Effect of Subsoiling and Deep Fertilizer Placement on Yields of Corn in Iowa and Illinois

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SYNOPSIS. Subsoiling to 16 and 24 inches depth did not increase corn yields in Iowa during 1955, 1956, and 1957. In Illinois, subsoiling to 12 and 18 inches depth produced a significant corn yield response at the lower depth in only 2 out of 14 experiments in 1955 and 1956. Fertilizer placed deep in the subsoiled channel was not as effective as fertilizer plowed under in the Iowa experiments.

DURING recent years considerable interest has developed in subsoiling and deep fertilizer placement in Iowa, Illinois, and surrounding states. Many have felt that compaction due to tillage machinery was creating slowly permeable layers that restricted water movement into and through the soil and thereby increased runoff and erosion. Others believed that pressure pans were restricting root development and still others believed subsoiling aided drainage.

In more recent years subsoiling has been proposed also as a means of applying fertilizer or lime into infertile and acid subsoils. It was believed that root growth in the subsoiled channels would be stimulated in this way, and yields would be increased as a result of the deep-placed fertilizer and better growing conditions.

Subsoiling has considerable appeal to farmers, but research has shown few benefits from subsoiling in the North Central United States (2, 3, 8, 10), where soils regularly freeze to considerable depth, although some benefits have

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been reported in the South and Southeast (6, 7) and in the West (4), where little or no soil freezing occurs. Duley (1) has summarized the research in the Great Plains and found no evidence of general benefits from subsoiling. Recently, workers in Indiana (9) have been working on stabilizing loosened subsoiled channels by placing bands of crop residues in the subsoiler slot. Studies in Kansas (5) and Minnesota (8) show that the draft requirement for subsoiling is high compared to other tillage operations, making it costly.

Prior to the start of this study very few quantitative data concerning the benefits of subsoiling were available in Iowa and Illinois. While data in the literature from surrounding states showed little benefit from subsoiling, it was thought that perhaps larger modern machinery may have created a compaction problem in Iowa and Illinois. It was thus the purpose of this study to compare corn yields on a number of locations and to measure soil bulk density on selected sites as influenced by subsoiling.

PROCEDURE

Iowa

Subsoiling and deep fertilizer placement experiments were started in the spring of 1955 and continued through 1958. Sites for the experiments were chosen in areas where considerable local interest existed and on soil types of major importance with wide contrasts in soil properties. Experiments were conducted on a total of 12 locations over 3 years and figure 1 presents the experiment locations and soil series.

The experimental treatments were:

- No subsoiling
  - a. no fertilizer
  - b. fertilizer plowed under
- Subsoiled to 16 inches depth
  - c. no fertilizer
  - d. fertilizer plowed under
  - e. fertilizer applied with subsoiler 12 or 16 inches deep
- Subsoiled to 24 inches depth
  - f. no fertilizer
  - g. fertilizer plowed under
  - h. fertilizer applied with subsoiler 18 or 24 inches deep

The treatments will be referred to later as treatments a through h. Two exceptions to the above treatments are indicated in the tables. In most cases the fertilizer was concentrated superphosphate at 80 pounds of P_2O_5 per acre, although the rate sometimes varied. In one case nitrogen was applied with the phosphorus.

A randomized complete block design was used with 4 or 6 replications. Plot size was 26⅔ feet (eight 40-inch rows) by 50 feet. The subsoiling and deep fertilization were done with the equipment shown in figure 2. Fields were subsoiled on 40-inch intervals and corn was planted directly over the subsoiled channel. All areas were subsoiled in the fall except on the Ida soil which was subsoiled in early spring. In the fall of 1955 treatments were applied at the Edina, Marshall, Galva, and Webster–Glencoe soil locations. On the Marshall and Grundy soils the treatments were repeated in the fall of 1956 on the same plots. Residual effects from the 1955 subsoiling treatments were measured on the Edina soil in 1957 and on the Webster–Glencoe soil in 1957 and 1958. The Galva experiment was relocated in 1956. The soils were dry for spring and fall subsoiling in 1955 but too wet for good soil shattering in 1956.

