Subsoiling Seldom Pays in the Midwest

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DESPITE THE EVIDENCE of completed research, interest in deep tillage methods comes and goes. A favorable report from some locality stimulates new interest and additional testing over a wide area. When the results from this testing show little or no advantage over normal tillage methods, interest subsides.

Then, another report of favorable results under certain soil and weather conditions revives interest and sets off a new series of tests. The glamour of new equipment or a novel way of placing fertilizer in the subsoil may catch the fancy of farm operators and researchers alike, and again the cry—more testing.

This recurring cycle of interest and testing may be due in part to short memories or because the research data available has not been reviewed, summarized, and published as one unit. This article attempts to fulfill the latter need.

Research has shown few benefits from either deep tillage or deep fertilizer placement in the Midwest. These practices sometimes increase yields, but costs increase greatly with the depth of soil treatment. The true value of any yield increase must be considered in relation to costs necessary for obtaining the increase.

The research data available lead to this general conclusion for the North-central States: *It is doubtful if expensive subsurface soil treatments will give economic returns for corn, alfalfa or other forage crops where good fertility and management practices are used on the normal surface plow layer.*

Deep Tillage

The conditions favoring tillage below the normal plow depth of 6-8 inches are limited to certain soil, cropping, and often specific weather conditions (5, 9, 10). Very compact layers tend to develop, for example, under machinery traffic on some of the medium-textured soils in the delta land of Mississippi and Louisiana. When this "pressure pan" is broken by deep tillage in the fall, moisture storage from winter rainfall may be improved, and yields of the following crop may be increased. The effects of deep tillage are usually temporary. These expensive treatments must be repeated often, and soil moisture content as well as weather conditions must be favorable if the treatment is to be effective.

Where soils freeze regularly to considerable depth or where droughts may cause shrinkage and subsoil cracking as in the North-central States, research has shown few benefits from deep tillage (2, 3, 4, 6, 7). These natural forces may change the subsoil structure more than is possible by deep tillage with a chisel drawn through the subsoil layers at a great expenditure of power (8, 11). In a review of the research on deep tillage in the Great Plains States, Duley found no evidence of general benefits from subsoiling (1).

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Subsoil Fertilization

Research on subsoil tillage alone or in combination with deep lime or fertilization experiments has been conducted in Iowa, Illinois, and Missouri. The results indicate expensive subsoil fertilization generally cannot be justified if good fertility and management practices are used for the surface plow layer.

Results from experiments at McCredie, Missouri, indicated possibilities for increasing the depth of the fertile root zone in one particular soil. Woodruff and Smith found that mixing lime into the plowsole layer of a Mexico silt loam soil (claypan soil with an acid B horizon) improved the growth and rooting depth of sweetclover (12). Shattering the plowsole layer without the addition of lime, however, proved detrimental to crop growth. This is probably because some of the acid subsoil was mixed with the topsoil.

Plowsole tillage and deep fertilization tests were conducted in Missouri from 1948 through 1958. Subsoiling and deep fertilization experiments were started in Iowa in 1955 and continued through 1958. Subsoiling tests in Illinois were conducted from 1954 through 1956. Some deep lime and fertilizer experiments were started in 1955 on a claypan soil at Carbondale, Illinois.

Results of the Missouri and Iowa subsoiling and deep fertilizer treatments and the Illinois subsoiling experi-

Reprinted from JOURNAL OF SOIL AND WATER CONSERVATION
Volume 15, Number 6, November, 1960

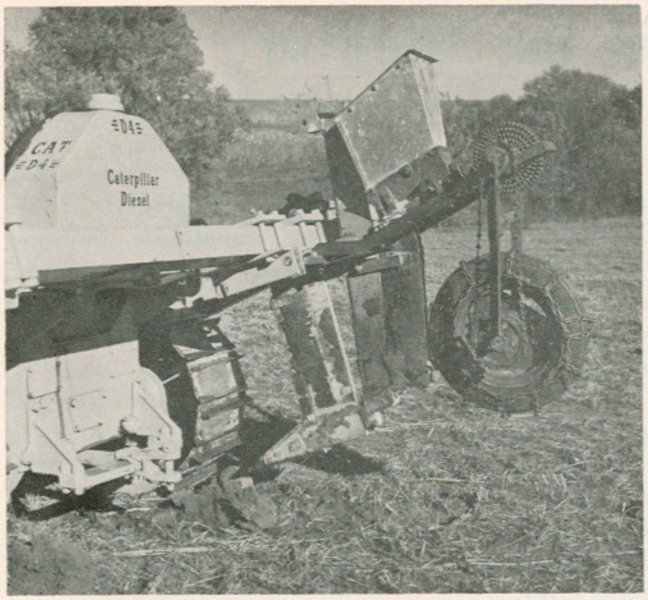

Figure 1. Subsoiler with fertilizer applicator. The ground wheel was used to drive the metering device, and the rear shank led the fertilizer to the bottom of the subsoiled channel.

