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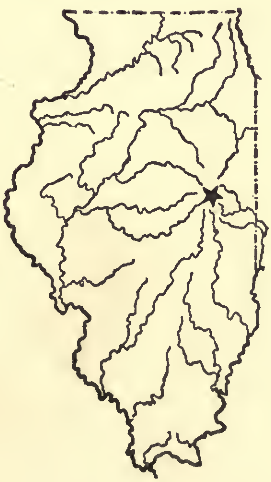
EXPERIMENTS WITH SUBSOILING, DEEP TILLING, AND SUBSOIL DYNAMITING

By Raymond S. Smith



URBANA, ILLINOIS, FEBRUARY, 1925

SUMMARY

Deep plowing and subsoil dynamiting experiments in Illinois as well as in other states indicate that these tillage methods cannot be expected materially to increase crop yields. That such methods are not superior to ordinary or medium-depth plowing has been indicated by subsoiling experiments conducted by the Illinois Agricultural Experiment Station on Gray Silt Loam On Tight Clay at Odin, Marion county; subsoiling, deep tilling, and dynamiting experiments on Gray Silt Loam On Tight Clay at Toledo, Cumberland county; and deep tilling experiments on Brown Silt Loam at Urbana, Champaign county.

Soil moisture determinations made during two seasons on the variously tilled plots at Toledo show that none of the tillage treatments used increased the downward movement of moisture thru the soil.

EXPERIMENTS WITH SUBSOILING, DEEP TILLING, AND SUBSOIL DYNAMITING

By Raymond S. Smith, Associate Chief in Soil Physics

Good plowing is often taken to mean deep plowing. The two, however, are not associated, and before a farmer decides to increase the depth of plowing beyond about 7 inches, he should consider whether the probable benefits will more than pay for the increased cost.

The purpose of plowing is to turn under organic matter of various kinds, to pulverize the surface so that the seed may be covered at the right depth, to control weeds, and to check surface runoff. In heavy soils, or soils which pack badly after rains, plowing is effective in helping to maintain a favorable physical condition. Plowing does not increase the water-holding capacity of the soil, even in arid regions; it does, however, increase the power of the soil to absorb rainfall, thus decreasing the amount of water carried away by surface runoff.

The supposed desirability of deep plowing seems to be based on the belief that only the portion of the soil which is loosened by the plow is utilized by the roots of the crop. There are no reasons for believing that the roots of crop plants behave in any way essentially different from the roots of wild plants, and the luxuriant growth of wild vegetation on land which has never been plowed is a matter of common knowledge.

There are soils, however, which are unfavorable to root penetration because they have an impervious subsoil, and it would be very desirable to overcome this condition. Whether this can be done by deep tillage of any kind will be discussed later.

The increased cost of deep plowing is considerable. If the depth is increased one inch, about 300,000 pounds, or 150 tons, of additional soil is turned for every acre plowed. This additional weight cannot be moved without expenditure of additional power, and power on the farm is costly.

In this bulletin the terms shallow, medium, and deep plowing are used with the following meanings:

Shallow plowing, less than 5 inches deep
Medium plowing, between 5 and 8 inches
Deep plowing, more than 8 inches deep

The only way to determine, with any degree of accuracy, how deep the plow is running is to make several careful measurements. It is almost always true that the plowman thinks he is plowing deeper than he actually is.

The subject of depth of plowing is of such general interest that a few of the experiments which have been conducted in other states, and all the Illinois experiments will be presented in this bulletin so that the reader may see whether there is any basis for the expectation that deep plowing will increase yields.

PLOWING EXPERIMENTS IN OTHER STATES

In 1918 Chilcott and Cole,[1] of the Bureau of Plant Industry of the United States Department of Agriculture, reported the results of extensive deep tillage work in the Great Plains which had been carried on for a period of years at twelve stations in nine states. The authors concluded that the "average results of a series of years show no measurable effect on crop yields as a result of subsoiling."

Results obtained by the Ohio Agricultural Experiment Station from experiments comparing ordinary plowing, deep plowing, and subsoiling, are summarized in Table 1. The authors comment on these results as follows: "It would be difficult to arrange a uniform treatment which would result in yields more nearly identical. In view of the expense involved, it is evident that the 7-inch plowing is by far the most profitable."