All areas were spring-plowed and the seedbeds were prepared in the conventional manner except on the Marshall soil, where the corn was planted by hard-ground listing with no prior tillage after the subsoiling, and on the Webster–Glencoe soil, which was fall-plowed. Uniform high amounts of nitrogen (except in the Ida experiment) and potash were applied at all locations. Row fertilizer (100 pounds per acre of 6–24–0) was applied at time of planting on the Grundy, Marshall, and Edina sites and care was taken to place the corn rows directly over the subsoiled channel. Corn stands were generally uniform at any one location and ranged between 12,000 and 16,000 plants per acre among locations. The stands were considered sufficient for optimum grain yields under the moisture conditions encountered.

Moisture limited corn growth at many locations. A summary of rainfall during the experimental period is given in table 1.

Iowa Soil Types

The soils at the experimental sites have been classified as follows:

Ida silt loam is an Azonal soil developed under grass vegetation on steep slopes from coarse-textured loess. At the site used for this experiment the soil was a uniform grayish-brown, calcareous, highly permeable silt loam throughout the profile. The slope was 12%.

Marshall silt loam is a Brunizem developed on thick loess. It has about 8 inches of a dark brown fine silt loam surface and a moderately permeable brown silty clay loam B horizon extending to a depth of 24 inches. The slope was 6%.

Galva silt loam is a Brunizem developed under grass vegetation from loess on nearly level to gentle slopes. The soils at both experimental sites have a dark brown silt loam surface to a 10-inch depth and a moderately permeable yellowish-brown silty clay loam subsoil extending to a depth of about 36 inches. The slopes at both locations ranged from 2 to 4%.

Webster and Glencoe are Humic Gley soils developed from Wisconsin till. The soils have a silty clay loam texture throughout the profile. The surface soil to a depth of about 18 inches is black, grading to an olive-gray mottled subsoil which extends to 32 inches. The slopes ranged from 0 to 1%.

Edina silt loam is a claypan soil which has developed on level topography from loess under grass vegetation. It consists of 8 inches of dark grayish-brown silt loam which grades into a light gray ashy silt loam subsurface horizon. The subsoil which begins abruptly at about 18 inches is a dark gray mottled plastic clay and extends to a depth of 3.5 feet.

Grundy silt loam is a Brunizem developed on gentle slopes from fine-textured loess under grass vegetation. It has a very dark

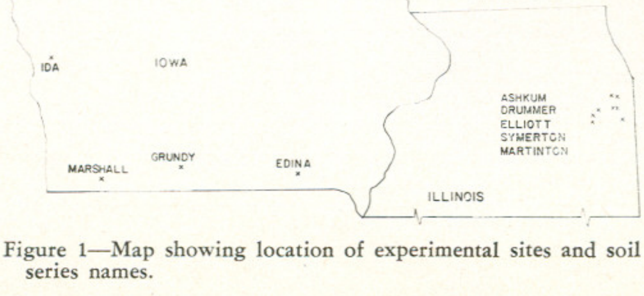

Figure 1—Map showing location of experimental sites and soil series names.

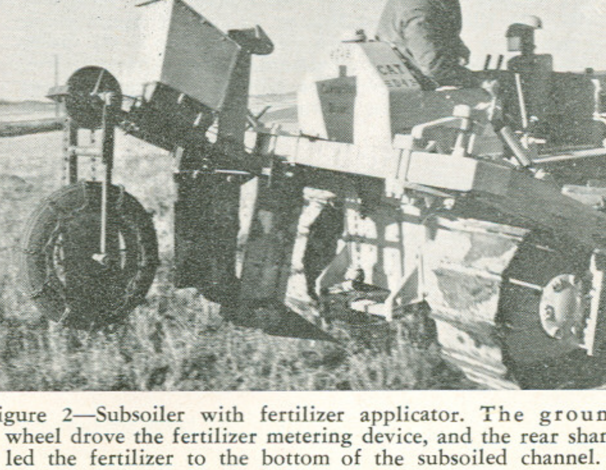

Figure 2—Subsoiler with fertilizer applicator. The ground wheel drove the fertilizer metering device, and the rear shank led the fertilizer to the bottom of the subsoiled channel.

Table 1—Precipitation and deviations from normal in inches during the corn-growing and winter periods at various locations in Iowa and Illinois where subsoiling and deep fertilizer placement experiments were conducted in 1955, 1956 and 1957.

