1965

# Organic Trenching in South Dakota Claypin Soils: Effects on Grain Yields, Soil Moisture, Root Penetration

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Technical Bulletin 26
November 1965

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## Root Penetration



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## ACKNOWLEDGEMENTS

The authors wish to express appreciation to the following: Ray Pederson of Redfield, South Dakota for use of his land for experimental purposes; Spink County Agricultural Extension Staff members for their encouragement and help in conducting this study; machinery dealers in Redfield for use of their machinery; members of the Agronomy and Agricultural Engineering Staff for their help and guidance.

# ORGANIC TRENCHING

## in South Dakota Claypan Soils[1]

## Effects on--

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## Root Penetration

**QUENTIN S. KINGSLEY and**
**F. E. SHUBECK**[2]

Solodized solonetz soils are sometimes referred to as claypan soils. These soils occupy large acreages in central and western South Dakota. Approximately a third of all the soils in Spink County have a claypan in the profile (28).

Water infiltration, air exchange and root penetration are decreased by the dense, nearly impervious *B2* horizon in claypan soils.

Penetration of water is extremely slow through the *B* horizons of these soils. Fireman and Reeves (9) 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 34 inches per year so the soil would have to be flooded for about 5 months during the summer before enough water could be absorbed to produce a good crop.

According to Page (21) air exchange in soils of the North Central States is frequently limited by soil compaction, and because of this, yields are reduced. Larson (18) has suggested bulk density limits of 1.0 to 1.4 for optimum oxygen availability and root penetration.

Chemical, cultural and mechani-

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[1]This investigation was performed in partial fulfillment of the requirements for the Master of Science Degree by Q. S. Kingsley. A copy of the original thesis is on file at the Lincoln Memorial Library, South Dakota State University, Brookings.

[2]Assistant Professor of Agronomy and Associate Professor of Agronomy, respectively, South Dakota Agricultural Experiment Station.

cal methods have been tried by research workers to overcome the limitation imposed by the claypan in soils.

Chemical methods have centered around the use of calcium compounds to replace sodium which is associated with formation of claypans found in South Dakota. Under dryland conditions in Spink County, applications of gypsum had no apparent effect on yield of wheat 2 years after application.[3] Under irrigation, however, applications of gypsum improved yields and water intake rates in alkali soils in Oregon (3) and Nevada (11).

Cultural methods investigated involved deep rooted legumes in a crop rotation and applications of commercial fertilizer to stimulate activity of roots and their penetration through the claypan. At the Newell Dryland Field Station, Osenbrug (20) concluded that deep rooted legumes such as alfalfa had a definite place on any farm producing livestock but they did not have a place in short rotations under the low rainfall conditions of that area. In general, green manure crops fell far short of paying for their use. At the Claypan Research Farm in Aurora County, South Dakota, Hovland (12) and Brage (4) found that continuous grain cropping was more profitable than short rotations with legumes. Responses to commercial fertilizer were varied and depended on the crop and season (13).

Mechanical methods investigated have depended upon a subsoiling chisel to shatter the claypan layer. These attempts have met with varying degrees of success. Smith (24) in Missouri showed that subsoiling was successful in reducing the volume and rate of runoff. The majority of results were not as encouraging (1, 4, 7, 12, 14, 15, 17, 23). In some instances, the subsoiling treatment was successful but the beneficial effect was temporary. When the soil became wet the plastic material resumed its impervious condition, thus minimizing effects of the mechanical treatments (12, 4).

A different approach to the problem was visualized by Jones (16) in 1939. He contemplated a system of deep tillage which would place humus in the lower soil stratum and thus prolong the beneficial effects of subsoiling.

In 1955, Spain and McCune (25, 26) devised a system of blowing organic matter into the soil in the form of a wedge extending from the soil surface to a depth of 18 to 20 inches. Their observations indicated this practice was more effective than subsoiling in increasing moisture infiltration.

Swartzendruber (27) and Curley (5) investigated water movement in mulched channels and Frazier (10) developed a technique to automatically record its movement in vertically mulched soil.

Vertical mulching may have a prolonged effect on the physical properties of soils that influence wa-

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[3]Shubeck, F. E., 1953. South Dakota State University, Unpublished data.

ter penetration. Spain (26) found soil near vertically mulched channels literally honeycombed with earthworms to a depth of 20 inches. Earthworm activity develops a favorable structure which increases infiltration. Parr (22) noted favorable changes in bulk density and aggregation resulting from vertical mulching which would also increase infiltration.

The purpose of this investigation was to determine the practicability of placing an organic wedge in a solodized-solonetz soil and to compare the effect of it to other mechanical and cultural practices currently used for improving grain yield, root growth, and moisture infiltration.

## EXPERIMENTAL METHODS AND PROCEDURES

### ESTABLISHING ORGANIC TRENCHES

Organic trenching is 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.

In this experiment organic trenching was performed by a subsoiling chisel with a pair of iron wings bolted to the sides to hold the fractured soil open until organic matter had been placed in the soil (figure 1). The space between wings at the top was 8 inches and the spread at the bottom was 4 inches. A four- to five-plow tractor was

**Figure 1. Organic trenching tool.**

necessary to pull the trenching machine through the soil.

Both trenching and subsoiling were performed at 84-inch intervals, allowing two 42-inch spaced corn rows between each pair of fractures with each row located 21 inches from an organic trench or subsoiling fracture. Plots were 75 feet in length and wide enough to accommodate five trenches. Depth of trenches was 18 to 20 inches. Straw was baled and slices of it were placed in the soil by hand at the rate of 7.8 tons per acre. Corn cobs were applied by hand at the rate of 1½ bushels per linear foot of trench. The cobs, as shown in figure 2 protruded above the soil surface by 6 to 8 inches and gradually receded over the 3-year span of the experiment.

## FIELD EXPERIMENTS

This investigation was conducted in Spink County in east central South Dakota. Approximately 15 acres were used in four separate field experiments for the years 1958 through 1960. No crop yields were obtained in 1959 because of severe hail damage. The four experiments were: (1) comparison of different organic materials in the trench, (2) comparison of organic trenching to other individual mechanical and cultural methods for improving yields, (3) evaluation of different combinations of organic trenching, legumes and subsoiling, and (4) evaluation of organic trenching combined with deep fertilizer placement.

In experiment No. 1, the materials compared were: corn cobs, flax straw, wheat straw and sweet clover. The cropping sequence was corn in 1958, wheat in 1959, and corn in 1960. Organic trenching was done once in the fall of 1957. The seedbed between trenches was pre-

**Figure 2. Appearance of trenches after being filled with corn cobs.**

pared with a rear-mounted field cultivator with spike tooth shovels. Direction of travel was parallel to trenches in an attempt to keep the organic wedge open and exposed at the soil surface.

In experiment No. 2, corn and wheat were the test crops in 1958 with rye and corn used as test crops in 1960. In the nitrogen treatment, ammonium nitrate was disked-in for wheat and rye but plowed-under for corn. Direction of travel while plowing was at right angles to trenches. Subsoiling was done every year in the fall in plots receiving this treatment. Organic trenching was done once, in the fall of 1957.

In experiment No. 3, the organic trenching and subsoiling performed in conjunction with legumes was done once, in the fall of 1957. Subsoiling in the small grain sequence was done once every fall. Wheat and rye were the only grain crops used. In legume plots, alfalfa was planted with wheat in 1958 and remained through the 1959 growing season and fall plowed at right angles to the trenches. Wheat straw was used as the organic mulching material.