TABLE 1.—AVERAGE YIELDS PER ACRE FOR TWELVE YEARS FOLLOWING DIFFERENT DEPTHS OF PLOWING

(From Ohio Agricultural Experiment Station Bulletin 362)

Crop	Ordinary plowing (7½ inches)		Deep plowing (15 inches)		Ordinary plowing plus subsoiling	
	Grain	Straw or hay	Grain	Straw or hay	Grain	Straw or hay
	bu.	*lbs.*	*bu.*	*lbs.*	*bu.*	*lbs.*
Corn	61.13	3 251	59.47	3 066	61.33	3 229
Oats	49.00	2 159	49.29	2 048	49.05	2 188
Wheat	31.50	3 483	31.49	3 517	31.65	3 549
Clover	.....	5 300	.....	5 060	.....	5 200

Noll,[1] of the Pennsylvania Agricultural Experiment Station, reports several years' work comparing the effect of ordinary plowing (7 inches) and deep plowing (12 inches), on the yields of corn, oats, barley, wheat, and alfalfa. He was led to conclude that "the two kinds of plowing gave practically the same results on all crops grown." Since the results with alfalfa are of special interest, they are given in Table 2.

[1]Chilcott, E. C., and Cole, John S. Subsoiling, deep tilling, and soil dynamiting in the Great Plains. Jour. Agr. Res. 14:481-521, 1918.

Numerous other experiments on depth of plowing, conducted under a wide range of climatic and soil conditions in many states, all lead to the conclusion that, while occasionally a combination of soil and climatic

Table 2.—Yield of Alfalfa from Shallow and from Deep-Plowed Plots[1]
(From Pennsylvania Agricultural Experiment Station Annual Report, 1912-1913)

	Shallow-plowed plots	Deep-plowed plots
	lbs.	*lbs.*
First cutting...............	1 768	1 725
Third cutting..............	871	827

[1]Second cutting not harvested because it was too light owing to drouth.

conditions may occur which makes deep plowing profitable, the returns thru a period of years will not justify the increased cost, excepting possibly in the case of sugar beets.

SUBSOIL DYNAMITING EXPERIMENTS IN OTHER STATES

The use of dynamite on soils having an impervious subsoil is strongly recommended by concerns having this material for sale. The fact that the character of the impervious material determines whether or not dynamite can be used beneficially seems to have been overlooked by them in their advertising. The effect of the exploding charge on a plastic clay subsoil is injurious rather than beneficial because the clay is compacted and not shattered. The accompanying illustration from Bulletin 209 of the Kansas Agricultural Experiment Station (Fig. 1) shows the effect produced by exploding a charge of dynamite in such a subsoil. The soil particles are forced out from the center of the charge and into the pore spaces of the surrounding soil mass, forming dense walls. These walls are very strongly compacted and may be easily separated from the adjacent soil, as was done in this Kansas work. Professors Call and Throckmorton comment as follows on the effect of dynamiting plastic clay subsoils: "It is evident from these observations that dynamiting does not crack and loosen plastic clay subsoils. In fact, the opposite effect is produced. The soil, instead of being shattered and cracked, is compacted and puddled, and the soil left in poorer physical condition than before the dynamiting was done." Similar effects were noted in the dynamiting experiments at Toledo, Illinois, which are discussed beginning on page 161. A number of other states have conducted subsoil dynamiting experiments and the results of practically

[1]Noll, C. F. Pennsylvania Agricultural Experiment Station Annual Report, 1912-1913.

FIG. 1.—A PARTLY BROKEN DYNAMITE JUG IN A HEAVY PLASTIC SUBSOIL

Produced by one-half stick of 20-percent "Red Cross" powder placed in the soil at a depth of three feet. Cavity twelve inches wide and fifteen inches deep; thickness of walls varied from two to six inches. "The soil, instead of being shattered and cracked, is compacted and puddled, and left in poorer physical condition than before the dynamiting was done." (Courtesy of the Kansas Agricultural Experiment Station.)

all of these experiments lead to the conclusion that for general farm crops as well as for fruit trees, the effect of dynamiting plastic subsoils is injurious rather than beneficial.

PLOWING EXPERIMENTS IN ILLINOIS

Considerable work has been done in Illinois in comparing the effects of medium and deep plowing, as already defined, on crop yields. The following experiments, all of which have been discontinued, include all the plowing studies made by this Station, excepting some early work with sugar beets, the results of which were published in 1898 in Bulletin 49.

EXPERIMENT AT ODIN: GRAY SILT LOAM ON TIGHT CLAY

From 1907 to 1919 a subsoiling experiment was carried on at the Odin experiment field, in Marion county. The soil on this field is classified as Gray Silt Loam On Tight Clay. The plastic, difficultly pervious stratum known as "tight clay" is from 8 to 12 inches thick and generally occurs about 19 inches below the surface, tho there is a great variation in its depth. In some places it comes very close to the surface, and gives rise to what are known as "scald spots."