ments as well as the preliminary results of the Carbondale experiment have already been published (3, 6, 7). The remainder of this article is a review of these tests and an examination of their significance.

Iowa Research Results

Iowa study sites were chosen where considerable local interest existed and on soil types of major importance exhibiting wide contrasts in soil properties. The treatments compared different depths of tillage, with and without applications of fertilizer in the tilled zone. The tillage treatments tested were a check treatment at normal plow depth and subsoiling to 16 and 24 inches. On one soil, Ida silt loam, the subsoiler penetrated to only 20, rather than the planned 24, inches.

The subsoiling and deep fertilization was done with the equipment shown in figure 1. Fields were subsoiled at 40-inch intervals, and corn rows were planted directly over the subsoiled channels. All subsoiling was done in the fall except on the Ida silt loam which was subsoiled in early spring.

The soils included in the study were Ida, Marshall, Galva, Edina, and Grundy silt loams and Webster-Glencoe silty clay loam. These soils represent the Brunizem, Humic-Gley, Regosol, and Planosol Great Soil Groups.

Subsoiling alone resulted in no significant changes in corn production in most cases. Table 1 shows the effect of subsoiling 16 and 24 inches deep at various locations in Iowa. Subsoiling at 24 inches decreased the corn yield on Edina silt loam by 9.7 bushels per acre in 1956 and 6.4 bushels per acre on Grundy silt loam in 1957.

While there was considerable local interest in Iowa, past research indicated that few benefits should have been expected from subsoiling on the soils studied. There were no severely compacted layers in the root zone within reach of subsoiling tools.

Effect of fertilizer placement in the subsoiler slots on crop yields on the Ida and Webster-Glencoe soils is summarized in table 2. The amounts of N, P_2O_5 and K_2O applied per acre were 80-80-0 for the Ida and 0-120-0 for the Webster-Glencoe soil. Fertilizer was distributed in a band in the bottom of the slot on Ida and in a zone extending upwards 4 inches from the bottom of the slot on the Webster-Glencoe soil.

Note that when the fertilizer was plowed down, yields were better than with deep placement. The lower yields for the 16-inch placement as compared to plow layer placement on the Webster-Glencoe soil were still noticeable 3 years after application.

Illinois Research Results

Subsoiling trials were made on Ashkum, Drummer, Elliott, Martinton, and Symerton soils at eight locations in Will and Kankakee counties. These soils are representative of the Brunizem and Humic-Gley Great Soil

TABLE 1
Effect of Subsoiling 16 and 24 Inches Deep on the Corn Yield at Various Locations in Iowa

Location number	*Time of subsoiling*	*Year corn grown*	*Soil type*	*Subsoiling depth* None	*Subsoiling depth* 16 inches	*Subsoiling depth* 24 inches
				Bushels per Acre		
1	April '55	'55	Ida silt loam	31.4	—	[1]30.4
2	Oct. '55	'56	Marshall silt loam	52.2	49.6	49.8
3	Oct. '55	'56	Galva silt loam	98.8	96.0	84.6
4	Oct. '55	'56	Webster-Glencoe silty clay loam	60.8	61.4	62.2
5	Nov. '55	'56	Edina silt loam	68.4	64.4	[2]58.7
6	Oct. '55	'56	Grundy silt loam	78.0	78.0	74.6
7	Nov. '56	'57	Galva silt loam	97.8	96.4	—
2	Oct. '55 and '56	'57	Marshall silt loam	99.4	103.5	97.8
6	Oct. '55 and '56	'57	Grundy silt loam	104.3	103.3	[3]97.9
5	Oct. '55	'57	Edina silt loam	59.3	56.3	55.2
4	Oct. '55	'57	Webster-Glencoe silty clay loam	73.4	71.0	75.6

[1] The subsoiler penetrated to only 20 inches. [2] Yield decrease over no subsoiling treatment significant at 1 percent level.
[3] Yield decrease over no subsoiling treatment significant at 5 percent level.