Experiment location No.	Soil series	May 1955 to Sept. 1955		Oct. 1955 to April 1956		May 1956 to Sept. 1956		Oct. 1956 to April 1957		May 1957 to Sept. 1957	
		Observed	Dev. from normal	Observed	Dev. from normal	Observed	Dev. from normal	Observed	Dev. from normal	Observed	Dev. from normal
				Iowa experiments							
1	Ida	11.00	-7.96								
2	Marshall			2.81	-8.79	16.31	-4.56	11.44	-2.77	19.82	-1.05
3	Galva			4.71	-3.11	13.96	-3.75				
4	Webster-Glencoe			5.54	-5.63	14.28	-5.61	6.95	-4.22	17.81	-2.08
5	Edina			7.14	-6.69	14.77	-5.40	10.27	-3.56	18.01	-2.16
6	Grundy			4.60	-7.90	17.85	-3.10	11.00	-1.74	16.49	-3.44
7	Galva							8.02	-1.66	22.72	+4.35
				Illinois experiments (Kankakee, Ill.)							
		Oct. 1954 to April 1955		May 1955 to Sept. 1955		Oct. 1955 to April 1956		May 1956 to Sept. 1956			
		Observed	Dev. from normal	Observed	Dev. from normal	Observed	Dev. from normal	Observed	Dev. from normal		
All locations		15.78	-0.43	13.62	-3.85	13.42	-2.79	12.52	-4.95		

grayish-brown fine silt loam surface 9 inches thick. The surface soil grades into a mottled grayish-brown and gray slowly permeable silty clay loam subsoil which reaches maximum density at a depth of about 20 inches. The subsoil is slowly permeable to a depth of 30 to 40 inches but below this depth it grades gradually into the more open and friable silty parent material. The slope is about 3%.

Illinois

Experiments were established at a total of 8 locations on Ashkum, Drummer, Elliott, Martinton, and Symerton soils (figure 1) to compare *(A)* no subsoiling, *(B)* subsoiling 10 to 12 inches deep and *(C)* subsoiling 16 to 18 inches deep. The subsoiling was done at 40-inch intervals with a commercial chisel-type subsoiler similar to the one shown in figure 2. The subsoiling was done in September of 1954 when the soil at all locations was relatively dry. The subsoiling on the Ashkum and Drummer soils was perpendicular to the direction of corn rows whereas on the Elliott, Martinton and Symerton soils the subsoiling was across the slope and thus generally parallel to the row direction. The treatments were arranged in a randomized block design and replicated 4 times. The plots were 50 feet wide and either 66 or 50 feet long.

All experiments were located on first- or second-year legume seedings. The experimental areas were fall plowed, usually several weeks after subsoiling, and prepared for corn planting in the conventional manner. The previous rotations had generally been 2 or 3 years of corn or soybeans followed by oats and 1 year of alfalfa. The fields had been limed and fertilized according to soil tests.

Corn yields were measured in all 8 experiments in 1955 and residual effects were measured in 1956 at the 6 sites in corn. Stand counts were uniform at any one location and varied from 12,000 to 15,000 plants per acre among locations. They were considered near optimum for the soil moisture conditions encountered.

Illinois Soil Types

The soils at the experimental sites have been classified as follows:

Ashkum silty clay loam is a Humic Gley. It is poorly drained and consists of 11 inches of black silty clay loam surface material which grades to a grayish brown mottled fine silty clay loam B horizon from 15 to 40 inches. Below 40 inches is grayish brown fine silty clay loam glacial till.

Drummer silty clay loams are Humic Gley soils. The soils at the 3 experimental sites are poorly drained and were similar in profile appearance. They have a mottled black silty clay loam extending to about 12 inches depth and grading to a gray or dark brown-mottled silty clay loam B horizon at about 14 inches and extending to 36 to 38 inches. Below 38 inches the soils varied somewhat but generally are stratified with loam and silty clay loam materials.

Elliott silt loam is a Brunizem. The soils at the two sites are imperfectly drained, have 8 inches of very dark gray silt loam on the surface grading to a brown silty clay loam B horizon from 15 to 32 inches. Below 32 inches is a grayish brown silty clay loam material.

Martinton silt loam is a Brunizem. The soil at the experimental site is imperfect to low moderately well drained. The surface 9 inches of soil was very dark gray silt loam. The B_2 horizon from 14 to 32 inches is brown to dark grayish brown mottled silty clay loam underlain by stratified silty clay loam and sandy clay loam layers to more than 60 inches.