TABLE 3.—ACRE YIELDS OF CORN GROWN ON GRAY SILT LOAM ON TIGHT CLAY, NOT TILE-DRAINED: ODIN FIELD

Plot	1		2		3		4		5	
Soil treatment[1]	None		R		RL		RLP		RLPK	
Tillage treatment	Not subsoiled	Subsoiled	Not subsoiled	Subsoiled	Not subsoiled	Subsoiled	Not subsoiled	Subsoiled	Not subsoiled	Subsoiled
	bu.	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*
1907[2]	50.3	7.3	49.9	38.9	41.8	48.8	48.6	42.8	70.8	63.5
1908[2]	42.2	36.4	37.8	24.8	34.6	31.4	40.4	45.8	75.0	57.8
1909	28.6	27.2	32.8	29.8	27.8	26.8	36.2	34.2	71.8	66.4
1910	32.8	17.9	26.5	31.4	38.0	37.8	36.6	36.5	76.7	85.4
1911	22.8	19.6	22.6	24.4	21.6	23.0	21.8	20.6	39.2	47.6
1912[3]	28.2	32.2	40.8	14.8	44.2	44.2	41.2	52.0	68.8	57.2
1913[2]	3.8	3.6	6.0	4.8	4.2	4.2	5.0	3.6	11.6	11.8
1914[2]	5.2	2.8	2.0	3.8	1.8	1.8	2.0	2.8	2.8	5.2
1915[2]	48.6	38.8	46.0	48.2	46.2	46.4	44.8	42.0	61.2	55.2
1916[2]	17.6	14.0	16.2	19.8	22.2	23.4	20.6	22.2	28.0	23.4
1917	7.4	9.4	12.7	7.7	7.0	8.0	7.0	12.0	34.6	32.8
1918[2]	2.8	6.0	6.8	5.6	8.8	9.0	10.4	9.6	17.2	18.2
1919	0.8	0.3	1.2	0.7	4.0	4.1	2.2	2.1	2.8	1.9
Average	23.7	19.7	23.2	19.6	23.3	23.8	24.4	25.1	43.1	40.5

[1]R = residues, L = lime, P = rock phosphate, K = kainit.
[2]Replowed in spring.
[3]Plowed and subsoiled in spring.

TABLE 4.—ACRE YIELDS OF CORN GROWN ON GRAY SILT LOAM ON TIGHT CLAY, TILE-DRAINED: ODIN FIELD

Plot	6		7		8		9		10	
Soil treatment	None		R		RL		RLP		RLPK	
Tillage treatment	Not subsoiled	Subsoiled	Not subsoiled	Subsoiled	Not subsoiled	Subsoiled	Not subsoiled	Subsoiled	Not subsoiled	Subsoiled
	bu.	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*
1907[1]	38.5	27.9	50.3	47.4	52.8	45.8	45.3	45.9	69.4	55.3
1908[1]	28.8	28.6	28.6	28.0	36.4	38.4	39.4	46.0	77.2	62.8
1909	30.0	21.0	28.0	24.6	30.6	30.2	21.6	41.0	36.2	54.4
1910	24.9	27.2	39.1	38.8	42.6	37.3	40.8	43.2	83.0	85.9
1911	10.8	7.0	15.4	15.4	27.8	22.4	23.8	19.2	32.2	33.2
1912[2]	24.0	31.2	38.4	33.2	53.0	50.8	57.6	54.2	62.0	39.8
1913[1]	1.2	2.8	1.8	2.4	4.0	4.0	7.2	12.2	8.6	8.6
1914[1]	3.4	5.2	4.6	4.8	2.4	3.0	2.0	2.2	3.4	4.8
1915[1]	22.0	24.6	35.0	38.4	49.0	41.6	41.6	41.8	53.6	44.8
1916[1]	9.2	10.8	15.2	13.2	16.8	18.6	18.4	17.6	35.8	30.6
1917	11.1	9.7	15.4	12.8	15.4	15.7	20.6	15.6	27.2	27.6
1918[1]	5.6	6.0	8.0	7.0	14.2	13.6	15.2	15.8	22.4	21.2
1919	0.1	0.3	0.2	0.2	1.6	1.8	1.5	2.4	4.2	4.6
Average	16.1	15.6	21.5	20.5	26.2	24.9	25.7	27.5	39.6	36.4

[1]Replowed in spring.
[2]Plowed and subsoiled in spring.