TABLE 2

The Effect of Plowed-under and Deep-placed Fertilizer on Corn and Oat Yields in Iowa

Soil type	*Time of application*	*Year crop grown*	*Crop*	*Fertilizer placement*[1] *No Fertilizer*	*Plowed under*	*16 inches deep*	*24 inches deep*
				Bushels per Acre			
Ida silt loam	April 1955	1955	Corn	21.0	39.8	—	[2]37.6
Webster-Glencoe silty clay loam	Oct. 1955	1956	Corn	54.4	68.5	[3]58.5	64.5
Webster-Glencoe silty clay loam	Oct. 1955	1957	Corn	62.0	82.9	[4]70.0	79.8
Webster-Glencoe silty clay loam	Oct. 1955	1958	Oats	50.0	73.9	[4]61.7	69.5

[1] The deep-placed fertilizer on the Ida silt loam was applied in the bottom of a subsoiled slot. For the Webster-Glencoe soil it was distributed from the bottom to 4 inches above the bottom of the subsoiled slot. In both experiments the fertilizer was banded at 40-inch intervals immediately below where the corn rows were placed. The fertilizer placed at the various positions on the Ida soil was 80–80–0 and on Webster soil was 0–120–0. In all cases the comparison between fertilizer and no fertilizer was significant at the .05 or .10 level of probability. [2] The subsoiler and fertilizer penetrated only to 20 inch depth. [3] Significantly lower at .05 probability level than for phosphate plowed under. [4] Significantly lower at .10 probability level than for phosphate plowed under.

TABLE 3

Effect of Subsoiling 12 and 18 Inches Deep in the Fall of 1955 on Corn Yields in 1956 and 1957 at Various Locations in Will and Kankakee Counties in Illinois

Location number	*Soil type*	*Depth subsoiled* *none*	*12 inches*	*18 inches*	*Depth subsoiled* *None*	*12 inches*	*18 inches*
		1956—Bushels per Acre			*1957—Bushels per Acre*		
1	Ashkum silty clay loam	79.3	76.7	83.5	109.7	102.0	99.2
2	Drummer silty clay loam	70.7	74.3	74.4	62.9	66.8	[1]84.3
3	Drummer silty clay loam	83.0	84.4	79.7	100.1	99.3	97.3
4	Drummer silty clay loam	67.9	78.6	75.3	—	—	—
5	Elliott silt loam	75.6	77.5	90.2	92.5	85.1	95.8
6	Elliott silt loam	50.1	53.2	58.4	71.0	74.2	67.0
7	Martinton silt loam	76.3	74.3	76.7	—	—	—
8	Symerton silt loam	96.3	96.2	[1]102.1	77.1	75.2	80.6

[1] Yield increase over no subsoiling treatment significant at .05 probability level.

Groups. Sub-soiling 10-12 and 16-18 inches deep was compared with ordinary plowing. An implement similar to that shown in figure 1 was used at 40-inch intervals. Subsoiling was done in September 1954, when the soils were relatively dry.

The subsoiling operations on the Ashkum and Drummer soils were perpendicular to the row directions; on the other soils it was done across the slope and generally parallel to the rows. The areas were first- or second-year legume seedings and were fall plowed, usually several weeks after subsoiling. Previous rotations generally had been 2 or 3 years of corn or soybeans, followed by oats and 1 year of alfalfa. Lime and phosphate had been applied to the fields on the basis of needs indicated by soil tests.

Th effect of subsoiling on corn yields in the first and second years after treatment of these soils is shown in table 3. Among the eight test areas in 1956, statistical analysis indicates that only on the Symerton soil subsoiled at 18 inches is there a good probability that the increased yield was due to subsoiling and not to other chance differences in the test plots. Six of the experiments were continued during the second year. Only the 18-inch treatment on one Drummer soil gave a substantial increased yield that was statistically significant, the other Drummer soil studied showed a small yield decrease in the second year.

These tests indicated that even for the same soil type, benefits from subsoiling can be expected only part of the time and at few locations. Benefits probably will occur where there are severely compacted soil layers in the root zone within reach of the subsoiler.