Symerton silt loam is a Brunizem, moderately well drained, has 8 inches of very dark gray brown silt loam which grades to a yellowish brown clay loam B horizon from 12 to 30 inches. Below 30 inches is a bright loam stratified material.

RESULTS

The effects of subsoiling treatments to 16 and 24 inches depth and a no subsoiling treatment on corn yields in Iowa are given in table 2. These values represent the mean of treatments a and b for no subsoiling, treatments c and d for the 16-inch subsoiling, and treatments f and g for the 24-inch subsoiling, without and with plowed-under fertilizer in each case.

In none of the 11 experiments did subsoiling produce a significant yield increase. A reduction of 9.7 bushels per acre for subsoiling at a 24-inch soil depth was significant on the Edina soil in 1956. Likewise, subsoiling to a depth of 24 inches decreased corn yields on the Grundy soil by 6.4 bushels per acre in 1957. In several other experiments the trend was toward lower yields from subsoiling although they were not significant at the 5% level.

During August and September of 1956 bulk density samples were taken on the Webster–Glencoe and Marshall experiments that had been subsoiled in the fall of 1955. The samples were taken with the equipment shown in figure 3 in the corn row which was planted over the subsoiled channel. The effects of subsoiling on bulk density of the

Table 2—Effect of subsoiling 16 and 24 inches deep on the yields of corn at various locations in Iowa.

Location No.	Time of subsoiling	Year corn grown	Soil type	Subsoiling treatment: None	16 inches	24 inches
				bushels per acre		
1	April 1955	1955	Ida silt loam	31.4	-	30.4†
2	Oct. 1955	1956	Marshall silt loam	52.2	49.6	49.8
3	Oct. 1955	1956	Galva silt loam	98.8	96.0	84.6
4	Oct. 1955	1956	Webster-Glencoe silty clay loam	60.8	61.4	62.2
5	Nov. 1955	1956	Edina silt loam	68.4	64.4	58.7**
6	Oct. 1955	1956	Grundy silt loam	78.0	78.0	74.6
7	Nov. 1956	1957	Galva silt loam	97.8	96.4	-
2	Oct. 1955 and 1956	1957	Marshall silt loam	99.4	103.5	97.8
6	Oct. 1955 and 1956	1957	Grundy silt loam	104.3	103.3	97.9*
5	Oct. 1955	1957	Edina silt loam	59.3	56.3	55.2
4	Oct. 1955	1957	Webster-Glencoe silty clay loam	73.4	71.0	75.6

* Yield decrease over no subsoiling treatment significant at 5% level.
** Yield decrease over no subsoiling treatment significant at 1% level.
† The subsoiler penetrated to only 20 inches.

Figure 3—Soil sampler used to obtain undisturbed soil cores. The core was sectioned into 3-inch increments for bulk density determinations.

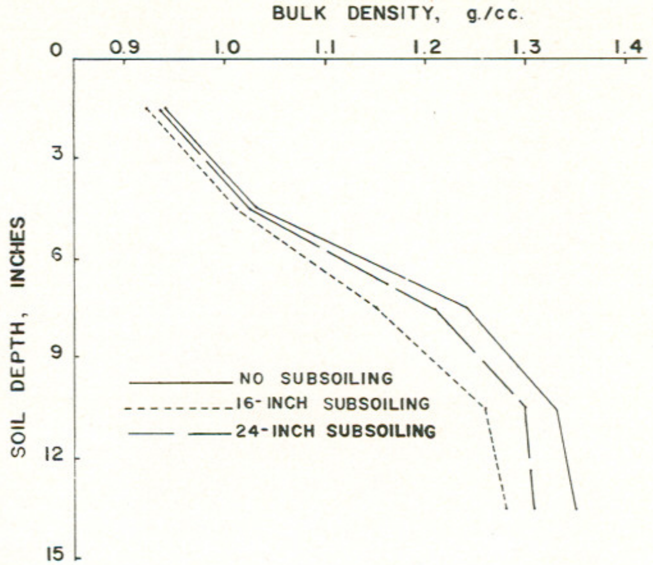

Figure 4—Effect of subsoiling on the bulk density of a Marshall silt loam approximately 10 months after treatment.