In experiment No. 4, the cropping sequence was corn in 1958, wheat in 1959 and rye in 1960. Fertilizer was applied deeply by using a modified subsoiler. Plowing direction was right angles to the trenches.

## SOILS OF EXPERIMENTAL PLOTS

Soils in the experimental area were developed from sediments deposited in Glacial Lake Dakota. The lake probably originated because of an end moraine formed by the Mankato ice sheet which prevented natural drainage to the south. Stream action finally cut through the end moraine and drained the lake. The lake bed surface is remarkably level, with a slope of only a few inches per mile in some areas.

Soils of the experimental area consist of a complex of Aberdeen silty clay loam, Tetonka silt loam and Exline silty clay loam. It is called a complex because the soil types occur together in such an irregular pattern and so closely spaced in such small individual units that they cannot be shown separately on maps of the scale normally used. Differences in productivity of these soils cause the "checker-board" appearance of the growing crops.

Physical and chemical data characterizing these soils (tables 1, 2 and 3) were taken from the Descriptive Legend of the Spink County Soil Survey, 1951 (unpublished data).[4] Soil samples for the analysis listed in the legend were taken from type locations in the area. These represent modal profiles of the respective soil types. Soils on the experimental plots were not analyzed but they had the same morphology as the modal profiles and therefore are assumed to have similar physical and chemical characteristics. A brief description of the soils in this complex follows.

### Aberdeen Silty Clay Loam

This is an imperfectly drained claypan soil which usually occurs in

[4]Copies available in Agronomy Office, South Dakota State University, Brookings, South Dakota.

**Table 1. Salinity, pH, Ionic Exchange, Bulk Density, Organic Carbon and Total Nitrogen in Aberdeen Silty Clay Loam.**

| Horizon and Depth (inches) | Salts Bureau cup % | Conductivity mmhos per cm. | pH paste | Carbonates % | Gypsum me/100 grams | Total Exchange capacity me/100 gm. | Exchangeable Cations me/100 grams Ca | Mg | Na | K | H | Soluble cations me/100 gm. Na | K | Bulk Density | Organic Carbon % | Total N % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 0-8 | tr. | 0.4 | 6.2 | 0.6 | ...... | 30.48 | 14.85 | 9.57 | 0.33 | 1.96 | 7.1 | 0.1 | 0.1 | 1.18 | 3.52 | 0.271 |
| A2 8-12 | tr. | 0.3 | 6.4 | 0.5 | ...... | 25.52 | 8.22 | 13.40 | 1.08 | 1.62 | 3.2 | 0.1 | 0.1 | 1.21 | 1.47 | 0.142 |
| B2 12-22 | tr. | 0.4 | 7.0 | 0.6 | ...... | 31.40 | 7.65 | 23.01 | 2.20 | 1.90 | 2.0 | 0.2 | 0.1 | 1.74 | 1.34 | 0.132 |
| B3 22-30 | tr. | 0.7 | 8.0 | 0.5 | ...... | 30.80 | 6.64 | 24.82 | 3.84 | 2.14 | .... | 0.4 | 0.2 | 1.69 | 0.76 | 0.078 |
| Clca 30-46 | 0.60 | 9.0 | 8.0 | 13.3 | 30.2 | 24.12 | * | * | 1.68 | 1.57 | .... | 4.5 | 0.5 | 1.38 | 0.32 | 0.040 |
| C21 46-60 | 0.53 | 9.8 | 8.0 | 14.3 | ...... | 23.85 | * | * | 4.16 | 1.52 | .... | 4.6 | 0.5 | 1.26 | 0.26 | 0.036 |
| C22 60-80 | 0.47 | 7.0 | 7.9 | 10.4 | ...... | 25.56 | * | * | 3.19 | 1.44 | .... | 3.5 | 0.6 | 1.32 | 0.18 | 0.036 |

* Calcareous horizons cations not determined.
Analyst: J. R. McHenry, USDA, Soil Laboratory, Bureau of Plant Industry, Soil and Agricultural Engineering, Mandan, North Dakota. 1950.
South Dakota Soil number: S-50-SD-58-2-(1-7).
Mandan Soil Laboratory number: MSL 351-357 inclusive.



**Table 2. Conductivity, pH, Ionic Exchange, Bulk Density, Organic Carbon and Total Nitrogen in Tetonka Silt Loam.**

| Horizon and Depth (inches) | Conductivity mmhos per cm. | pH paste | Carbonates % | Total Exchange Capacity me/100 gm. | Exchangeable Cations me/100 gm. Ca | Mg | Na | K | Soluble Cations me/100 gm. Na | K | Bulk Density | Organic Carbon % | Total N % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 0-4 | 0.35 | 5.6 | tr. | 22.5 | 11.2 | 3.6 | 0.0 | 1.3 | 0 | tr. | 1.23 | 3.75 | 0.297 |
| A2 4-8 | 0.30 | 5.6 | tr. | 12.3 | 8.2 | 4.7 | 0.0 | 1.0 | 0 | tr. | 1.47 | 0.85 | 0.100 |
| B21 8-14 | 0.25 | 5.8 | tr. | 21.0 | 11.4 | 7.2 | 0.0 | 1.2 | 0 | tr. | 1.74 | 0.53 | 0.068 |
| B22 14-43 | 0.40 | 7.0 | tr. | 21.6 | 14.2 | 8.0 | 0.2 | 0.8 | 0 | tr. | 1.94 | 0.38 | 0.052 |
| Cca 25-43 | 0.40 | 8.0 | 19.0 | 17.7 | * | * | 0.4 | 0.4 | 0 | tr. | 1.70 | 0.40 | 0.049 |
| C 43-60 | 1.35 | 8.1 | 13.5 | 16.0 | * | * | 1.6 | 0.3 | 0.4 | 0 | ...... | 0.19 | 0.029 |

* Calcareous horizons cations not determined.
Analyst: J. R. McHenry, USDA, Soil Laboratory, Bureau of Plant Industry, Soil and Agricultural Engineering, Mandan, North Dakota, 1951.
South Dakota Sample number: S-51-SD-58-4.
Mandan Soil Laboratory number: 790-795 inclusive.

Table 3. Conductivity, pH, Ionic Exchange, Organic Carbon in Exline Silt Loam.

| Horizon and Depth (inches) | | Salts Bureau cup % | Conductivity mmhos per cm. | Carbonate % | Total Exchange Capacity me/100 gm. | Exchangeable Cations me/100 grams* Na | Exchangeable Cations me/100 grams* K | Soluble Cations me/100 gm. Na | Soluble Cations me/100 gm. K | Organic Carbon % |
|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-2 | ...... | 0.6 | .... | 29.9 | 0.1 | 2.2 | 0.1 | 0.1 | 5.88 |
| A2 | 2-4 | ..... | 0.8 | .... | 21.5 | 0.5 | 1.4 | 0.2 | 0.1 | 3.19 |
| B2 | 4-17 | ...... | 1.8 | .... | 33.2 | 1.9 | 1.6 | 0.8 | tr. | 1.04 |
| B3 | 17-20 | 0.24 | 4.0 | 5 | 30.5 | 3.1 | 1.2 | 1.7 | tr. | 0.61 |
| Cca | 20-36 | 0.21 | 4.5 | 18 | 25.3 | 2.4 | 0.7 | 1.7 | tr. | 0.56 |
| C | 36-65 | 0.23 | 6.5 | 13 | 13.5 | 1.7 | 0.3 | 1.6 | tr. | 0.19 |

* $Ca^{++}$ and $Mg^{++}$ were not determined.
Analyst: J. R. McHenry, USDA, Soil Laboratory, Bureau of Plant Industry, Soil and Agricultural Engineering, Mandan, North Dakota, 1949.
South Dakota Soil number: S-49-SD-58-5-(1-6).
Mandan Soil Laboratory number: MSL 1302-1307.

level positions and in large areas away from streams. The claypan may be encountered at a depth of 12 to 28 inches. Parent material is lacustrine silts and clays which are slowly permeable. Salts and alkali are usually present below the subsoil. It is classified as a solodized solonetz and is the most prevalent soil at the experimental site. Laboratory data for this soil are shown in table 1.