TABLE 5.—SUMMARY OF ACRE YIELDS OF CORN FROM TILED PLOTS AND FROM PLOTS NOT TILED: ODIN FIELD

Soil treatment	None		R		RL		RLP		RLPK	
Tillage treatment . .	Not sub-soiled	Sub-soiled	Not sub-soiled	Sub-soiled	Not sub-soiled	Sub-soiled	Not sub-soiled	Sub-soiled	Not sub-soiled	Sub-soiled
	bu.	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*
1907[1]	44.4	37.6	50.1	43.2	47.3	47.3	47.0	44.4	70.1	59.4
1908[1]	35.5	32.5	33.2	26.4	35.5	34.9	39.9	45.9	76.1	60.3
1909	29.3	24.1	30.4	27.2	29.2	28.5	28.9	37.6	54.0	60.4
1910	28.9	22.5	32.8	35.1	40.3	37.5	38.7	39.9	79.9	85.7
1911	16.8	13.3	19.0	19.9	24.7	22.7	22.8	19.9	35.7	40.4
1912[2]	26.1	31.7	39.6	24.0	48.6	47.5	49.4	53.1	65.4	48.5
1913[1]	2.5	3.2	3.9	3.6	4.1	4.1	6.1	7.9	10.1	10.2
1914[1]	4.3	4.0	3.3	4.3	2.1	2.4	2.0	2.5	3.1	5.0
1915[1]	35.3	31.7	40.5	43.3	47.6	44.0	43.2	41.9	57.4	50.0
1916[1]	13.4	12.4	15.7	16.5	19.5	21.0	19.5	19.9	31.9	27.0
1917	9.3	9.5	14.1	10.3	11.2	11.8	13.8	13.8	30.9	30.2
1918[1]	4.2	6.0	7.4	6.3	11.5	11.3	12.8	12.7	19.8	19.7
1919	0.5	0.3	0.7	0.4	2.8	3.0	1.9	2.3	3.5	3.3
Average	19.9	17.7	22.3	20.0	24.7	24.3	25.0	26.3	41.3	38.4

[1]Replowed in spring. [2]Plowed and subsoiled in spring.

During this 13-year period the rotation used was corn, soybeans, wheat, and clover. There were four failures of the corn crop, three poor corn crops, four poor wheat crops, and twelve clover failures. The large proportion of crop failures which occurred in spite of supposedly good soil treatment makes it clear that crops on this soil type are very sensitive to climatic conditions during the growing season. It was the appreciation of this fact that led to the starting of the subsoiling work, in an attempt to determine whether such tillage treatment would improve the unfavorable subsoil condition. It should be stated, however, that when seasonal conditions are favorable, large crops can be grown on this soil if it is properly treated.

One-half of each plot was plowed and subsoiled in the late fall. Exceptions to this procedure are noted in footnotes following Tables 3 and 4. The yields of the crops other than corn are omitted because they were

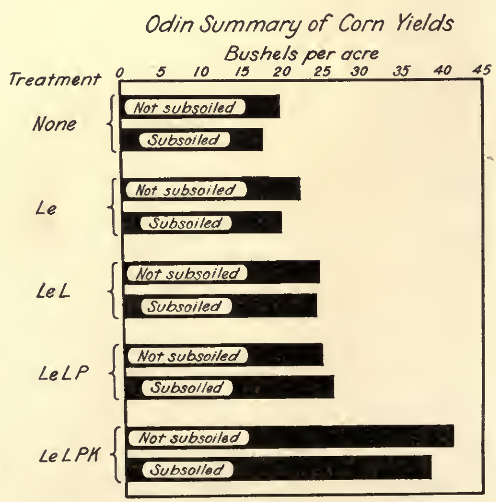


FIG. 2.—SLIGHT VARIATIONS INDICATE THAT SUBSOILING HAS NO EFFECT ON CORN YIELDS

not harvested by half plots. The complete data for corn given in Tables 3 and 4 show the variations which enter into the averages given in the summary, Table 5.

In every case the differences in yield between the subsoiled plots and the plots not subsoiled are so small that the only possible conclusion is that subsoiling has neither increased nor decreased the corn yields.

The averages given in Table 5 are shown in graphic form in Fig. 2.

EXPERIMENT AT TOLEDO: GRAY SILT LOAM ON TIGHT CLAY

In 1913 another experiment was started on Gray Silt Loam On Tight Clay at Toledo, Cumberland county, to compare the effects of subsoiling, deep tillage, and subsoil dynamiting with ordinary plowing, in a rotation of corn, soybeans, wheat, and sweet clover. Four series of four 1/10-acre plots each were laid out so that each crop was grown each year. The second-year sweet clover stubble was plowed late in

FIG. 3.—DEEP TILLAGE MACHINE. REAR DISK TURNS THE SOIL IN THE BOTTOM OF FURROW MADE BY FRONT DISK

This machine mixed the subsurface and in places the subsoil with the surface soil to such an extent as to change the color of the surface. Decreased yields were apparently the result of this mixing.

the fall for corn. One ton of rock phosphate per acre was applied on all plots in the fall of 1914, and again in the fall of 1918. Four tons of limestone per acre was applied on all plots in 1913, three tons per acre was applied for the 1917 crop, and two tons per acre for the 1921 crop.

