14 inches. By use of the field cultivator instead of the plow, the trenches were kept open at the surface. Corn was planted parallel to and between the trenches but wheat was planted at right angles to the trenches.

2. A comparison of organic trenching to other individual mechanical and cultural methods of improving yields on claypan soils.

The treatments were:

1. Organic trenching (wheat straw)
2. Trenching without adding organic matter
3. Subsoiling with conventional subsoiler
4. Sweet clover catch crop (planted with wheat)
5. Twenty pounds of nitrogen per acre per year.
6. Check (no treatment)

Corn and wheat were the test crops in 1958 with rye and corn used as test crops in 1960. The nitrogen in treatment 5 was disced in for wheat and rye and plowed under for corn. For treatment 3, subsoiling was done every year in the fall when the ground was dry to cause fracturing of the claypan.

3. Evaluation of different combinations of organic trenching, legumes and subsoiling.

In Experiment 2, individual cultural methods were compared to organic trenching, but in Experiment 3, the organic trenching was compared to several combinations of trenching using legumes and subsoiling. In treatments 2 and 3, the mechanical operations were performed only at the beginning of the experiment in the fall of 1957. In treatment 5, the subsoiling was done once every year. Wheat and rye were the only grain crops used. Alfalfa was planted with wheat in 1958 and remained through the 1959 season. It was fall plowed in 1959. Wheat straw was used as the organic material.

The cropping sequence and treatments for 1958, 1959 and 1960 were:

	1958	1959	1960
1.	Wheat + alfalfa	Alfalfa	Rye
2.	Wheat + alfalfa + organic trench	Alfalfa	Rye
3.	Wheat + alfalfa + subsoil	Alfalfa	Rye
4.	Wheat	Wheat	Rye
5.	Wheat + subsoil	Wheat + subsoil	Rye + subsoil
6.	Wheat + organic matter on surface	Wheat	Rye

4. Investigation of the possibilities of combining deeply placed fertilizer with organic trenching and subsoiling.

The emphasis in this experiment was placed on whether or not deeply placed fertilizer was beneficial and not what was the best rate or ratio. The cropping sequence was corn in 1958, wheat in 1959 and rye in 1960. Fertilizer was applied deeply by using a modified subsoiler (Figure II) with a tube attached to dispense the fertilizer at the bottom of the trench or chisel slit.

The treatments were:

1. Deep placement of 80 pounds of N + 80 pounds of P_2O_5 + organic trenching (rye straw)
2. Deep placement of 80 pounds of N + 80 pounds of P_2O_5 + subsoiling
3. Surface placement of 80 pounds of N + 80 pounds of P_2O_5 + subsoiling
4. Check

5. Surface placement of 80 pounds of N + 80 pounds of P_2O_5 and no mechanical treatment

6. Surface placement of 40 pounds of N + 40 pounds of P_2O_5 and deep application of 40 pounds of N + 40 pounds of P_2O_5 with subsoiler.

Experimental Plot Design

A randomized block design was used with four replications of each treatment except one experiment which had three replications. The plot size was 36 feet by 75 feet. Analysis of variance was completed and the standard deviation of the treatment means was calculated. Treatment averages were determined and the multiple range test described by Duncan (7) was used to determine treatment differences at the 5 per cent probability level.

Procedure Used in Organic Trenching

The organic trenching was performed with a subsoiling chisel, that had a pair of iron wings bolted on the sides to hold the fractured soil open until organic matter had been placed into the soil, as illustrated in Figures III and IV. The space between the wings at the top was 8 inches and the bottom spread was 4 inches. A four to five plow tractor or crawler tractor was necessary to perform this operation. Five 75-foot trenches were placed in each plot spaced 84 inches apart. The depth of the trench was 18 to 20 inches. Each trench held 175 pounds of straw or 7.8 tons straw per acre. The straw was baled and slices from it were placed in the soil by hand. Corn cobs were applied by hand at the rate of 1 1/2 bushels per linear foot of trench. The cobs as shown in Figure V, protruded above the soil surface by 6 to 8 inches and gradually receded as the organic matter settled.

Figure I. The field cultivator used for seedbed preparation between the trenches

Figure II. A modified subsoiling chisel for deep application of fertilizer

Figure III. The organic trenching tool and organic material used in performing the operation

Figure IV. A monolith of the organic trenching treatment showing the soil and organic matter relationship

Figure V. The appearance of a trench after being filled with corn cobs

Planting and Harvesting Methods

Corn was planted with a conventional corn planter at the rate of 8,000 plants per acre in 75-foot rows. Two rows 70 feet long were harvested for yield. The wheat was planted at 1 1/4 bushels per acre and rye at 1 bushel per acre with an International press drill. A sample 6 feet wide and 70 feet long was harvested with a combine for yield determinations. A legume attachment to the drill was used for planting the sweet clover and alfalfa. No seed or forage were taken from the legumes.

Root Sampling Procedure

Root samples were taken from two treatments: organic trenching and check plots.

There were four sample sites chosen for root sampling from each of the two above treatments. The area sampled extended from the plant to the center between the rows. The first sample was taken at the plant (in the row), the second at 6.6 inches from the row, and the third 13.3 inches from the row and the fourth at 20 inches from the row. The rows were 42 inches apart. The diameter of the core was 1 5/8 inches. The cores were 3 1/2 feet long and were cut into 1-foot lengths preparatory to washing out the roots. This method, with a few modifications, was described by Fehrenbacker *et al.* (9).

The method of root separation from soil was based on the procedure described by McKell (23).

In this method cores were placed in containers (Figure VI) full of water and the samples were then allowed to soak until the soil was wet through. The contents from these soaking cans were rinsed into a larger pail equipped with an overflow spout. A pressure stream of water from a garden hose and nozzle held about 2 inches above the bottom of the can circulated and washed the root-soil-water mixture. Fine particles of soil were carried into suspension by the stream of water and spilled out of the can and passed through a fine mesh screen basket. When the water ran clean and the roots were washed free of soil particles, the roots were floated out the overflow and caught on the screen. The larger root masses were removed from the screen but the smaller roots and foreign material left on the screen were removed and placed in an air operated grain separator. This machine separated heavy material from light roots which were caught on a screen. The root samples were then oven dried and weighed on a highly sensitive scale. Root weights are reported as pounds per acre.

Soil Moisture Sampling

Soil samples for moisture determinations were taken at 1-foot intervals to a depth of 5 feet in five positions with respect to the trench. A mounted post-hole digger was used to obtain these samples. The location of the five samples were: at the trench, one pair 21 inches on either side, one pair 42 inches on either side. The pair of samples 21 inches on either side of the trench coincided with the location of the corn rows. The samples in nontrenched plots were similarly located with respect to the corn rows. Values at the five lateral spacings were averaged for each 1-foot depth in a treatment.

Bulk Density Samples

Bulk density samples were taken from the same relative location as the soil moisture samples. One sample was taken in each of the four replications for the organic trench treatment and the check plot. The procedure presented by Lyon et al. (22) was used to determine bulk density. The 15 atmosphere percentage water content of soil was determined by the use of a pressure membrane (32). The results were averaged for each 1-foot depth in a treatment.