### Tetonka Silt Loam

Tetonka silt loam is an imperfectly drained soil occurring in shallow depressions. Parent material is local deposition from higher lying adjacent soils. The upper part of the soil is friable, but at depths of 18 to 24 inches a claypan is present. The soil is slowly permeable but not saline. It is classified as a solod. Laboratory data for the Tetonka are given in table 2.

### Exline Silty Clay Loam

This is an imperfectly drained claypan soil with the claypan frequently occurring at plow depth. It developed in level, low-lying positions from clayey alluvium parent material. It is classified as a solodized solonetz. This soil occurs in a few scattered spots at the experimental site. As a rule, these soils are not cultivated unless they occur as small areas intimately associated with other more desirable soils. Chemical data for Exline silty clay loam are given in table 3.

## EXPERIMENTAL PLOT DESIGN

A randomized block design was used with four replications of each treatment except one experiment which had three replications. Plot size was 36x75 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 (6) was used to determine treatment differences at the 5% probability level.

## HARVESTING, PLANTING METHODS

Corn was planted with a conventional corn planter at the rate of 8,000 plants per acre. Two rows 70 feet long were harvested for yield. Wheat was planted with an International press drill at 1¼ bushels per acre. Rye was planted with the same machine but at 1 bushel per acre. For small grain yield determinations a sample 6 feet wide and 70 feet long was harvested with a combine. A legume attachment to the drill was used for planting alfalfa and sweet clover. No seed or forage samples were taken of the legumes.

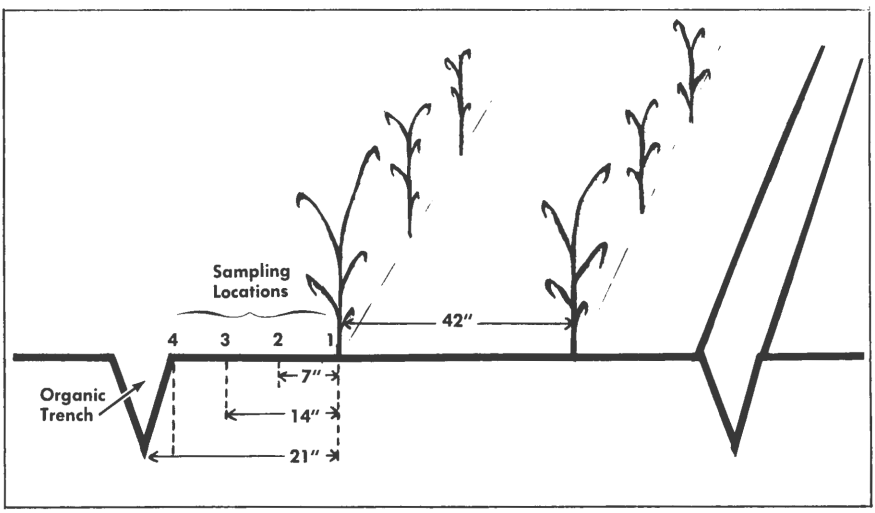
## ROOT SAMPLING PROCEDURE

Root samples were taken from two treatments in the first experiment: (1) organic trenching with corn cobs, and, (2) check plots.

There were four sample locations chosen for root sampling from each of the two above treatments as shown in figure 3. The sampling site extended in a line at right angles to corn rows. In organic trenched plots the first sample was taken in the corn row which was 21 inches from the trench. The second sample was taken 7 inches from the row which was 14 inches from the trench. The third sample was 14 inches from the row and 7 inches from the trench. The fourth was 20 inches from the row and 1 inch from the trench. In check plots that had no wedge of organic matter, root samples were taken in the same corresponding positions relative to corn rows.

Diameter of soil cores was 1⅝ inches. Cores were 3½ feet long and were cut into 1-foot lengths preparatory to washing out roots. This method with a few modifications, was described by Fehrenbacker *et al.* (8).

**Figure 3. Location of root sampling positions relative to organic trench and corn row.**



To separate roots from soil, cores were placed in containers (figure 4) full of water and allowed to soak until soil was wet through. 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, spilled out of the can and passed through a fine mesh screen basket. When roots were washed free of soil particles and the water ran clean, roots were floated out the overflow and caught on the screen. Larger root masses were removed from the screen but smaller roots and foreign material left on

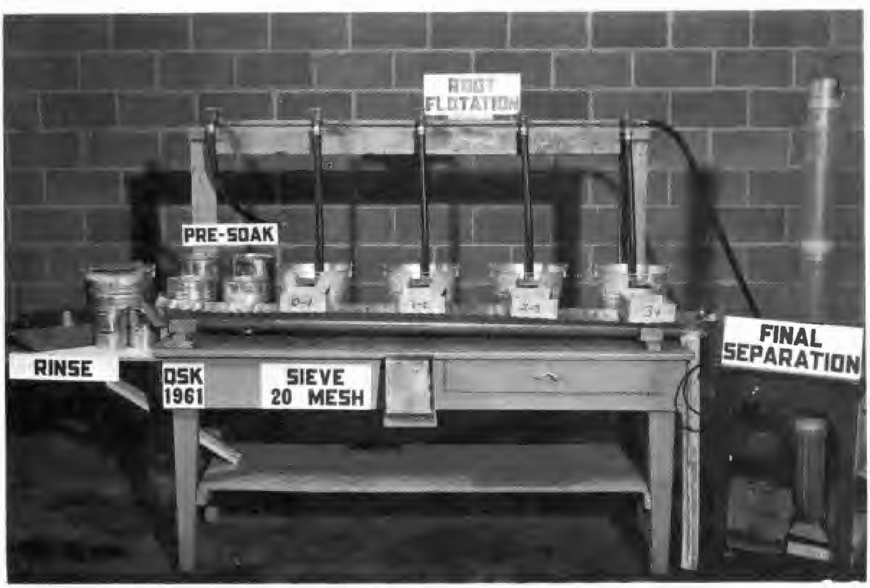



**Figure 4. Apparatus used for separation of corn roots from soil.**

the screen were removed and placed in an air operated grain separator. This machine separated heavy material from lighter roots which were caught on the screen. Root samples were then oven dried, weighed, and reported in pounds per acre. This method of root separation from soil was based on the procedure described by McKell (19).