The depth from the surface to the tight clay varies on this field, as is always found to be the case with this soil type. In places, the

TABLE 6.—EFFECT OF DEPTH OF PLOWING ON CROP YIELDS: TOLEDO FIELD

(Yields of corn, soybeans,[1] and wheat in bushels per acre; sweet clover[1] in pounds per acre)

Plot	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
	Corn	Soybeans[2]	Corn	Soybeans	Wheat	Sweet clover	Corn	Soybeans	Wheat	Sweet clover
1	8.2	O.P. 13.2	37.6	11.5	22.5	O.P. 180	49.6	20.7	21.1	60
2	8.8	S.S. 11.0	40.0	13.0	15.3	S.S. 250	44.0	19.7	19.5	60
3	9.6	D.T. 11.7	36.8	11.5	11.0	D.T. 200	49.6	19.0	16.6	75
4	7.8	D. 11.6	37.8	12.5	12.2	D. 280	45.4	19.0	16.8	110
	Soybeans	Wheat	Soybeans	Corn	Soybeans	Wheat	Sweet clover	Corn	Soybeans	Wheat
5	1.5	2.6	O.P. 17.2	40.4	8.8	4.2	O.P. 390	46.0	29.3	9.7
6	2.5	11.5	S.S. 17.5	37.6	8.8	3.7	S.S. 320	50.8	28.7	12.0
7	3.0	11.7	D.T. 16.8	36.4	9.3	5.5	D.T. 250	30.0	27.8	7.2
8	2.6	10.9	D. 16.2	41.6	11.6	8.7	D. 330	44.2	28.8	5.9
	Oats Not harvested	Corn	Wheat	Sweet clover No seed recovered	Corn	Soybeans	Wheat	Sweet clover	Corn	Soybeans
9		34.6	7.5		21.4	10.3	16.3	O.P. 435	52.4	17.6
10		36.1	7.5		21.4	9.0	19.7	S.S. 385	49.2	15.6
11		36.7	8.3		14.8	4.5	16.0	D.T. 340	41.5	16.6
12		35.1	8.0		17.2	9.2	18.7	D. 560	42.7	17.8
	Oats Not harvested	Corn	Soybeans	Wheat Not harvested	Sweet clover	Corn	Soybeans	Oats[3]	Sweet clover	Corn
13		30.6	13.3		O.P. 190	30.4	16.0	21.9	O.P. 70	49.7
14		35.8	11.5		S.S. 230	40.5	18.3	25.0	S.S. 70	56.8
15		35.6	13.2		D.T. 210	39.0	17.5	28.1	D.T. 70	51.4
16		35.9	11.5		D. 190	48.6	16.2	22.2	D. 60	49.9

[1]The loss of seed in the soybean and sweet clover harvest was so large that no significance is attached to the yields of these crops. They are included so that the record may be complete.

[2]O.P.= ordinary plowing. S.S.= subsoiled. D.T.= deep tilled. D.= dynamited.

[3]Wheat failure; oats substituted.

subsoil plow and deep tillage machine penetrated the tight clay, but as a rule this impervious stratum occurred 1 to 16 inches below the depth to which the implements ran. The deep tilling was done with a deep tillage machine, illustrated in Fig. 3, which mixed the subsurface, and in places the subsoil, with the surface soil to such an extent as to change the color of the surface. On the dynamite plots, the charge was placed well into the tight clay stratum. The size of the charge was determined each year by experimentation, the object being to use as heavy a charge as possible without blowing the soil out and forming a hole. The charges usually consisted of one-third of a stick of 20-percent dynamite. They were spaced 8 feet, 3 inches apart each way on two of the plots and 11 feet apart each way on the other two. Fig. 4 shows the method used in spacing the charges.

The results of this experiment show that none of the tillage treatments—subsoiling, deep tilling, or dynamiting—had any beneficial effect on crop yields. Deep tilling apparently decreased yields, probably because of the mixing of the subsurface and subsoil with the surface soil.

Table 6 shows the yields of all the crops during the time of the experiment, 1913 to 1922, and also the time when the various series were plowed, subsoiled, deep-tilled, and dynamited. It should be explained that the tilling was done in the late fall of the year indicated, for the following corn crop.

In Table 7 the results of the Toledo experiment are summarized.

TABLE 7.—SUMMARY OF CROP YIELDS: TOLEDO FIELD
(Bushels per acre)

Tillage treatment	Corn 9 crops	Soybeans 7 crops	Wheat 6 crops	Sweet clover seed 6 crops
Plowed 7 inches deep	40.2	16.3	13.5	3.68
Subsoiled 14 inches deep	41.9	16.2	12.9	3.65
Deep tilled 14 inches	37.4	15.2	10.8	3.18
Dynamited	40.3	16.4	11.7	4.25

SUBSOILING, DEEP TILLING, AND DYNAMITING FAIL TO OPEN UP TIGHT CLAY SUBSOIL

The fundamental cause of the frequent crop failures, low yields, and relatively low agricultural value of Gray Silt Loam On Tight Clay is the presence of the tight clay subsoil. In the spring the soil is supersaturated. The surplus water which cannot be removed by surface drainage remains until removed by evaporation. This condition results in poor root growth and the crops are very sensitive to the dry, hot weather which commonly follows the spring rains.