Soils of Experimental Plots

Soils in the experimental plots were described by Westin et al. (41). They occur on the Glacial Lake Dakota plain created by the Mankato Glaciation. A brief description of the soils are as follows:

1. Aberdeen Silty Clay Loam

This is an imperfectly drained claypan soil occurring on level positions and is extensive, usually occurring in large bodies away from streams. The claypan may be encountered at depths of 12 to 28 inches. The parent material is lake-laid silts and clays which are slowly permeable with salts and alkali usually present below the subsoil. The soil is classified as a solodized solonetz.

Profile Description

A1	0-8"	Black, friable silty clay loam of weak granular structure, high in organic matter.
A2	8-12"	Dark gray, friable silty clay loam of blocky or platy structure.
B2	12-28"	Very dark gray, compact silty clay of blocky structure.

Cca	28-46"	Dark yellowish-brown, friable silty clay loam of massive structure, highly calcareous, usually moderately saline.
C	46-60"	Light yellowish-brown, friable, laminated, silts and clays, calcareous, usually moderately saline.

2. <u>Exline Silty Clay Loam</u>

This complex consists dominantly of imperfectly drained claypan soils with very thin surfaces occurring on level, low lying positions and the claypan is at or below plow depth. The parent material is clayey alluvium. This soil is classified as solodized solonetz.

<u>Profile Description</u>

A1	0-2"	Very dark gray, friable silt loam of granular structure.
A2	2-4"	Gray, friable silt loam of platy structure.
B2	4-19"	Black, compact silty clay, structure consists of strongly developed round-topped columns; salt accumulation starts in lower part.
Cca	19-31"	Light olive gray silty clay, strongly calcareous, usually strongly saline.
C	31-60"	Light gray silty clay or silty clay loam, moderately calcareous, usually strongly saline.

3. <u>Tetonka Silt Loam</u>

This is an imperfectly drained soil occurring in shallow depressions in all parts of Spink County and is classified as solod. The parent material is local wash from higher-lying adjacent soils. The profile is friable in the upper part but at depths of from 8 to 14 inches a claypan is encountered. The soil is slowly permeable but not saline.

__Profile__ __Description__

A1	0-4"	Black, friable silt loam of platy structure.
A2	4-10"	Gray (when dry), friable silt loam of platy structure.
B2	10-26"	Black, firm clay loam of blocky structure.
B3	26-44"	Dark grayish-brown, weak blocky clay loam.
Cca	44-60"	Olive gray, calcareous, clay loam glacial till or lacustrine silts and clays.

__Weather__ __Data__

Rainfall data were taken from three United States Weather Bureau Stations which formed a triangle of the site on which the experiments were conducted. The stations used were Redfield, Ashton and the Irrigation Research Farm, six miles east of Redfield. The rainfall data were averaged and therefore present an approximation of moisture conditions at the site.

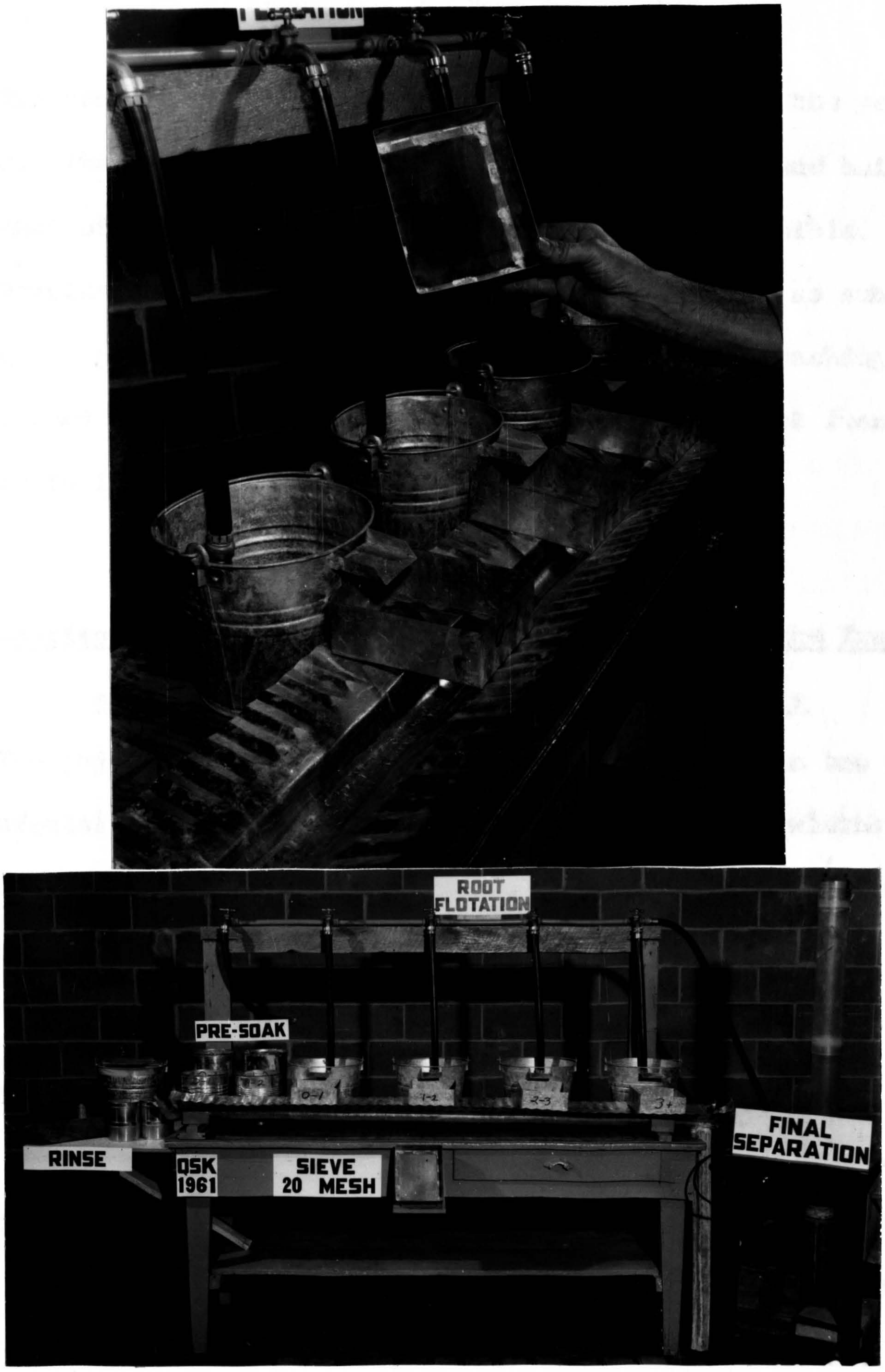


Figure VI. The apparatus used for separation of the corn roots from the soil

RESULTS AND DISCUSSION

The results of these experiments are reported for the years 1958 and 1960. The 1959 data were lost due to driving rains and hail which ruined much of the crop and made accurate sampling impossible.