## SOIL MOISTURE SAMPLING

To measure soil moisture in organic trenched plots, samples were taken in five positions extending in a line running at right angles to the trench and on both sides of the trench. Locations of the five samples with respect to trench and corn rows were: at the trench, one pair 21 inches on each side of the trench (in corn rows), and one pair 42 inches on each side of trench (between corn rows). Samples in non-trenched plots were similarly located with respect to corn rows. Values for all five sampling locations were averaged for each 1-foot depth, so a true picture of available moisture for the entire area was obtained and not for a few square feet close to the organic trenches. All soil moisture samples were taken with a mounted post-hole digger.

## WEATHER DATA

Rainfall data were taken from three United States Weather Bureau Stations which if joined by a line on a map would form a triangle around the site on which the experiments were conducted. The stations used were Redfield, Ashton and the Irrigation Research Farm situated 6 miles east of Redfield. Rainfall data were averaged for these three locations and therefore presented an approximation of moisture conditions at the site.

**Table 4. Average Monthly Rainfall in Inches for the Three Closest Reporting Stations in 1957 through 1960.**

| Month | 1957 | 1958 | 1959 | 1960 |
|---|---|---|---|---|
| January | 0.14 | Trace | 0.28 | 0.53 |
| February | 0.48 | 1.95 | 0.53 | 0.53 |
| March | 0.25 | 0.42 | 0.06 | 0.62 |
| April | 3.92 | 2.10 | 0.20 | 2.33 |
| May | 5.01 | 2.26 | 3.07 | 2.08 |
| June | 4.26 | 2.45 | 2.32 | 4.94 |
| July | 2.54 | 1.95 | 1.60 | 2.37 |
| August | 3.07 | 1.04 | 1.11 | 3.70 |
| September | 1.79 | 0.37 | 2.81 | 1.44 |
| October | 3.06 | 0.21 | 1.88 | 0.58 |
| November | 0.99 | 0.96 | 0.36 | 0.61 |
| December | 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 |

*Normal for the City of Redfield, South Dakota.

The years 1957 and 1960 had above-average rainfall and 1958 and 1959 were years with below-average rainfall. Late summer and fall of 1957 were unusually wet. This made organic trenching difficult to perform because of reduced traction for wheel-type tractors.

## RESULTS AND DISCUSSION

Results of this investigation are reported as individual experiments for the years 1958 and 1960. The 1959 data were lost due to hail damage which ruined most of the crop and made accurate sampling impossible.

It should be noted that subsoiling was performed every year and that organic trenching was performed once, in the fall of 1957.

## EXPERIMENT NO. 1

### Comparisons of the different organic materials placed in the trench and effect of organic wedge on root penetration.

The objectives of this experiment were: (1) to compare durability of several organic materials placed in the trench, and (2) to measure effect of organic trenching on root proliferation and yield of grain.

This was the only experiment in which the land was not plowed after organic trenching was completed. A field cultivator was used for seedbed preparation. Direction of tillage was parallel to the trenches so that the filled trenches would remain open and undisturbed at the surface.

### DURABILITY OF ORGANIC MATTER

Four different materials were placed in the trenches in the fall of 1957 and rated for their durability in 1960, the last year of the experiment. These materials were ranked in order of increasing durability: 1. wheat stubble, 2. sweet clover, 3. corn cobs, 4. flax straw.

Measurements used to determine the degree of decomposition were: (1) resistance to separation of organic matter when pulled apart manually, and, (2) visual ratings of color and degree of physical breakdown of original stalks or stems.

Differences in rate of decomposition of sweet clover, corn cobs and flax straw were small. When the sweet clover was cut, stems were large and 3 to 4 feet tall but leaves were still green. The higher nitrogen content in sweet clover leaves may have been responsible for its slightly faster rate of decomposition compared to corn cobs and flax straw. Rate of decomposition of all materials increased with depth in the trench. Figure 5 shows the appearance of corn cobs after being buried for 3 years.

### COMPACTION OF ORGANIC MATTER

Corn cobs did not pack very closely the first two years. This permitted excessive aeration and loss of moisture at the trench wall. This was especially noticeable at shallow depths. By 1960, the corn cobs had settled sufficiently to prevent excessive air movement. Loss of moisture at the trench wall was then about

**Figure 5. A mass of corn cobs removed from the trench after being buried for 3 years.**

the same as that in the untrenched check plot for the first 3 feet of soil depth (compare figures 11 and 12).

Measurements were made of all four materials in 1960 to note amount of compaction. All materials had settled approximately 2 inches below the soil surface and the trench had narrowed by the same amount.

## YIELD DIFFERENCES

In 1958, sweet clover forage placed in the trenches appeared to be more successful in increasing corn yields than the other types of organic matter (table 5). This could be attributed to the higher nitrogen content in the legume material. Other residues with wider C:N ratios were not as beneficial.

Corn yields in plots receiving corn cobs, flax straw and wheat straw were much higher in 1960 than in 1958. Where sweet clover was placed in the trench, corn yields were highest the first year of the experiment. Leguminous residue with its narrow C:N ratio gave a quick boost to corn yield but did not have the prolonged beneficial effect of residues with a wider C:N ratio.

**Table 5. Effect of Organic Trench Materials on Yield of Corn**

| Treatment | Yield of Corn in Bu. per 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 straw | 9.1 | 18.4 |

*No grain was harvested in 1959 because of hail damage.

**A Duncan's multiple range test was calculated to compare treatment means. Treatment numbers were taken from table 5 and arranged below in order of increasing yield.**

| 1958 | | | | 1960 | | | |
|---|---|---|---|---|---|---|---|
| 4 | 3 | 2 | 1 | 4 | 3 | 2 | 1 |
| ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ |

(1958: 2 and 1 underscored by one line; 4 and 3 underscored by another line. 1960: 4 underscored alone; 3, 2 and 1 underscored by one line.)

Any two means not underscored by the same line are significantly different at the 5% confidence level.

## EFFECT ON ROOT PENETRATION

Root studies were conducted on organic-trenched plots that received corn cobs and on check plots that received no organic matter or mechanical treatment. The purpose of this study was to see how effective organic trenching was in increasing root growth at different soil depths and distances from the trench.

Effect of treatment on root weight is shown in figure 6.

With only one exception there was an increase in weights of roots-per-acre in organic-trenched plots compared to check plots at every depth sampled, and at every interval from the plant. The exception was at the 0—1 foot level in the corn row. This was also the location farthest away from the organic trench. At the 0—1 foot level, weight of roots per acre increased as sampling locations approached the trench.

The ratio of amount of roots in organic trenched plots to amount of roots in check plots was quite constant at most depths and sampling locations except at 14 inches from the plant and 2—3 foot depth. At this location and depth the amount of roots in organic trenched plots far exceeded that of the check plot. This can be attributed to the rupturing of the claypan which permitted roots to penetrate through and proliferate in the strata below (figure 7).

This trend also was apparent in the next sampling depth, in the 3—3½ foot level, but it was not so pronounced because the majority of corn roots normally are in the upper 3 feet.

The sampling location 20 inches from the plant was farthest from the plant but closest to the trench. Here again root weights at the 2—3 foot level were substantially greater in organic trenched plots.

## EXPERIMENT NO. 2

### Comparison of organic trenching to other individual mechanical and cultural methods of improving yields and conserving moisture.