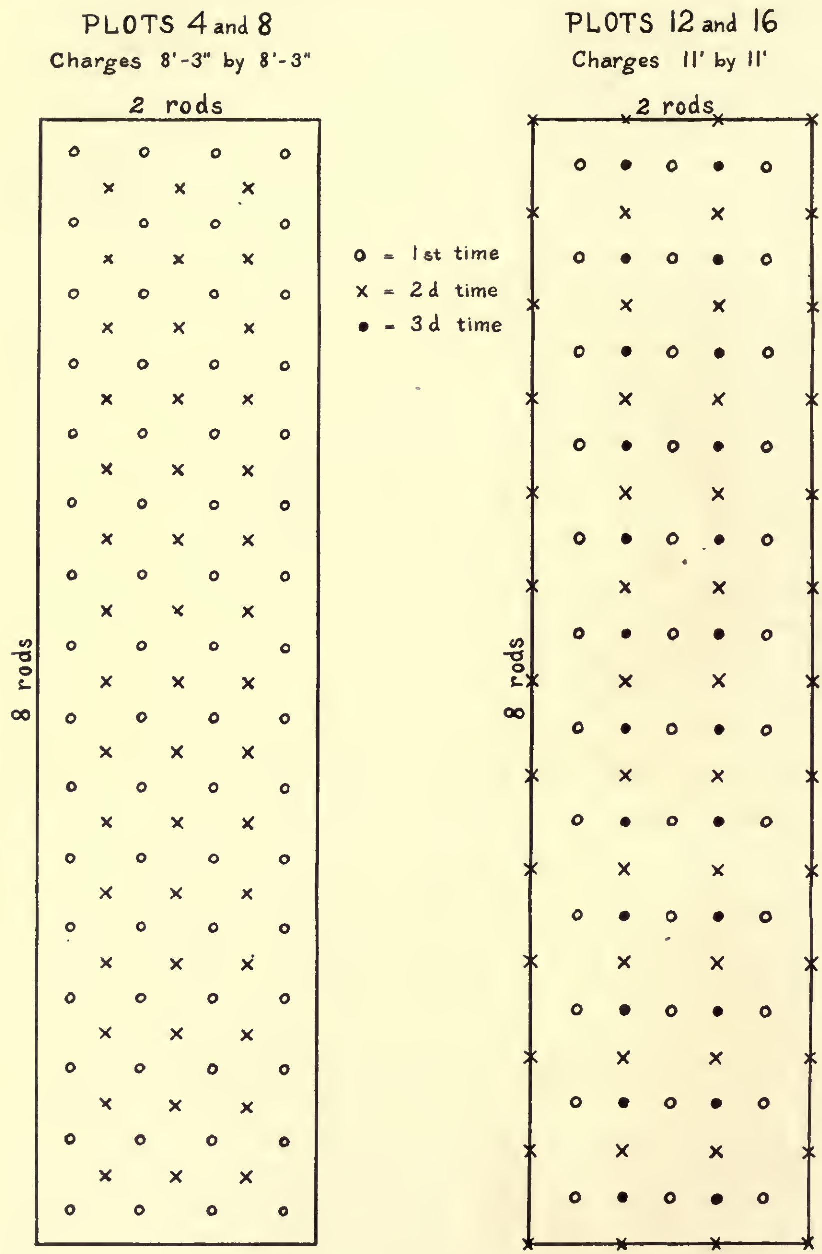


FIG. 4.—METHOD OF SPACING CHARGES ON DYNAMITED PLOTS

The charge was placed well into the tight clay stratum and made as heavy as possible without being so heavy as to blow the soil out and form a hole.

That a solution of this problem is not to be found in subsoiling, deep tilling, or dynamiting is indicated by the results of these experiments. Any such treatment to be effective would have to shatter or open up this impervious stratum sufficiently to increase the passage of water thru it and to allow roots to penetrate it readily. The character of the material is such that it is rarely, if ever, dry enough to be shattered, and it seems very unlikely that it would remain shattered any length of time even if such a condition could be produced.

FIG. 5.—DEPRESSION FOUND IN THE SPRING OVER EACH SPOT WHERE A CHARGE OF DYNAMITE WAS EXPLODED THE PREVIOUS FALL

These basins were entirely impervious to water. A subsoil that is plastic in nature cannot be opened up successfully with dynamite.

The dynamite charges, instead of shattering the tight clay, formed perfect basins with highly compacted walls which were entirely impervious to water. In the spring, the location of every charge of the previous fall was indicated by a small depression. (See Fig. 5.) It appears to be a universal rule that dynamite cannot be used successfully to open up a subsoil which is plastic in nature.