The experiments started at Carbondale in 1955 are on Weir silt loam, a claypan soil. Phosphate and potash

Figure 2. A cross section of an area subsoiled on a 42-inch spacing at a depth of 24 inches. About one-half the subsoil between normal depth of plowing and the depth of subsoiling was disturbed by the subsoiling operation.

fertilizer were mixed with the soil at 1, 2, 3, and 4 times the total requirements indicated by soil tests for the upper 3 feet of soil. This mixing of fertilizer and soil was done to depths of 9, 18, 27, and 36 inches. The 9-inch depth mixing was done by plowing and disking, while a disk plow was used for this purpose to the 18-inch depth. At depths greater than 18 inches the soil was removed to the 27- or 36-inch depth, mixed with lime and fertilizer by using road grading equipment and then replaced on the test plots.

Preliminary results reported for 1956 showed that even though corn rooting was influenced markedly, yields were not affected by depth to which lime and fertilizer were mixed with the soil (3). *Lime and fertilizer increased yields and mixing the fertilizer in the topsoil was as effective as mixing it in the subsoil layers.*

Higher rates of fertilization above minimum requirements did not give significant yield increases. Higher rates of fertilizer application in the surface soil layer tended to decrease yields. It still is too early for a report of any residual effects of these treatments to be available.

▶ *Missouri Research Results*

Subsoiling alone appeared to be detrimental to yields in these studies conducted on the claypan Mexico silt loam at McCredie from 1941 to 1953. This is probably because subsoil tillage unavoidably mixes some of the acid subsoil with the more fertile topsoil. Only when lime and phosphate fertilizer were mixed with the subsoil or placed in subsoil slots was there any evidence of benefit (6, 12). The lime and phosphate were applied in furrow bottoms and mixed into 7 inches of the subsoil by shattering the layer with a road plow or a lister point before the topsoil was again turned into each furrow. This method improved the rooting and growth of sweetclover and resulted in a small increase in corn and soybean yields, but it did not increase the yields of small grains.

These plots, originally treated in 1941 and retreated in 1947, were seeded to alfalfa in 1955 to study the residual effects on hay yields from subsoil shattering and deep placement of lime and fertilizer. For 10 cuttings during the following 3 years, the average increase per cutting was 0.09 tons per acre on the treated plots. Though small, the increase was consistent enough to be significant and to indicate that deep treatment of acid subsoils may benefit deep-rooting legumes.

Beef production and the carrying capacity of a brome-ladino pasture treated by shattering the subsoil with a lister point, then mixing lime and fertilizer with the soil to a depth of about 15 inches, were not significantly better than that of a surface-fertilized bluegrass pasture. Runoff, likewise, was not significantly different.

The plowsole method of treatment on terraced areas gave an apparent average yield increase per acre of 4.0 bushels of corn for 7 crop years and 2.45 bushels of soybeans for 2 crop years, but the increases were not statistically significant. There was a small, but not significant, decrease in average runoff (0.28 inches per year) on the treated plots. Runoff decreased during each period that a sweetclover cover crop was growing. Thus, the small average decrease in runoff can be attributed to drying of the soil to greater depths by deeper rooting of the clover in the treated areas. The drier soil absorbed more rainfall, thus reducing runoff.

Four methods of placing or mixing lime alone and lime plus concentrated super-phosphate were tested in 1954. Lime was applied at the rate of 8 tons per acre alone or in combination with 400 pounds of 45-percent phosphate. Corn was grown on one set of plots, alfalfa on another. With each of the crops, each of the four methods of treatment was replicated four times for comparison with untreated check plots.

The treatments were lime or lime and phosphate (a) applied to the plowsole, (b) placed in subsoil slots to a 20-inch depth at 21-inch intervals, (c) placed in subsoil slots to a 30-inch depth at 42-inch intervals, and (d) mixed into the subsoil by a double plowing method. (The last method consisted of mixing about one-fourth of the lime or lime and phosphate into the surface and plowing 12 inches deep. The rest of the lime or lime and phosphate was mixed into the exposed subsoil. Then the subsoil was inverted into place by another 12-inch plowing.)

The results of these treatments in terms of corn yields are summarized in table 4. Placement of lime on the plowsole showed little benefit to corn. Small but significant average increases resulted from lime placement in the subsoil slots and from the double plowing method. The concentrated superphosphate had little effect or tended to decrease yields when placed with the lime.

Though statistically significant, the corn yield increases from deep placement of lime or lime and phosphate are too small to be of practical value. The average annual corn yield increases resulting from deep placement in subsoil slots from 1955 through 1958 were 7.8, –0.8, 1.6, and 1.9 bushels per acre. The treatment was most effective for the first crop after treatment.