Results from treatments conducted every year such as subsoiling, are reported on a yearly basis. Results from organic trenching, which was performed once in three years, will be residual effect from treatment done in 1957.

Experiment 1

Comparisons of Several Organic Materials Placed in the Trench and Root Penetration Studies in Claypan Soils

The objectives of this experiment were to ascertain how lasting and beneficial the different organic materials were, and whether the organic matter would hold the trench open, and what effect organic trenching had on root penetration.

Lasting Effect

The different materials were rated for their durability or lasting effect in 1960, the last year of the experiment. The measurements were: (1) the resistance to separation of the organic matter when pulled apart manually, and (2) visual rating of color and degree of physical breakdown of the original stalks or stems.

The materials are ranked below with the most durable first.

1. Flax straw
2. Corn cobs
3. Sweet clover
4. Wheat stubble

The visual evidence of decomposition of the organic matter in the corn cob treatment is shown in Figure VII.

By 1960 the flax straw, corn cobs and sweet clover were not greatly different from one another in their resistance to decomposition but the wheat straw was decomposed to a much higher degree. The higher nitrogen content in the sweet clover may have been responsible for its slightly more rapid decomposition than the corn cobs and flax straw.

The general rate of decomposition of the organic material decreased with depth. The corn cobs, Figure VII, show decomposition of the soft inner pithy material, but the hard outer portion of the corn cob was decomposed less.

<u>Amount of Compaction of Organic Matter</u>

Corn cobs did not pack very closely the first two years and considerable desiccation of the soil was noticed both on and around the trench, note Figure VIII. By 1960 the corn cobs had settled sufficiently to restrict excessive air movement and the associated drying of the soil on the trench walls.

Measurements were made of all four materials to note organic matter compaction. All the materials had settled about two inches from the soil surface and the trench had narrowed by the same amount.

Table 1. A Comparison of Different Materials Placed in Trench on Yield of Corn 1958 and 1960

Treatment	Yield of corn in bu/acre* 1958	1960
1. Sweet clover	28.5	25.1
2. Corn cobs	18.9	29.2
3. Flax straw	14.0	24.5
4. Wheat stubble	9.1	18.4

*Corn was not harvested in 1959 because of hail damage.

A Duncan's multiple range test was calculated to compare treatment means.

```
              1958
4        3          2________1
______________________

              1960
4        3__________1________2
-
```

Any two means not underscored by the same line are significantly different.
Any two means underscored by the same line are not significantly different.

<u>Yield Differences</u>

In 1958, the advantageous influence created by the different kinds of organic material in the trench was typified by the yield of corn following the sweet clover treatment. The legume material was higher in nitrogen content than the other organic materials used, consequently the corn yield was more than for the corn cob treatment, which had a high C:N ratio. As shown in Table 1, there was approximately a 10-bushel increase in corn yield in favor of using sweet clover rather than corn cobs. The corn cob treatment yielded about 5 bushels more corn than the flax straw treatment, and 9 bushels more corn than the wheat stubble treatment.

With the sweet clover treatment, there was no increase in corn yield in 1960 compared to that in 1958. Apparently a considerable amount of the nitrogen from the legume was used by the crop prior to 1960. In general, the leguminous residue with its narrower C:N ratio did not have the lasting beneficial effect as the residues with a wide C:N ratio.

Figure VII. A mass of corn cobs removed from the trench after being buried for three years

Figure VIII. The effect of corn cobs in the trench at the end of two years on the vegetation growing on and near it