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

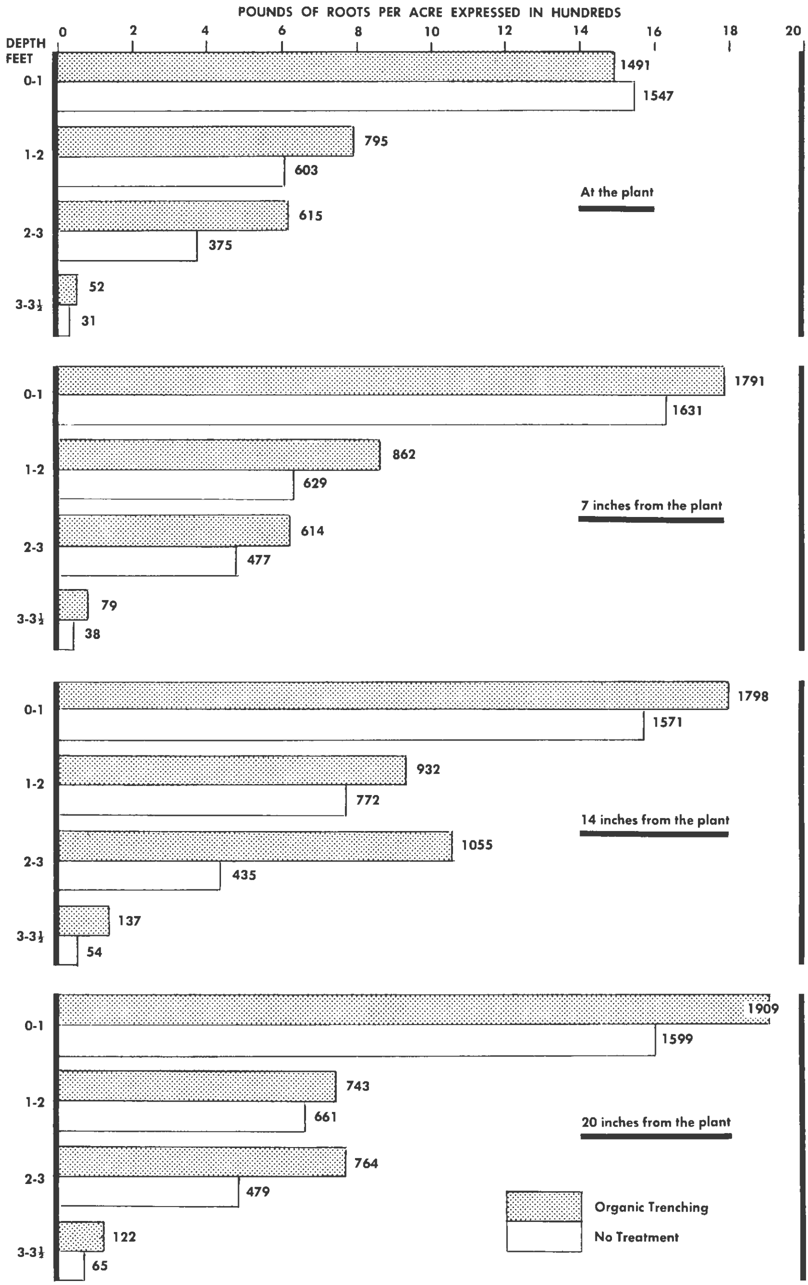



Figure 6. Effect of organic trenching and check plot on corn root distribution.

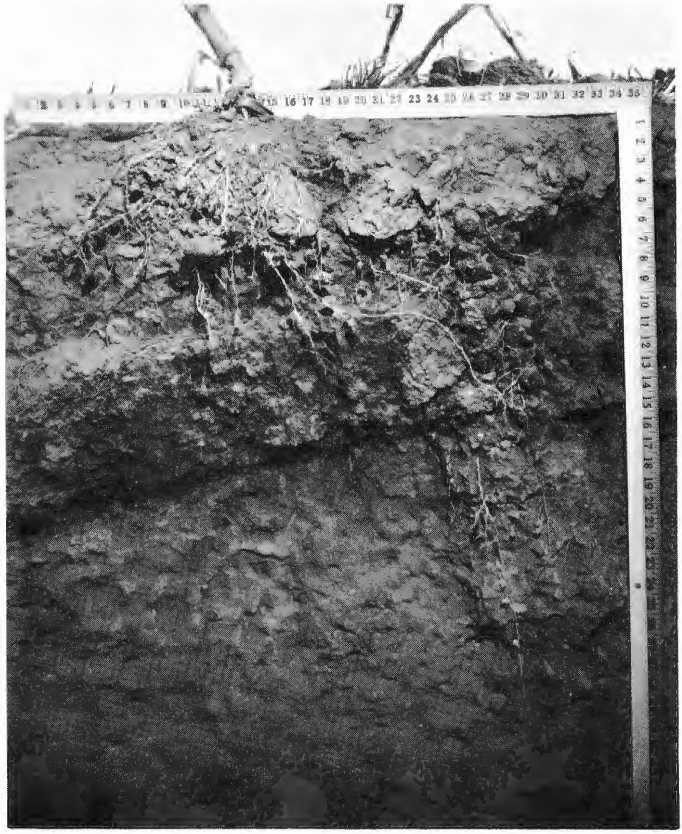


**Figure 7. Corn root growth through claypan in organic trench located in right center of picture.**

was accomplished by investigating two different but related questions: (1) effect on grain yield, and (2) effect on moisture conservation.

## TREATMENTS

In the first treatment (table 6), wheat straw was used for organic matter in organic trenched plots. Organic trenching was done once during the experiment, in the fall of 1957. Distances between trenches and spacings of trenches and corn rows were the same as in experiment No. 1. Corn and wheat were the test crops in 1958 with rye and corn used as test crops in 1960. Corn was planted parallel to the trenches. A plow was used in seedbed preparation for this experiment with furrows at right angles to the trenches. This had a shearing action on the organic wedge with part of the trench covered over by the furrow slice.

In the second treatment the trenching tool was used without adding organic matter. This treat-

**Table 6. Comparison of Organic Trenching With Other Mechanical and Cultural Methods for Improving Grain Yields, 1958.**

| Treatment | Year Performed | Corn Bu/A | Wheat Bu/A |
|---|---|---|---|
| 1. Organic trenching | 1957 only | 20.3 | 8.7 |
| 2. Trenching without organic matter | 1957 only | 13.0 | 12.1 |
| 3. Subsoiling | Every year | 10.0 | 15.7 |
| 4. Sweet clover catch crop | Every year | ---- | ------ |
| 5. Twenty lbs. of nitrogen/acre | Every year | 18.1 | 16.9 |
| 6. Check | --------------- | 16.6 | 11.7 |

ment was included to separate any possible effects of the extra soil disturbance caused by the subsoiler "wings" from the effects of the organic wedge. This was done once, in the fall of 1957.

In the third treatment, a conventional subsoiler was used. Depth of penetration was similar to that of organic trenching. Subsoiling was performed every year in the fall when the ground was dry to cause maximum fracturing of the claypan.

In the fourth treatment, sweet clover was planted with wheat and plowed the same fall for corn. This treatment was included because deep rooted legumes have been moderately successful in previous experiments in overcoming limitations imposed by claypans.

The fifth treatment involved use of commercial fertilizer to stimulate root extension and proliferation in an attempt to minimize effects of the claypan. Previous experiments on similar soils have indicated that broadcast applications of phosphorus have not increased wheat yields.[5] Therefore, nitrogen alone was broadcast on the surface and disked-in for wheat and rye but plowed-under for corn.

A check plot with no deep tillage, no organic matter additions, and no fertilizer applications was included for comparative purposes.