Effects of the treatments on alfalfa yields are shown in table 5. Lime alone placed in the subsoil by these methods was of little benefit for alfalfa. In connection with superphosphate, placement in the more closely spaced slots gave a small hay yield increase.

Reasons for the difference in the response of corn and alfalfa to these methods of subsoil applications of lime or lime and phosphate must lie in chemical reactions among soil, phosphate, and lime, and in differences in the nature of corn and alfalfa roots. Examination of the soil in observation trenches across the plots in the fall of 1958 showed no evidence of alfalfa root concentrations on the plowsole or in the slots, but there was some concentration of corn roots in the treated zones containing considerable unreacted lime.

TABLE 4
Comparison of Lime and Phosphate Deep Placement Methods as Shown by Corn Yields

Subsoil treatments[1]	*Average yield 1955-58*	*Average increase over untreated subsoil*	*Probability level*[2]
		Bushels per Acre	
Untreated subsoil	95.8	—	—
Effect of lime alone:			
All lime treatments	99.0	3.2	<.01
Plowsole	96.5	0.7	.28
Plowed, 12 inches deep[3]	97.5	1.7	.02
Subsoil cleft, 7-20 in., 21 in. spacing	98.7	2.9	<.01
Subsoil cleft, 7-30 in., 42 in. spacing	103.4	7.6	<.01
Effect of Phosphate alone:			
Plowsole	99.2	3.4	<.01
Effect of Phosphate plus lime:			
Plowsole	97.0	1.2	.10
Increase over lime alone	—	0.5	.68
Plowed 12 inches deep[3]	98.1	2.3	<.01
Increase over lime alone	—	0.6	.37
Subsoil cleft, 7-20 in., 21 in. spacing	96.7	0.9	.19
Increase over lime alone	—	—2.0	<.01
Subsoil cleft, 7-30 in., 42 in. spacing	101.5	5.7	<.01
Increase over lime alone	—	—1.9	<.01

[1] Lime at 8 tons per acre and/or concentrated super-phosphate at 200 pounds per acre P_2O_5. The surface soil of all plots had lime, phosphate and potash added according to soil test requirements
[2] Probability level of .01 or less is considered as highly significant; those between .01 and .05 as significant; and those greater than .05 as not significant.
[3] Lime at 2 tons per acre was disked into the surface. The soil was plowed 12 inches deep and an additional 6 tons per acre of lime was mixed into the exposed subsoil. The subsoil was turned into place with the surface soil on top again by a second 12-inch plowing.

TABLE 5
Comparison of Lime and Phosphate Deep Placement Methods as Shown by Alfalfa Hay Yields

Subsoil treatments[1]	*Average yield*	*Average increase over untreated subsoil*	*Probability level*[2]
		Tons per Acre per Cutting	
Untreated subsoil	1.10	—	—
Effect of lime alone:			
All treatments	1.10	.00	>.99
Plowsole	1.08	—.02	.64
Plowed 12 in. deep[3]	1.11	.01	.75
Subsoil cleft, 7-20 in., 21 in. spacing	1.09	—.01	.84
Subsoil cleft, 7-30 in., 42 in. spacing	1.08	—.02	.64
Effect of phosphate alone:			
Plowsole	1.14	.04	.30
Effect of phosphate plus lime:			
Plowsole	1.16	.06	.09
Increase over lime alone	—	.08	.04
Plowed 12 in. deep[3]	1.09	—.01	.75
Increase over lime alone	—	—.02	.52
Subsoil cleft, 7-20 in., 21 in. spacing	1.18	.08	.03
Increase over lime alone	—	.09	.02
Subsoil cleft, 7-30 in., 42 in. spacing	1.13	.03	.45
Increase over lime alone	—	.05	.35

[1, 2, 3] See corresponding footnotes, table 4.

Conclusions

The results of these and other studies indicate that the benefits, when they occur, from deep tillage and deep fertilization are both variable and relatively small in the Midwest. Considering the expense it is doubtful if subsoiling treatments can be justified in the North-central States—particularly as compared with the use of good fertility and management practices in the usual plow layer.

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Contribution from the Soil and Water Conservation Research Division and the Agricultural Engineering Research Division, Agricultural Research Service, in cooperation with the Iowa and Missouri Agricultural Experiment Stations. Journal Paper No. J-3729 of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa; Project 787. Missouri Agricultural Experiment Station Journal Series No. 2071.