Marshall soil are given in figure 4 and for the Webster–Glencoe soil in figure 5.

On the Marshall soil the differences in bulk density between the check and the 16-inch subsoiling were significantly different in the 6- to 9-, 9- to 12-, and 12- to 15-inch layers. The differences between the check and the 24-inch subsoiling were not significant at the 5% level. Differences in bulk density between subsoiling and no subsoiling were not significant at any depth on the Webster–Glencoe soil. In both soils the bulk density values are in the range where little or no increase in plant growth would be expected from a loosening of the soil. In the two soils studied no compacted horizon within the surface 15 inches was found to exist and visual observations indicated that compacted layers did not occur within the top 2 feet of soil on these 2 soils or in any of the other soils studied.

The effects of subsoiling 12 and 18 inches deep in the fall of 1954 on corn yields at 8 locations in Illinois in 1955 and at 6 of the same locations in 1956 are shown in table 3. In one location in 1955 on Symerton silt loam a significant yield increase of 5.8 bushels per acre was obtained from the 18-inch subsoiling although the increase due to 12-inch subsoiling was less than 2 bushels per acre and not significant. While a significant yield increase at only 1 location was obtained in 1955 on the sloping Elliott, Martinton, and Symerton soils the average increases due to subsoiling 12 and 18 inches deep were 0.7 and 7.2 bushels per acre, respectively. Mean yield increases on the nearly level Drummer and Ashkum soils were even smaller and not significant, averaging 3 bushels per acre.

Corn yields were significantly increased due to the residual effects of subsoiling at only 1 of the 6 locations in 1956 and this occurred only when the subsoiling was done at an 18-inch depth. There were increases or decreases at other locations and depths but none was significant.

The responses to fertilizer and the comparisons of fertilizer plowed under with fertilizer placed in bands 16 or 24 inches deep are given in table 4. The table shows only

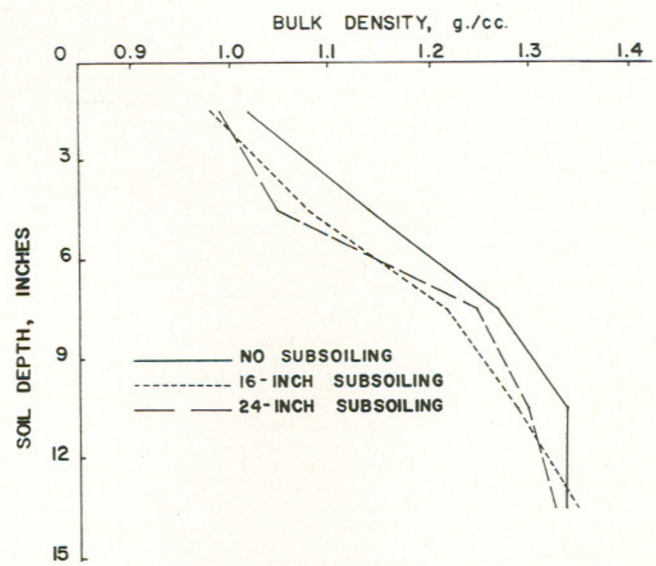

Figure 5—Effect of subsoiling on the bulk density of a Webster–Glencoe silty clay loam approximately 10 months after treatment.

those experiments in which a statistically significant response to fertilizer or placement occurred.

The experiments on the Ida soil in 1955 and the Webster–Glencoe soil in 1956, 1957, and 1958 showed a significant response to fertilizer. On the Ida soil there was no significant difference in the effects of plowed-under and deep-placed fertilizer. In 1956 on the Webster–Glencoe location the yield reduction caused by the 16-inch-deep placement of phosphorus as compared to plowed-under phosphorus was significant at the 5% level and in 1957 and 1958 it was significant at the 10% level. In all years at the Webster–Glencoe locations the mean yields were lower when the phosphorus was placed at the 24-inch depth as compared to the plowed-under phosphorus but the differences were not significant.

Table 3—Effect of subsoiling 12 and 18 inches deep in the fall of 1955 at various locations in Will and Kankakee Counties in Illinois on corn yields in 1956 and 1957.