Corn and spring wheat was the planned cropping sequence but winter rye was substituted for wheat after a hail storm in 1959.

## CORN, WHEAT YIELDS, 1958

Grain yields for the six treatments in the first year of this experiment are presented in table 6.

Differences in corn yields due to treatments were not significant at the 5% level.

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**A Duncan's multiple range test was calculated to compare treatment means of wheat. Treatment numbers were taken from table 6 and arranged below in order of increasing yield.**

1 6 2 3 5

Any two means not underscored by the same line are significantly different at the 5% confidence level.

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Organic trenching appeared to have a beneficial effect on corn yield in 1958, the first crop year after the trenching operation (table 6). How-

[5]Shubeck, F. E. Unpublished data. 1951.

ever, this was not statistically significant.

Subsoiling and trenching without an organic wedge were not successful in increasing corn yields. These mechanical operations were performed in the fall of 1957, a year with 6 inches above-average rainfall. As a result, the wet subsoil was not broken up effectively.

There was no sweetclover catch crop preceding the 1958 corn so no corn yields were given for this treatment.

Twenty pounds of nitrogen per acre appeared to increase corn yield slightly.

Yield of wheat in organic trenched plots was low in 1958. At planting time early in the spring, the soil was nearly saturated with water from heavy rainfall in 1957, from spring rains in 1958 and from melting snow. The organic trenches served as efficient moisture collecting devices and as a result, the additional water had a detrimental effect on seedbed preparation and wheat stands. The soil surface became hard and crusted, thus reducing seedling emergence. Later in the season, by corn planting time, this excess moisture had drained through the wedge into the subsoil and appeared to have a beneficial effect on corn yield in 1958.

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

The subsoiling treatment appeared to increase yield of wheat over that of the check plot but the difference was not significant.

No sweet clover catch crop preceded the 1958 wheat so no wheat yield was reported for this treatment.

Nitrogen fertilizer applied for wheat in 1958 proved to be a satisfactory and statistically significant method of increasing wheat yields on these claypan soils.

## CORN, RYE YIELDS, 1960

Winter rye was substituted for wheat after the hail storm in 1959 in order to control weeds and keep a cover on the land the rest of the year. Yields of corn and rye in 1960 are given in table 7.

Differences in corn yields due to treatments approached significance at the 5% level.

**A Duncan's multiple range test was calculated to compare treatment means of winter rye. Treatment numbers were taken from table 7 and arrayed below in order of increasing yield.**

6 2 3 5 4 1

Any two means not underscored by the same line are significantly different at the 5% level.

The third crop year after organic matter was placed in the trenches was 1960. Yield of corn in organic trenched plots in 1960 was about the same as in the check plots (table 7). This is a reversal from promising effects of this treatment on corn in 1958.

Residual effect from trenching without an organic wedge did not increase corn yields in 1960.

**Table 7. Comparison of Effect of Organic Trenching and Other Mechanical and Cultural Practices on Grain Yields, 1960.**

| Treatment | Year performed | Corn Bu/A | Winter rye Bu/A |
|---|---|---|---|
| 1. Organic trenching | 1957 | 14.8 | 19.2 |
| 2. Trenching without organic matter | 1957 | 10.8 | 14.0 |
| 3. Subsoiling | Every year | 20.9 | 14.1 |
| 4. Sweet clover catch crop | Every small grain year | 18.9 | 19.1 |
| 5. Twenty pounds of nitrogen/A | Every year | 22.5 | 16.0 |
| 6. Check | ———— | 15.0 | 12.9 |

Commercial nitrogen, sweet clover catch crop and subsoiling all appeared to increase corn yield compared to the check plot.

Winter rye yield in organic trenched plots was significantly greater than in the check plots in 1960.

A sweetclover catch crop planted with wheat in 1959 was effective in increasing yield of the following rye in 1960. This increase was statistically significant at the 5% level. Success of sweetclover in increasing rye yields could be attributed to the effect of its deep roots and to nitrogen returned to the soil. Twenty pounds of nitrogen applied per acre (estimated to equal that returned by a sweet clover catch crop) also appeared to increase rye yield.

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

## INFLUENCE OF ORGANIC TRENCHING ON SOIL MOISTURE

A comprehensive soil moisture study was completed involving each of the six treatments with corn in this experiment. The purpose was to evaluate organic trenching as a water conserving practice compared to other mechanical and cultural treatments.

To measure soil moisture in organic trenched plots, samples were taken in five positions extending along a line running at right angles to the trench and on both sides of the trench. The values for all five sampling locations were averaged for each sampling depth so a true picture of available moisture for the entire area was obtained and not for a few square feet close to the organic trenches.

To measure soil moisture in plots that were not organic trenched, soil moisture samples were taken in the same relative position in respect to where the trench would normally have been.

### EFFECT ON SOIL MOISTURE, FALL 1959

Figure 8 shows the effect of six treatments on available moisture on November 4, 1959. Organic trenches were 2 years old by this date. There was ½- to 1-inch more available soil moisture in each foot of soil in or-

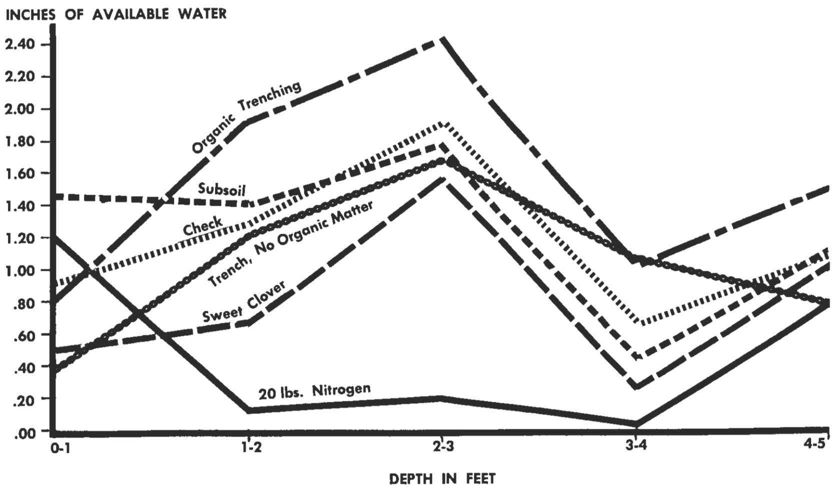



**Figure 8. Effect of legume, commercial nitrogen and mechanical treatment on available soil moisture under corn November 4, 1959.**

ganic-trenched plots compared to the other plots. This would indicate that the organic wedge was an effective way of increasing infiltration and reducing runoff.

In the plot where 20 pounds of nitrogen were applied annually, there appeared to be an unusually small amount of water at the 1-2 and 2-3 foot depths compared to the other treatments. The amount of water above the 1 foot level in this plot was greater than in most of the other plots. There are two possible explanations:

1. The claypan may have been closer to the surface in the fertilized plot than in other plots. This would account for the greater accumulation of moisture close to the surface above the claypan and the smaller amounts at the 1–2 and 2–3 foot depths because the claypan restricted its downward movement.
2. Fertilizer may have encouraged a greater root development of the winter rye which utilized moisture at the 1–2 and 2–3 foot depths. An experiment in Hand County in 1956 by Baxter and Fine (2) supports this explanation. They found that corn used more water from the 4 foot soil profile where 40 pounds of nitrogen were applied than where no nitrogen was used.

There were only minor differences in soil water due to the other treatments.