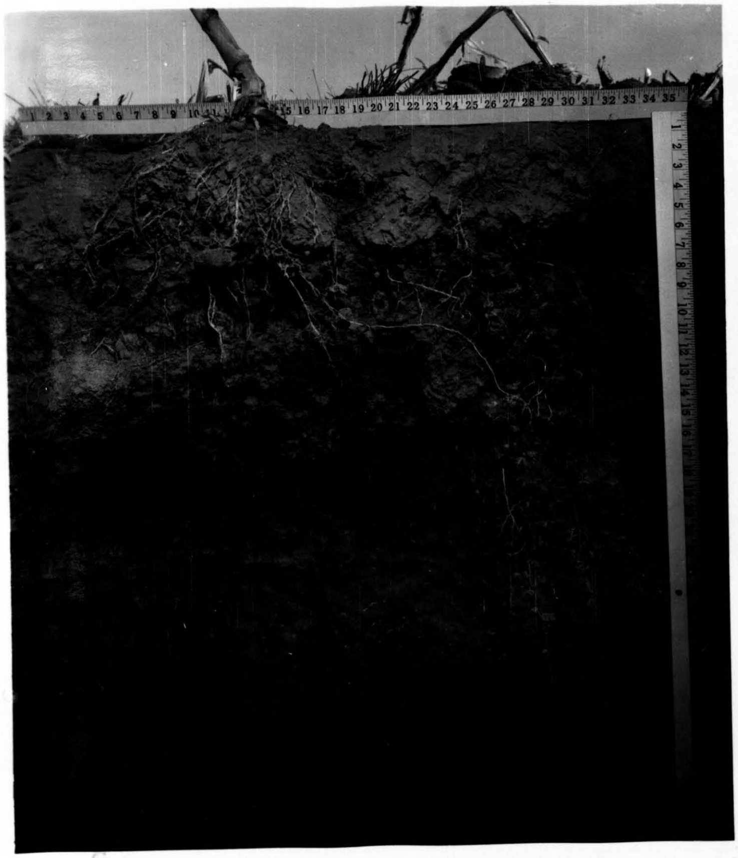


Figure IX. Corn root growth in an organic trenching treatment

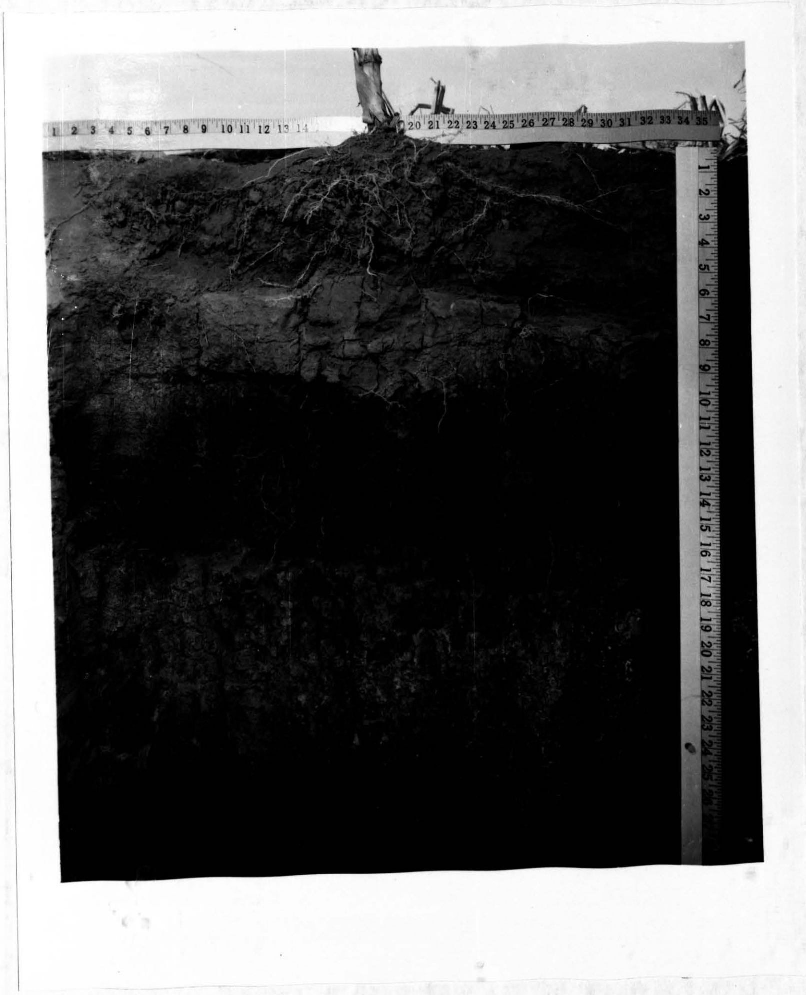


Figure X. Corn root growth in a no treatment plot

Root Studies

Root studies as illustrated in Figures IX and X were conducted to compare the effect of organic trenching (using corn cobs) with no treatment on the pounds of roots produced at various depths in the soil. The effect of treatment on root weight is shown in Figure XI.

With only one exception, there was an increase in weight of roots per acre in the organic trenched plots compared to the check plots at every depth sampled and at every interval from the plant. The exception was at the 0-1 foot level with the sample location closest to the plant. This was also the sample farthest away from the trench.

As the sampling locations approached the trench, the weight of roots per acre increased at the 0-1 foot soil depth.

The relationship of the amounts of roots in the trenched plots to those in the check plots was quite constant at most depths and sampling locations except at the 2-3 foot depth, 13.3 inches from the plant. At this location and depth the amount of roots in the trench plot far exceeded that of the check plot. This can be attributed to the rupturing of the claypan, permitting the roots to penetrate through the claypan and proliferate in the strata below (Figure IX). This trend was apparent at the next sampling depth in the 3-4 foot level, but it was not so pronounced because the majority of the corn roots normally are in the upper 3 feet.

The sampling location 20 inches from the plant was the farthest from the plant but the closest location to the trench. Here again the

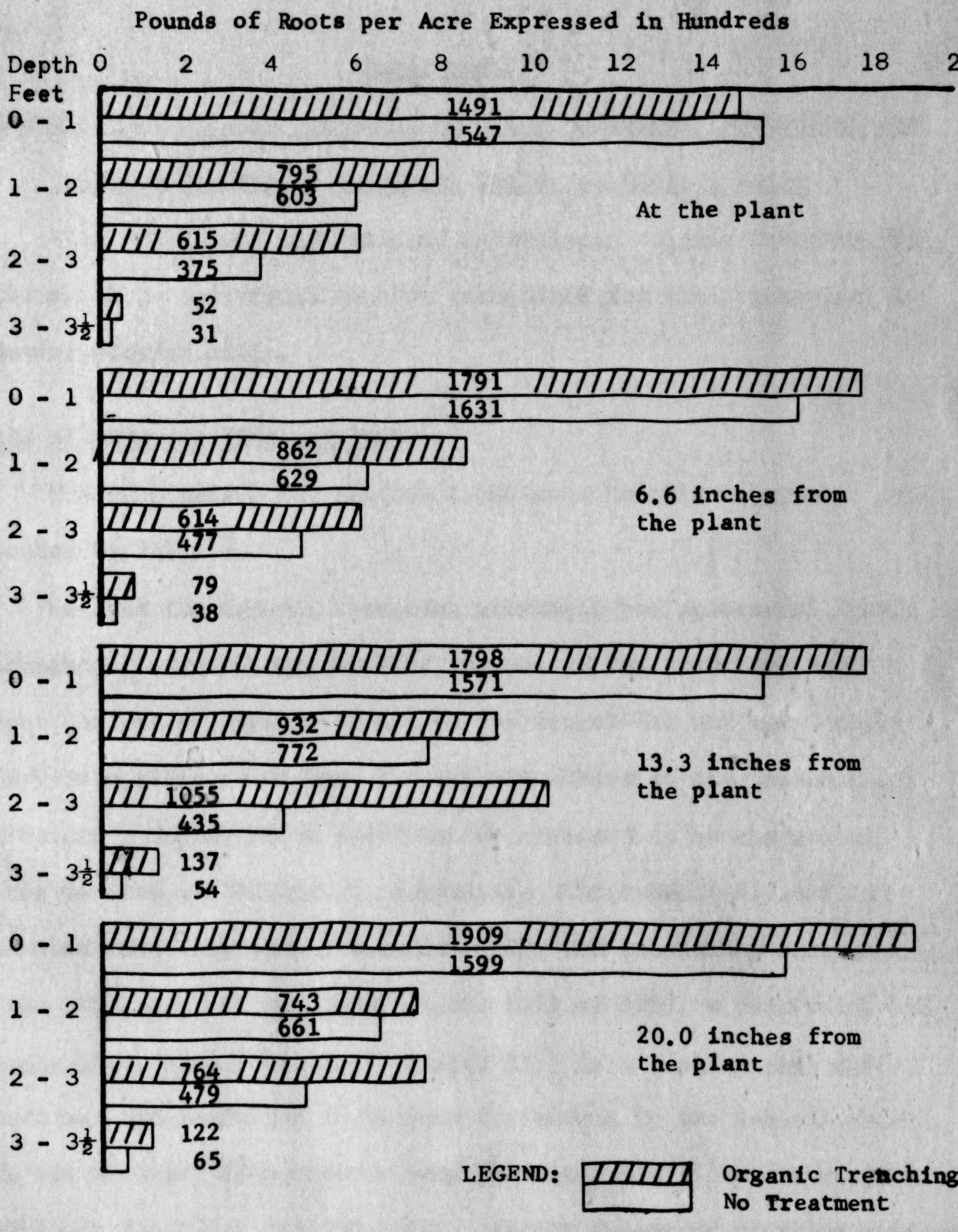


Figure XI. Effect of organic trenching and check plot on corn root distribution root weights at the 2-3 foot level were substantially greater for the organic trenched plots.

Experiment 2

A Comparison of Organic Trenching to Other Individual Mechanical and Cultural Methods of Improving Yields on Claypan Soils

This experiment was designed to evaluate organic trenching by comparing it to individual methods recognized for their potential in improving claypan soils.

Yields of Corn for 1958 and 1960

The corn yields for the six treatments in this experiment are presented in Table 2.