The term "hardpan" is commonly applied to the tight clay stratum; however, it is very different from true hardpan. True hardpan is not known to occur in Illinois. It is a cemented stratum common in semi-arid regions and it can be broken up successfully with dynamite. Tight clay is not a cemented layer; instead, it is very plastic, due to its high percentage of very fine particles. The effect of the dynamite charges on the plastic clay was harmful, rather than beneficial, as is shown in Fig. 6, and as was shown in the Kansas work.

In order to get further evidence as to whether the subsoiling, deep tilling, or dynamiting had any effect on the passage of moisture thru the tight clay stratum, samples were taken in the spring of 1919 and of 1920 for the purpose of making moisture determinations. It was

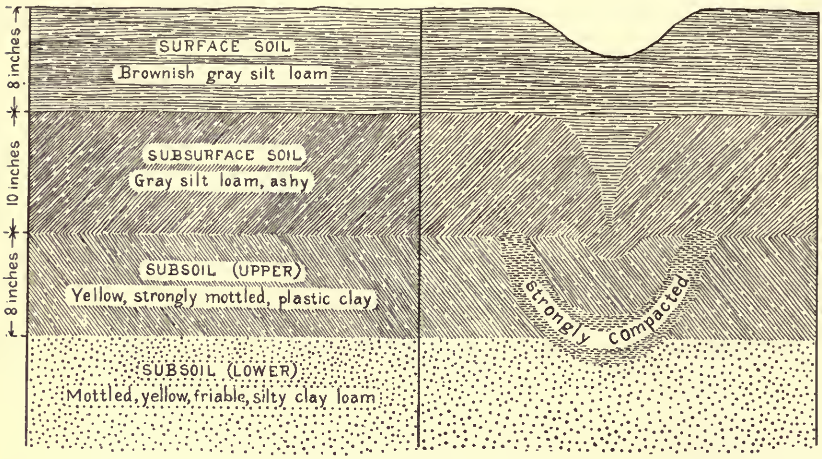


FIG. 6.—SKETCH OF SOIL PROFILE FOR GRAY SILT LOAM ON TIGHT CLAY, SHOWING THE COMPACTING EFFECT OF EXPLODING A DYNAMITE CHARGE IN THE PLASTIC CLAY STRATUM

thought that if any of these tillage treatments increased the passage of water thru the tight clay stratum, it would be shown in the moisture content of the surface and subsurface during the period of excess moisture in the early spring.

TABLE 8.—PERCENTAGE OF MOISTURE IN SURFACE AND SUBSURFACE: TOLEDO FIELD[1]

Plot	5	6	7	8
Tillage treatment	Plowed 7 in.	Subsoiled	Deep tilled	Dynamited
Surface—0-8 Inches				
April 30	29.4 ± 0.33	29.3 ± 0.24	27.2 ± 0.16	29.4 ± 0.27
May 7	27.5 ± 0.35	27.8 ± 0.25	25.8 ± 0.22	29.8 ± 0.18
May 15	28.2 ± 0.50	28.2 ± 0.25	25.1 ± 0.25	29.2 ± 0.21
May 21	28.9 ± 0.28	28.3 ± 0.27	26.1 ± 0.20	28.4 ± 0.28
Seasonal average	28.5 ± 0.19	28.4 ± 0.12	26.1 ± 0.10	29.3 ± 0.12
Subsurface—8 Inches to the Tight Clay				
April 30	25.0 ± 0.44	22.9 ± 0.34	23.8 ± 0.16	24.2 ± 0.26
May 7	23.3 ± 0.40	22.0 ± 0.32	22.9 ± 0.20	24.6 ± 0.23
May 15	24.1 ± 0.46	24.1 ± 0.30	23.7 ± 0.18	25.1 ± 0.29
May 21	26.3 ± 0.34	25.7 ± 0.41	25.5 ± 0.27	25.9 ± 0.18
Seasonal average	24.9 ± 0.20	23.9 ± 0.17	24.0 ± 0.10	24.9 ± 0.12

[1]Fourteen samples from each plot on each date.

It will be noted by reference to Table 8 that there were no significant differences in 1920 in the moisture content of the plots which had received the various tillage treatments the previous fall and also in the fall of 1915. It seems apparent that none of the tillage treatments, subsoiling, deep tilling, or dynamiting, had any effect which was reflected in the moisture content of this poorly drained prairie soil.

EXPERIMENT AT URBANA: SOIL VARYING FROM BROWN SILT LOAM TO BLACK CLAY LOAM

In 1915, an experiment on time and depth of plowing was started on the 900 and 1000 series of the University South Farm. The soil on these two series varies from Brown Silt Loam to Black Clay Loam, probably corresponding to Muscatine silt loam and Clyde clay loam as classified by the Bureau of Soils of the United States Department of Agriculture. A four-year rotation of corn, corn, oats, and sweet clover occupies these two series, each crop being grown each year.

The times and depths of the various plowing operations are shown in Table 9. A two-bottom gang was used for the 3 to 4-inch depth, and the 7-inch depth, and a deep tillage machine for the 12 to 14-inch depth.