## EFFECT ON SOIL MOISTURE, SPRING 1960

Figure 9 shows effect of six treatments on available soil water on April 29, 1960. Organic trenching plots again had more moisture than any of the other treatments and the margin in its favor was greater in the upper 3 feet than in the November 4, 1959, sampling.

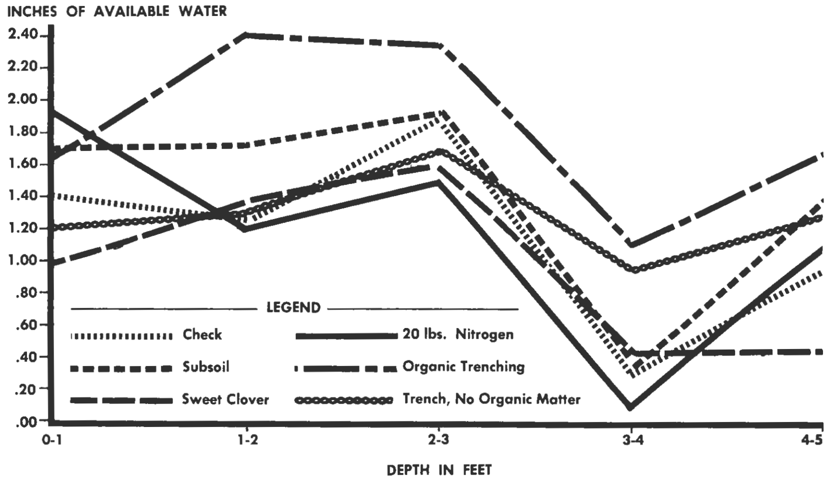



**Figure 9. Effect of legume, commercial nitrogen and mechanical treatment on available soil moisture under corn April 29, 1960.**

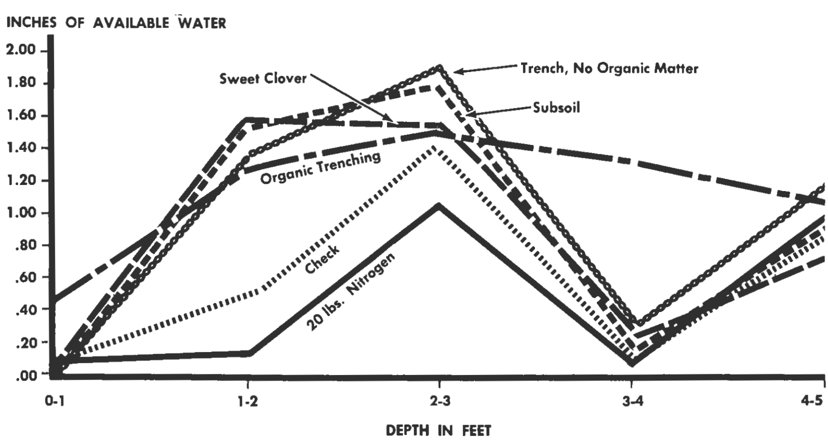
Subsoiling with a conventional chisel was not effective in increasing soil moisture reserves at the lower sampling depths, according to these data.

In plots where 20 pounds of nitrogen were added annually, the soil moisture diagrams in the spring resembled those of the check plot. These samples were taken from the same plots as those in 1959 but from different areas within the same plots.

## EFFECT ON SOIL MOISTURE, FALL 1960

Figure 10 shows effect of the six treatments on available soil moisture on October 7, 1960.

**Figure 10. Effect of legume, commercial nitrogen and mechanical treatment on available soil moisture under corn October 7, 1960.**



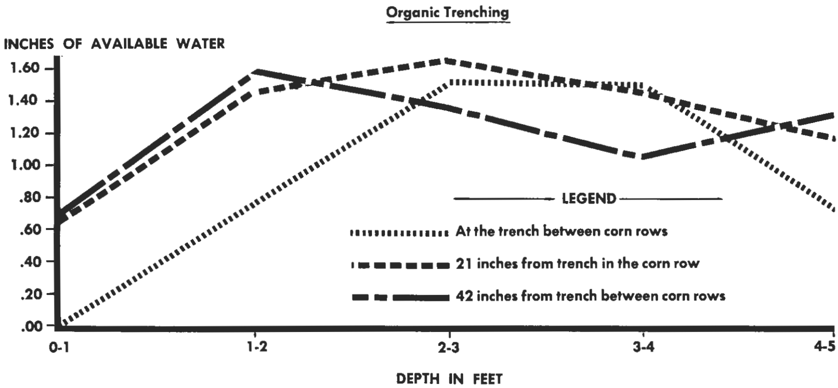


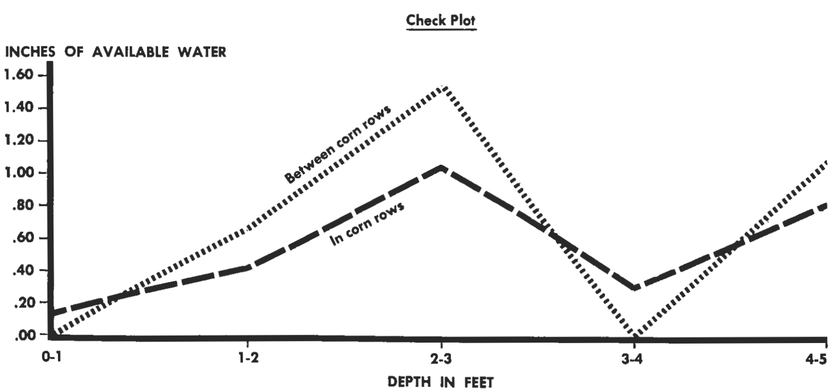

**Figure 11. Influence of sampling distance from organic trench on available soil moisture under corn October 7, 1960.**

There were some treatment-engendered differences in content of soil water to a depth of 3 feet, but with all treatments there was a constant trend of increasing moisture with soil depth to the 3-foot level. At the 3–4 foot depth, however, there was a much greater amount of water in the organic-trenched plots than in any of the others. This indicated that the organic wedge was effective in permitting moisture to penetrate through the claypan and into the subsoil.

## EFFECT OF DISTANCES ON SOIL MOISTURE

Figure 11 shows amount of available soil moisture under corn at three sampling locations with respect to the row and organic trench. One sampling location was at the trench which was centered between two corn rows. The second sample location was 21 inches to the right and 21 inches to the left of the trench, which coincided with corn rows. The samples taken from 21 inches on each side of the trench

**Figure 12. Available soil moisture in the check plot October 7, 1960.**



were averaged and plotted with one line in figure 11. The third sample location was 42 inches on each side of the trench. The available soil moisture values at this spacing were also averaged and plotted with one line. In check plots, soil moisture samples were taken from corresponding positions relative to the corn rows. Results are shown in figure 12.

In the organic trenched plot, there was more total available water and it was distributed more uniformly down through the profile than in the check plot. This indicated that organic trenching allowed more normal infiltration of moisture without being restricted by the impervious claypan layer.

There were variations in amounts of soil moisture at different distances from the trench but not as much as might be expected. Soil close to the trench was dry at 0–1 foot sampling depth, but moisture content increased with depth down to 3 feet. Samples taken 21 inches from the trench indicated a similar trend. At 42 inches from the trench, soil water content deep in the profile was similar to that in the soil close to the trench. Evidently, water got through the claypan by means of the organic wedge and then spread out laterally beneath the claypan.