In 1958 the organic trenching treatment was successful from a standpoint of corn yields, whereas the use of the trenching tool without the use of organic matter in the trench did not give satisfactory corn yields. Without the organic matter in the trench the soil became puddled, water infiltration appeared to be restricted, and the seedbed was difficult to prepare. The subsoiled plots produced unsatisfactory corn yields in 1958. The subsoiling treatment for the 1958 corn was performed in the fall of 1957, a year which had 6 inches above normal rainfall (Table 3). As a result, this wet subsoil was not conducive to maximum fracturing by the subsoil chisel. There was no sweet clover catch crop preceding the 1958 corn so no corn yields are given for that year. Twenty pounds of nitrogen appeared to have a slight beneficial effect on corn yield in 1958.

By 1960 the corn yields for the organic trenched plots had taken a sudden drop to a level about equal to that of the check plot. This occurred despite the fact that there was more soil moisture in the organic trenched plots, as shown in Figure XIII. This inconsistency is difficult to explain because with small grain the organic trenching treatment was still effective for increasing rye yields in 1960 as illustrated in Table 4. Apparently this difference was not due to seedbed preparation because the operations for both corn and rye were similar and consisted of plowing, discing and harrowing. The plowing was at right angles to the trench. Consequently the plowing sheared off the top of the organic wedge and partially covered it with surface soil. During the 1960 growing season, there appeared to be an excess of water for corn in the organic trenched plots. The corn plants were retarded in growth and were pale green to yellowish in color. These detrimental effects were not apparent in the winter rye which was planted in the fall of 1959 and had a root system partially developed by the spring of 1960.

An adverse residual effect from trenching without the use of organic matter was reflected in the corn yields in 1960. The results and the explanations were the same as those for 1958. However, treatment means of the 1958 and the 1960 corn yields were not significantly different at the 5 per cent level.

Table 2. Comparison of Organic Trenching with Other Promising Mechanical and Cultural Methods for Improving Corn Yields on Claypan Soils

Treatment	Yield of corn in bu/acre* 1958	1960
1. Organic trenching	20.3	14.8
2. Trenching without organic matter	13.0	10.8
3. Subsoiling	10.0	20.9
4. Sweet clover catch crop	----	18.9
5. Twenty pounds of nitrogen	18.1	22.5
6. Check	16.6	15.0

*Corn was not harvested in 1959 because of hail damage.

Yields of Wheat in 1958 and Rye in 1960

The effectiveness of organic trenching on small grain yields was much more favorable in 1960 than in 1958. This is a direct reversal of the effects on corn shown in Table 2. The real difference lies in the unfavorable yield of wheat in 1958 on the organic trenched plots. At wheat planting time, early in the spring, the soil was nearly saturated with water from heavy rainfall in 1957. The organic trenched treatment served as a moisture collecting device and consequently the additional water had a detrimental effect on seedbed preparation and wheat stands. The surface became hard and crusted, thus reducing seedling emergence. Later in the season, by corn planting time, this excess moisture had drained into the subsoil and had a beneficial effect on the corn yield in 1958 which had a relatively dry summer.

The difficulties in preparing the seedbed were not so severe in the plots that were trenched without the use of organic matter, and the wheat yield in 1958 was comparable to that of the check plot.

The subsoiling was done in the fall of 1957 for the 1958 wheat

Table 3. Approximate Monthly Rainfall for 1957, 1958, 1959 and 1960 at the Experimental Site in Spink County, South Dakota

	Rainfall (inches)								
	1957	1958	1959	1960		1957	1958	1959	1960
Jan.	0.14	T*	0.28	0.53	July	2.54	1.95	1.60	2.37
Feb.	0.48	1.95	0.53	0.53	Aug.	3.07	1.04	1.11	3.70
March	0.25	0.42	0.06	0.62	Sept.	1.79	0.37	2.81	1.44
April	3.92	2.10	0.20	2.33	Oct.	3.06	0.21	1.88	0.58
May	5.01	2.26	3.07	2.08	Nov.	0.99	0.96	0.36	0.61
June	4.26	2.45	2.32	4.94	Dec.	0.30	0.35	0.43	0.84
					Total	23.81	14.06	14.65	20.57
					Normal**	17.35	17.35	17.35	17.35
					Variation	+6.46	-3.29	-2.70	+3.22

*T=trace of precipitation.
**The normal for the city of Redfield, South Dakota.

crop. There appeared to be an increase in wheat yield for this treatment compared to the check plot, but it was not significantly so at the 5 per cent level, using Duncan's multiple range test.

No sweet clover catch crop preceded the 1958 wheat so no wheat yield is reported in Table 4 for this treatment.

Twenty pounds of nitrogen applied to the wheat in 1958 proved to be a satisfactory and statistically significant method for increasing wheat yields on this claypan soil.

The rye yield in 1960 on the organic trenched plots was significantly greater than on the check plots. This was winter rye, planted in 1959. Apparently the excessive moisture in the trenches noted for corn was not detrimental for this winter small grain crop.

The effectiveness of the sweet clover catch crop on rye yield in 1960 was also pronounced. The yield increase for this treatment over the check was also statistically significant at the 5 per cent level. The success of the legumes in increasing the rye yields could be attributed to the effect of their deep roots and to the symbiotic nitrogen returned to the soil.

Twenty pounds of nitrogen appeared to increase the yield of rye. With less soil variation, this difference would probably have been significant.

Residual effects of trenching without the use of organic matter and the annual subsoiling treatment had little or no effect on rye yield in 1960.

Table 4. Comparison of Organic Trenching with Other Promising Mechanical and Cultural Methods for Improving Wheat and Rye Yields on Claypan Soils

Treatment	Yield of wheat and rye in bu/acre* Wheat 1958	Rye 1960
1. Organic trenching	8.7	19.2
2. Trench without organic matter	12.1	14.0
3. Subsoiling	15.7	14.1
4. Sweet clover catch crop	----	19.1
5. Twenty pounds of nitrogen	16.9	16.0
6. Check	11.7	12.9

*Wheat was not harvested in 1959 because of hail damage.

A Duncan's multiple range test was calculated to compare treatment means.

1958 wheat

```
1     6     2     3_____5
      ______________
_____________
```

1960 rye

```
6     2     3     5_____4_____1
___________________
```

Any two means not underscored by the same line are significantly different.
Any two means underscored by the same line are not significantly different.

Soil Moisture Study

In Figures XII and XIII the inches of soil moisture for all the sampling points (under each of two corn rows and in the centers on each side of the two rows) were averaged and plotted.

In the fall of 1959 and in the spring of 1960 before corn planting, there was more moisture in the organic trenched plots at almost every soil depth than for any other treatment. An interesting comparison can be made of the organic trench to the trenching without organic matter treatment in regard to water infiltration at the 3-4 foot level. In the fall of 1959 and the following spring before corn planting, there was little difference in inches of available water between the two treatments at this depth. At corn picking time, the effectiveness of the organic wedge on moisture infiltration was reflected by the greater amount of available moisture for this treatment at the 3-4 foot depth.

Subsoiling was not particularly effective in increasing soil moisture reserves according to these data.