Also in Table 9, the yields of first-year corn are given for the period of the experiment, 1915 to 1920, and the yields of second-year corn for the last four years.

The results indicate that, in so far as the yield of corn is concerned, there is no choice between 12 to 14-inch fall plowing, 7-inch fall plowing, and 7-inch spring plowing, but that 3 to 4-inch spring plowing is apparently too shallow for the best growth of corn. The differences, however, in favor of the deeper plowing as compared with the shallow, are not large enough to be at all conclusive. The consistent character of the results indicates that no increases in yields can be expected on these soil types following plowing to a depth of 12 to 14 inches with the deep tillage machine.

COOPERATIVE EXPERIMENTS

1912 Experiment

Late in May, 1912, two one-half acre plots were plowed 6 to 7 inches deep and two other half-acre plots plowed 12 to 14 inches deep on a farm two miles south of Urbana, on soil which is classified as Brown Silt Loam. Corn was planted within a few days following the plowing, after disking, rolling, and harrowing. The crop yields are given in Table 10.

This experiment, while inconclusive because of lack of replication and also because but one year's work was done, indicates that plowing to a depth of 12 to 14 inches for corn a few days before planting is

TABLE 9.—ACRE YIELDS OF CORN FOLLOWING SPRING AND FALL PLOWING AT VARIOUS DEPTHS
(Series 900 and 1000—University South Farm, Urbana)

Time of plowing	Depth	1915		1916		1917		1918		1919		1920		6-yr. av.	4-yr. av.
		1st crop	2d crop	1st crop	2d crop	1st crop	2d crop	1st crop	2d crop	1st crop	2d crop	1st crop	2d crop	1st crop	2d crop
	in.	*bu.*		*bu.*		*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*	*bu.*
Fall	12–14	67.0	......	43.0	......	72.4	65.5	61.3	49.9	64.2	69.3	86.6	69.7	65.7	63.6
	7	66.6	......	40.2	......	70.7	65.0	63.4	51.8	61.0	66.9	88.3	69.4	65.0	63.3
Spring	7	65.0	......	44.9	......	72.9	61.7	65.8	56.1	56.9	64.4	90.1	67.0	65.9	62.3
	3–4	67.1	......	43.1	......	70.3	58.1	65.7	55.9	52.4	65.6	82.9	63.9	63.6	60.9

harmful on Brown Silt Loam. There is reason to believe it would be equally harmful on any soil.

TABLE 10.—ACRE YIELDS OF CORN GROWN IN COOPERATIVE EXPERIMENT: URBANA, 1912

Tillage treatment	Individual plots	Average
	bu.	*bu.*
Plowed 6 to 7 inches deep........	67.7 64.9	66.3
Deep tilled 12 to 14 inches	63.3 59.5	56.4

1913 Experiment

In the late fall of 1912, four one-acre plots were plowed 6 to 7 inches deep and four other one-acre plots plowed 12 to 14 inches deep with the deep tillage machine. The next spring the seed bed was prepared and the corn planted. Table 11 gives the yields secured.

TABLE 11.—ACRE YIELDS OF CORN GROWN IN COOPERATIVE EXPERIMENT: URBANA, 1913

Tillage treatment	Individual plots	Average
	bu.	*bu.*
Plowed 6 to 7 inches deep........	49.1 47.2 40.7 42.6	44.9 ± 1.62
Deep tilled 12 to 14 inches	47.6 43.7 44.3 48.2	45.9 ± 0.94

It will be noted that the difference in the average yields is so small as entirely to lack significance, and also that there is considerable difference shown in the yields of individual plots which received the same tillage treatment. This fact emphasizes the necessity of having a sufficient number of plots in any work of this sort to give a reasonably reliable average. By proper selection these figures could be used to prove either that ordinary plowing is superior or that deep tilling is superior, when, as a matter of fact, there is no significant difference shown between the two when measured in terms of the corn crop.

THE COST CONSIDERATION

The merits of any tillage practice are determined by the net returns resulting from that particular practice. It costs at least twice as much to subsoil a field as it does to plow it at an ordinary depth. Probably a fair statement is that when it costs $2.50 an acre to plow 7 inches deep, it will cost $5 an acre to subsoil, and $7 an acre to deep till. It was found at this Station that it takes four horses to pull a subsoil plow and six horses to pull the deep tillage machine. At Toledo, a two-plow tractor was used for two years to pull the deep tillage machine, and it was overloaded.

The cost of dynamiting varies considerably because of differences in the costs of material and labor, but it is always high. If the charges are placed at intervals of one rod each way, and one-third stick of 20-percent dynamite is used for each shot, the cost, including labor, will range from $20 to $25 an acre, when dynamite costs 30 cents a pound. It is apparent that very large increases in yield would have to follow the dynamite treatment to justify its use for general farm crops.

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