The soil moisture diagram for the check plot was considerably different (figure 12). In the first place, very little moisture got through the claypan and down to the 3–4 foot level. With no mechanical break-up of the claypan, variations in soil moisture due to sampling locations were relatively small.

Perhaps the most striking results of this study were centered around moisture infiltration and conservation. The efficiency of organic trenching in increasing infiltration under the circumstances of this experiment was outstanding and was considered the most significant contribution of the investigation. It would be interesting to know how effective this technique would be in conserving moisture on sloping land.

It should be remembered that even with machinery that will complete all operations with one trip over the land, organic trenching is a costly operation. No economic analysis has been made, but the feasibility will depend on the soil, climate, and the nature and value of crops which are grown.

## EXPERIMENT NO. 3

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

In this experiment, several different combinations of cultural and mechanical methods were investigated rather than individual methods as in Experiment No. 2. The reason for doing this was the possibility that any single method would not have the maximum beneficial effect and that two methods may be necessary to bring yields up to optimum levels.

Organic trenching and subsoiling were done in the same way and with the same spacings as in Experiment No. 2. Wheat straw was used as the

**Table 8. Effect of Different Combinations of Trenching, Legumes and Subsoiling on Yield of Wheat and Rye**

| Treatments | Yield of wheat and rye in bu/acre<br>Wheat 1958 | 1959* | Rye 1962 |
|---|---|---|---|
| 1. Wheat and 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. Check-no legumes or mechanical treatment | 17.3 | Wheat | 28.5 |
| 5. Subsoil every year | 16.9 | Wheat + Subsoil | 26.0 |
| 6. Organic matter on surface with no trenching or subsoiling | 15.6 | Wheat | 29.8 |

*No grain harvested because of hail damage.

organic material and organic trenching was done only once, in the fall of 1957. Conventional subsoiling was done each fall prior to planting wheat. No subsoiling was performed in established alfalfa. Wheat and rye were the only grain crops used. Alfalfa was planted with wheat in 1958 and remained through the 1959 growing season. It was plowed in the fall of 1959.

Effects of different combinations of mechanical and cultural methods in improving crop yields are presented in table 8.

**A Duncan's multiple range test was calculated to compare treatment means of winter rye. Treatment numbers were taken from table 8 and arranged below in order of increasing yield.**

5 4 6 3 1 2

Any two means not underscored by the same line are significantly different at the 5% level.

In 1958 essentially no differences in wheat yield were due to the different treatments (table 8). This was the year that legumes were planted so no effect on grain yield was expected from the legumes.

In 1960 the beneficial effects of different treatments were indicated by rye yields. A combination of alfalfa and organic trenching gave a favorable and statistically significant yield increase of rye over that of the check plot. The combination of alfalfa and organic trenching appeared to increase yield of rye a little more than the alfalfa treatment without the organic trenching.

The effect of subsoiling plus alfalfa on rye yields was about the same as that due to alfalfa without the subsoiling.

Subsoiling every year resulted in rye yields about the same as those of the check plots in 1960.

In this experiment, increases in rye yield that were obtained appear to be due mainly to the legumes.

In treatment 6, the same amount of organic matter used in organic trenching was spread on the soil surface and plowed under in the fall of 1957. The objective was to determine if placement of the organic matter had an influence on yield. Rye yield from this treatment was about the same as the check plot. This indicated that the organic matter placed in a wedge extending down through the claypan was more effective than surface applications.

## EXPERIMENT NO. 4

### Influence of deep placed fertilizer combined with organic trenching and subsoiling.

The objective of this experiment was to determine desirability of deep fertilizer placement when the claypan was held open with an organic wedge. Emphasis was placed on placement rather than on optimum rates and ratios.

Organic trenching was done in the fall of 1957. Fertilizer was applied in the spring of 1958. Deep application was accomplished by using a modified subsoiler.

Cropping sequence was corn in 1958, wheat in 1959 and rye in 1960. No yields are given for 1959 because of hail damage.

Spacings between trenches and their positions relative to corn rows were similar to those described previously.

Results of this experiment are presented in table 9.

In 1958, all fertilized plots yielded more corn than the check plot but the combination of organic trenching and deep fertilizer placement averaged the highest.

In 1960, the winter rye crop measured residual effect of commercial fertilizer and mechanical treatments. In general, yield differences due to treatments were small. However, organic trenching plus deeply placed 80–34–0 appeared to yield a little better than the other treatments. This difference approached significance at the 5% level. The apparent yield increase could be attributed primarily to organic trenching rather than to residual effect of deep placed fertilizer because yields were inferior in other plots that received the fertilizer but not the organic wedge.

**Table 9. Effect of Deeply Placed Fertilizer, Organic Trenching and Subsoiling on Yields of Corn and Rye**

| Treatment* | Bu Corn/Acre 1958 | Bu Rye/Acre 1960 |
|---|---|---|
| 1. Deep placed 80–34–0 with organic trenching | 54.8 | 32.8 |
| 2. Deep placed 80–34–0 with subsoiling | 38.1 | 27.8 |
| 3. Broadcast on surface 80–34–0 with subsoiling | 30.6 | 27.2 |
| 4. Check | 20.3 | 27.9 |
| 5. Broadcast on surface 80–34–0 | 41.1 | 28.1 |
| 6. Broadcast on surface 40–17–0 plus deep placed 40–17–0 | 35.0 | 26.4 |

* Where fertilizer was applied, the first number gives the pounds of nitrogen and the second number gives the pounds of P applied per acre.

## SUMMARY AND CONCLUSIONS

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

This investigation summarizes one approach to the problem. It involved fracturing the claypan with an improvised tool, and placing a wedge of organic matter in the newly created opening to prevent closure of the fracture by soil settling or flowing.

Organic trenching was compared to other mechanical and cultural treatments for improving grain yields, conserving moisture and increasing root growth. In addition several combinations of organic trenching and older methods were evaluated.

A wedge of organic matter increased yields of rye the third crop year after it was placed in the soil. The organic wedge also increased corn yields, but these increases were not significant at the 5% level.

Some of the older methods were successful in improving grain yields. When moisture was abundant, a sweet clover catch crop increased yields of following grain crops. Subsoiling every year appeared to have a slight beneficial effect on grain yield, but these apparent increases were not significant at the 5% confidence level.

Combinations of older methods with organic trenching were successful. Residual effects from the combination of alfalfa and organic trenching gave increases in yield of rye over that of the check plot. When alfalfa was grown in rotation, effects of subsoiling on yields were minimized.

Perhaps the most significant contribution of this investigation was the information obtained on moisture infiltration and conservation. In the fall of 1959 and in the spring of 1960 organic-trenched plots contained more moisture than any other plots at almost every soil depth.

The wedge of organic matter was successful in encouraging root development beneath the claypan. With only one exception, root mass increased in the organic trenched plots compared to check plots at every depth sampled and at every interval from the plant.

Durability of different materials placed in the trench was investigated. The most resistant was flax straw, then corn cobs, sweet clover and wheat stubble. At the end of 3 years, all wedges were intact but they had settled approximately 2 inches below the soil surface.

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

A combination of organic trenching and deep placed fertilizer was successful. Corn yields from this treatment averaged more than twice that of the check plot.

Residual effect of organic materials placed in a wedge gave greater yield increases than broadcasting the same amount of organic matter on the surface and plowing it under.

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