The effectiveness of the sweet clover catch crop residues in increasing soil moisture in a wet year is shown in Figure XIII. In the fall of 1959 and spring of 1960 the soil moisture under corn preceded by sweet clover was rather small in amount compared to the other treatments. Evidently, the preceding sweet clover used a considerable amount of the available moisture to make its growth. However, late in the year with above average rainfall, the reserves of soil moisture under corn preceded by sweet clover had been built up to an amount comparable to that from organic trenching to a depth of 3 feet but not below the 3-foot depth.

In the plots where 20 pounds of nitrogen were applied annually, there was less moisture in the fall of 1959, in the spring of 1960, and at corn picking time in 1960.

Figure XIV shows the amount of moisture under corn in the fall of 1960 for the organic trenched plot and the check plot. This figure emphasizes the amount of moisture at the different sampling locations with respect to the plant row and organic trench at the different depths sampled.

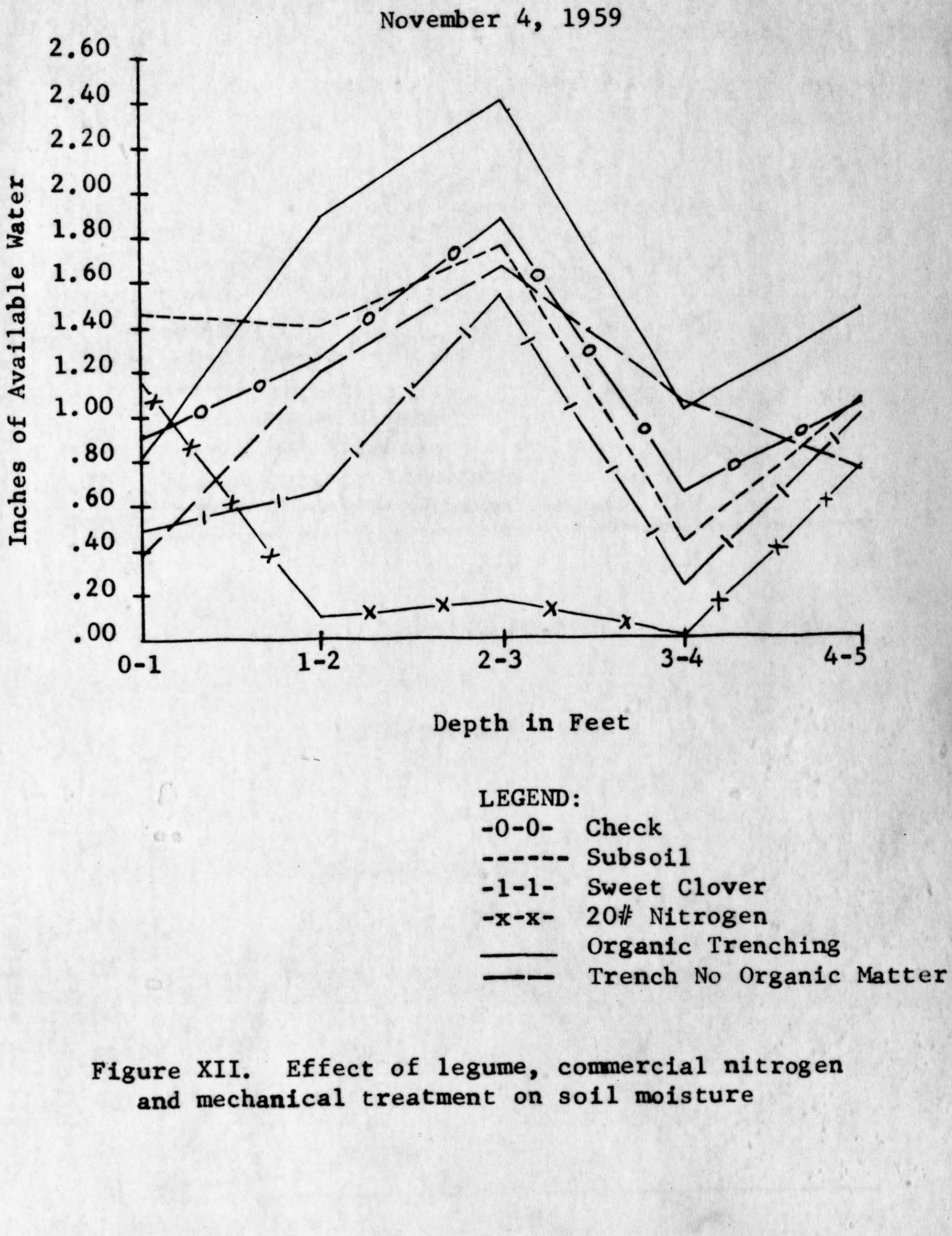
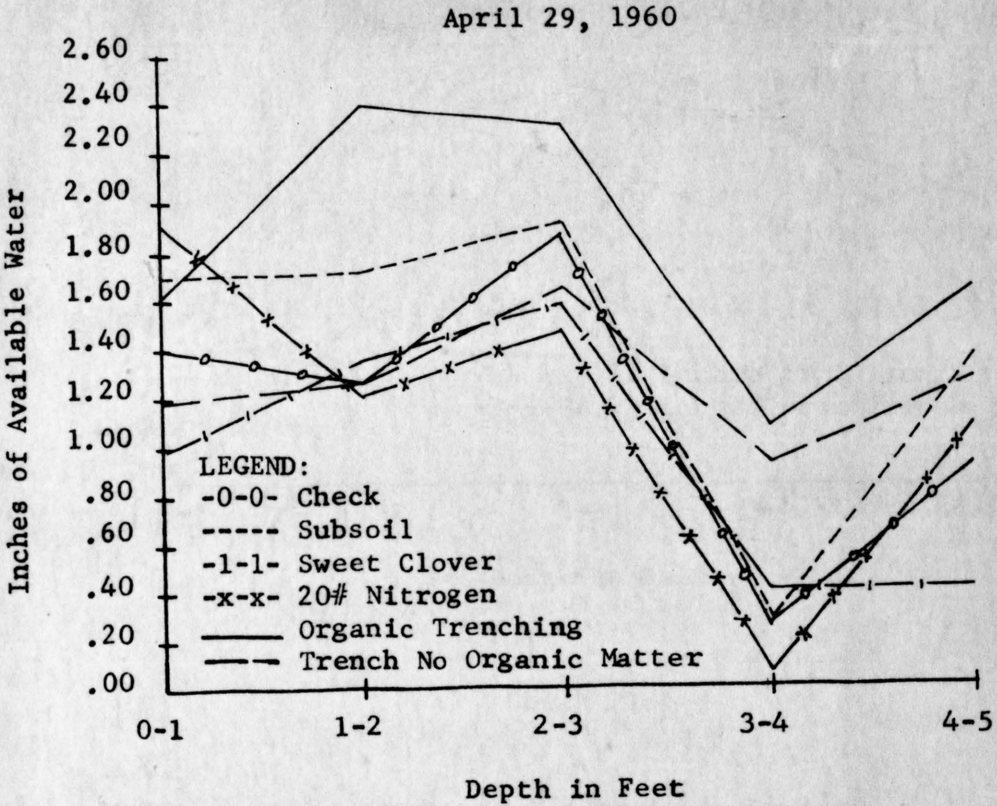


Figure XII. Effect of legume, commercial nitrogen and mechanical treatment on soil moisture



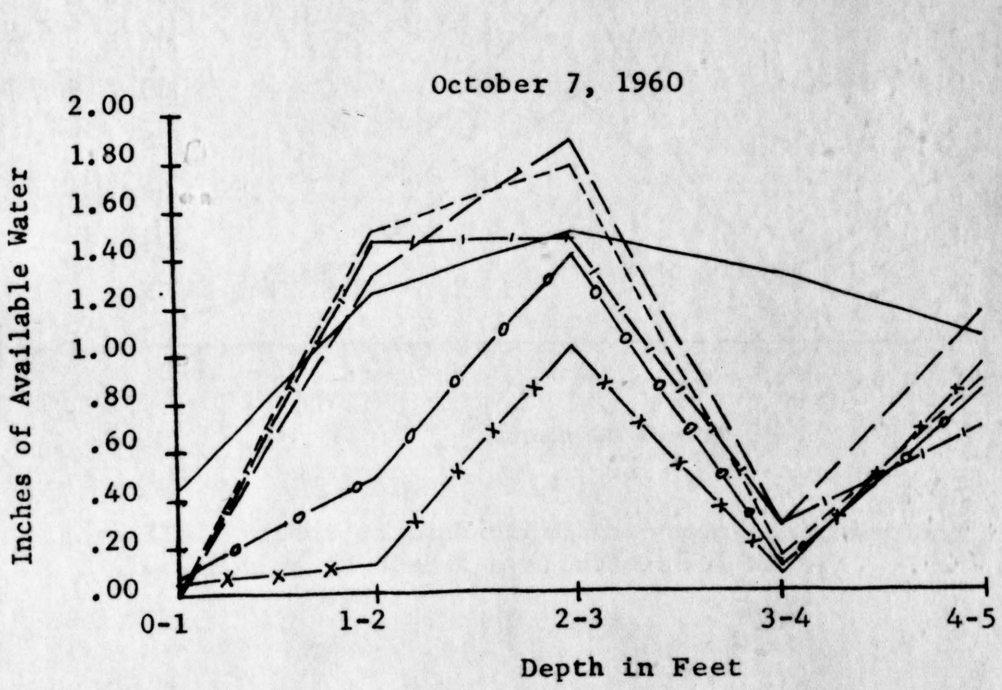


Figure XIII. Effect of legume, commercial nitrogen and mechanical treatment on soil moisture

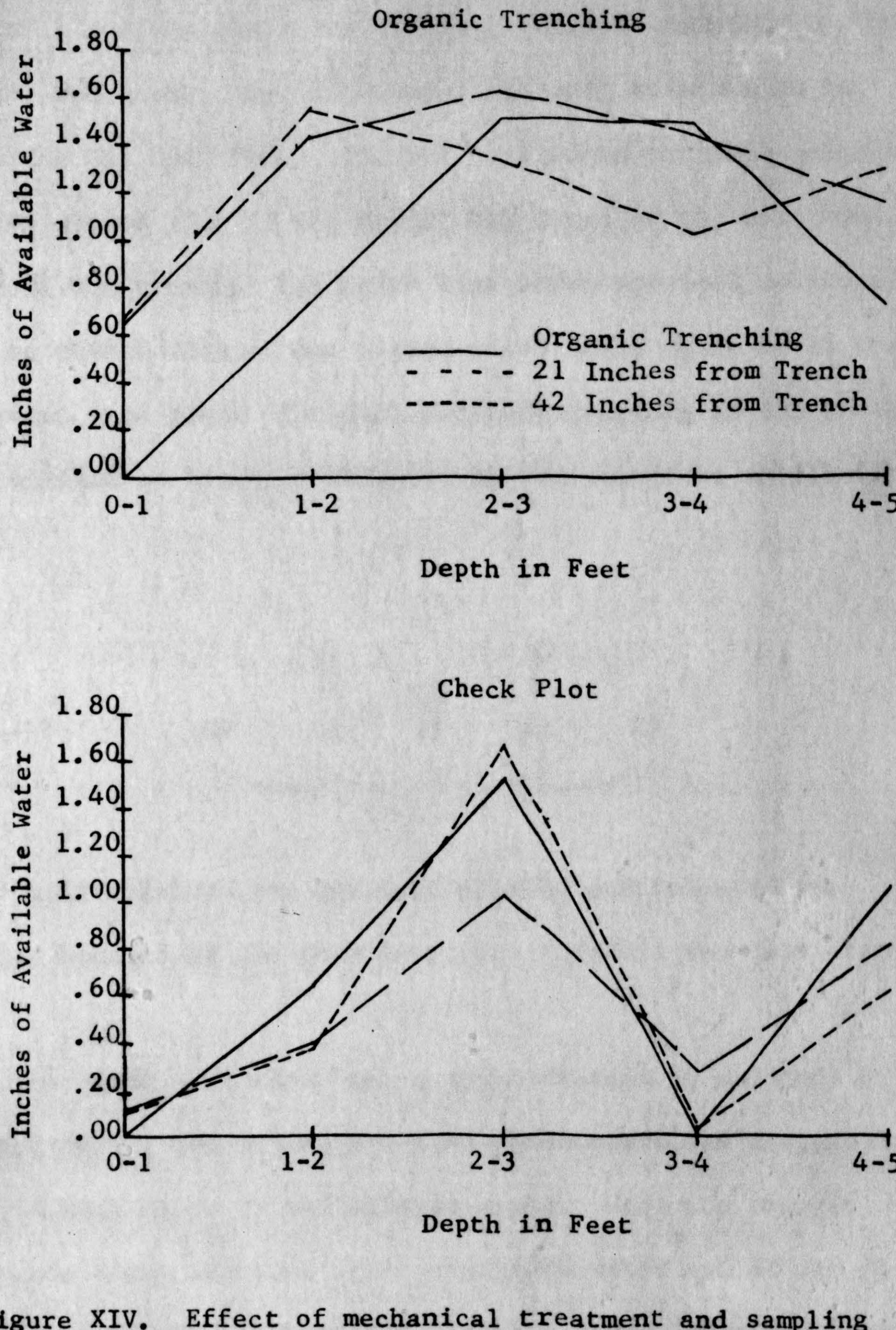
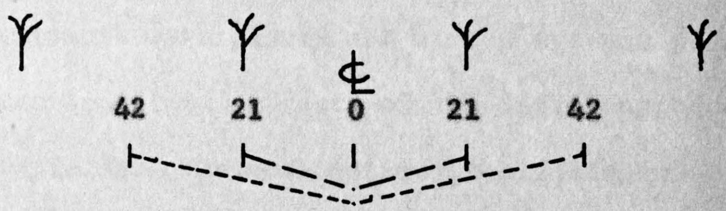


Figure XIV. Effect of mechanical treatment and sampling location on inches of available soil water

Three lines are shown representing the soil moisture in the organic trenched plots. One line shows the soil moisture at the trench between two corn rows. Another line shows the soil moisture 21 inches on either side of the trench which was in the corn rows on both sides of the trench. The third line shows the soil moisture 42 inches on either side of the trench which would again be in the center between corn rows. The soil moisture sampling in the check plots was similar in location relative to the corn rows as illustrated.



The soil moisture for the fall of 1960 was selected for presentation because of the more favorable rainfall for this crop year.

In the check plot there was a concentration of moisture at the 2-3 foot depth, but at the 3-4 foot depth there was a severe deficiency - very close to the wilting point. With the organic trenched plots there was more total available water and it was distributed more uniformly through the profile. This indicates that the organic trenching allowed a more normal infiltration of moisture, unimpeded by the impervious layer.

Experiment 3

Evaluation of Different Combinations of Organic Trenching, Legumes and Subsoiling

The effect of different combinations of organic trenching, legumes and other mechanical methods of improving yields on claypan soils are shown in Table 5.

In 1958 there were essentially no differences in wheat yield due to the different treatments. This was the first crop yield after the mechanical treatments in the fall of 1957.

In 1959 no yields were taken because of hail damage. In the fall all six treatments were plowed and winter rye was planted.

In 1960 the beneficial effects of the different treatments are indicated by rye yields. The combination of alfalfa and organic trenching gave a very favorable yield increase in rye which was statistically significant over the check yields. However, this was not significantly greater than that from alfalfa without trenching. By comparing the yield of treatment 3 to treatment 1 it becomes apparent that when alfalfa is grown, the additional effects of subsoiling on yield were reduced. In this experiment, subsoiling every year without the alfalfa resulted in rye yields about the same as that of the check plot. In treatment 6 the same amount of organic matter, as was placed in the trench, was spread on the surface and plowed under. The object was to determine if the placement of the organic matter had an influence on the yield. The rye yield from this treatment was about the same as the check plot. Perhaps if commercial nitrogen or legume residues had been added, as in treatment 2, the yields would have been comparable.

Table 5. Effect of Different Combinations of Trenching, Legumes and Subsoiling on Yield of Wheat and Rye

Treatment	Yield of wheat and rye in bu/acre		
	Wheat 1958	1959*	Rye 1960
1. Wheat + alfalfa	17.3	Alf.	37.2
2. Organic trench + wheat + alfalfa	15.8	Alf.	41.1
3. Subsoiling + wheat + alfalfa	17.1	Alf.	36.1
4. Wheat (check plot)	17.3	Wheat	28.5
5. Subsoil every year + wheat	16.9	Wheat + subsoil	26.0
6. Organic matter on surface with no trenching or subsoiling	15.6	Wheat	29.8

*Wheat was not harvested in 1959 because of hail damage.

A Duncan's multiple range test was calculated to compare treatment means.

1960

5	4	6	3	1	2
			———	———	———
		———	———	———	
———	———	———	———		

Any two means not underscored by the same line are significantly different.
Any two means underscored by the same line are not significantly different.

Experiment 4

Investigation of the Possibilities of Combining Deeply Placed Fertilizer with Organic Trenching and Subsoiling

The effect on corn and rye yields from this experiment are shown in Table 6.

Although not statistically significant at the 5 per cent level, there appeared to be an increase in corn yield in 1958 for all fertilized plots over the check plot. The combination of 80 pounds of nitrogen + 80 pounds of P_2O_5 placed deeply and organic trenching showed the greatest yield response.

In 1959 the wheat was hailed on and no yields were taken.

The winter rye in 1960 measured the residual effect of commercial fertilizer and mechanical treatments performed in 1957. In general, the differences due to most treatments were small. However, the deep placed 80-80-0 treatment plus organic trenching appeared to yield a little better than the other treatments. This difference approached significance at the 5 per cent level. This difference could be attributed primarily to the organic trenching rather than to the deep placed fertilizer because treatment 2 had the same fertilizer applied in the same place, but no organic trenching, and the yield of treatment 2 was about the same as the check treatment.

Table 6. Investigate Possibilities of Deeply Placed Fertilizer with Organic Trenching and Subsoiling on Yields of Corn and Rye

Treatment	Yield in bushels per acre* Corn 1958	Rye 1960
1. Deep placed 80-80-0 + organic trench	54.8	32.8
2. Deep placed 80-80-0 + subsoiling	38.1	27.8
3. Surface placed 80-80-0 + subsoiling	30.6	27.2
4. Check	20.3	27.9
5. Surface placed 80-80-0	41.1	28.1
6. Surface placed 40-40-0 + deep placed 40-40-0	25.0	26.4

The corn yields for 1958 and the rye yields for 1960 are not significantly different at the 5 per cent confidence level.
*Wheat was not harvested in 1959 because of hail damage.

SUMMARY AND CONCLUSIONS

The impervious nature of claypan soils respecting water infiltration, air exchange and root penetration has long been recognized by farmers and research workers.

This investigation summarizes an approach to this problem. The method involves fracturing the claypan, with an improvised tool, and placing a wedge of organic matter in the newly created opening. The purpose of the wedge is to prevent closure of the fracture by soil settling and soil filling.

This method was compared to other mechanical and cultural treatments for improving the yields on claypan soils. In addition, several combinations of this and older methods were evaluated.

The method of putting a wedge of organic matter through the claypan had a beneficial effect on yields depending upon the season and the test crop grown.

The organic trenching treatment had a marked beneficial effect on water infiltration and root penetration on these claypan soils.

Some of the older and better established methods were also successful for improving grain yields. The combination of older methods and organic trenching were satisfactory and resulted in improved grain yields.

The durability of the different materials placed in the trench are listed with the most resistant to decomposition first: flax straw, corn cobs, sweet clover and wheat stubble.

At the end of three years, all the materials used had settled 2 inches below the soil surface and the lateral width of the trench had narrowed by the same amount.

The different materials placed in the trench had a profound effect on the yield of corn.

With one exception, there was an increase in mass of roots per acre in the organic trenched plots compared to the check plots at every depth sampled and at every interval from the plant.

Where the organic wedge was composed of small grain straw, the organic trench treatment had variable success measured by yields of corn and rye. The variability was due to different climatic conditions and test crops used.

When moisture was abundant, sweet clover had a pronounced beneficial effect on the yield of subsequent crops.

The use of the trenching tool without placing a wedge of organic matter in the soil had little or no beneficial residual effect on yields.

Subsoiling every year appeared to have a slight beneficial effect on grain yields, but these apparent differences were not significant in any case at the 5 per cent confidence level.

In the fall of 1959 and in the spring of 1960 before corn planting, there was more moisture in the organic trenched plots than for any other treatment at almost every soil depth.

Residual effect from the combination of alfalfa and organic trenching gave very favorable increases in rye which were statistically significant over the check yield (at the 5 per cent level).

When alfalfa was grown in the rotation, the effects of subsoiling on yields were minimized.

The combination of organic trenching and deep placed fertilizer appeared to have beneficial effects on the yields of corn and rye.

The placement of the organic material in a wedge that penetrated through the claypan was more beneficial than broadcasting the same amount of organic matter on the surface.

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