Location No.	Soil type	1955 subsoiling			1956 subsoiling		
		None	12 inches	18 inches	None	12 inches	18 inches
		bushels per acre					
1	Askum 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	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	102.1*	77.1	75.2	80.6

* Yield increase over no subsoiling treatment significant at 5% level.

Table 4—The effect of plowed-under and deep-placed fertilizer on yields of corn and oats in Iowa.

Experiment location No.	Soil type	Time of application	Year crop	Test crop	No fertilizer	Fertilizer placement*		
						Plowed under	16 inches deep	24 inches deep
						bushels per acre		
1	Ida silt loam	April 1955	1955	Corn	21.0	39.8	-	37.6†
4	Webster-Glencoe silty clay loam	Oct. 1955	1956	Corn	54.4	68.5	58.5‡	64.5
4	Webster-Glencoe silty clay loam	Oct. 1955	1957	Corn	62.0	82.9	70.0§	79.8
4	Webster-Glencoe silty clay loam	Oct. 1955	1958	Oats	50.0	73.9	61.7¶	69.5

* The deep-placed fertilizer on the Ida silt loam was applied in April 1955 in the bottom of a subsoiled slot. That on the Webster soil was distributed in a band from the bottom to 4 inches above the bottom of the subsoiled slot in October 1955. In both experiments the fertilizer was banded at 40-inch intervals immediately below where the corn rows were placed. The fertilizer on the Ida soil was 80+80+0 and on the Webster soil was 0+120+0. In all cases the comparison between fertilizer and no fertilizer was significant at the 5% or 1% level.
† The subsoiler and fertilizer penetrated to only 20 inches depth.
‡ Significantly lower than Plowed-under at 5% level.
§ Significantly lower than Plowed-under at 10% level.

DISCUSSION

In this study the treatment plots were randomized without protection from runoff between plots. However, rainfall was below normal with few excessive storms at any of the locations. Observations indicated that runoff was negligible. Thus conditions for measuring differences in yields due to differences in runoff were not present in these experiments. On the Webster–Glencoe and Edina soils in Iowa and the Ashkum and Drummer soils in Illinois, where drainage is sometimes desirable, rainfall was low enough so that excess soil moisture was not a problem. Moisture deficiencies frequently occurred, in all experiments in 1955 and 1956 and in some locations in 1957 (see table 1). Thus, if the subsoiling encouraged deeper root penetration into moist soil it likely would have been reflected in increased yields. If, however, the loosened subsoiled slot remained open from the time of treatment application in the fall until the time of seedbed preparation in the spring, evaporation of moisture from deeper layers may have caused the decreased yields obtained after subsoiling. A small amount of mixing of less fertile subsoil with more fertile surface soil also occurred.

In experiments in other sections of the country where subsoiling has improved crop yields, pressure or natural compacted zones have been observed and root restriction due to the compacted zone was usually noticed. No such compacted soil horizons limiting vertical root extension were observed in these experiments. Thus, from the bulk density and profile characteristics of the soils studied yield increases from subsoiling probably should not be expected. However, at the time of initiation of these experiments considerable local interest was expressed and many farmers were using subsoiling equipment on the same soil types as studied in these experiments.

In only 2 of the 7 experimental locations did phosphorus or phosphorus plus nitrogen produce a significant increase in corn yields over the no fertilizer treatments. In both cases the plowed-under fertilizer was more effective than the deep-placed fertilizer. The Ida experiment in 1955 was conducted under severe drouth conditions, and the Webster–Glencoe experiment in 1956, 1957, and 1958 under moderate to good moisture conditions. Thus some range in soil moisture conditions was sampled.

SUMMARY

Subsoiling to 16 and 24 inches depth did not produce significant yield increases in 12 experiments on 7 important soil types in Iowa in 1955 through 1958. In 2 cases subsoiling to 24 inches depth decreased corn yields significantly. In Illinois in 1955, corn yields were increased significantly by subsoiling to 18 inches depth in 1 out of 8 experiments on 5 soil types. The residual effect of subsoiling increased yields at 1 of the 6 locations in 1956. Measurements at two locations in Iowa generally showed small and unimportant decreases in soil bulk density due to subsoiling.

Significant responses to fertilizer were obtained at two locations in Iowa. On an Ida soil under drouth conditions, phosphorus plus nitrogen produced insignificantly greater yield increases when plowed under than when placed in the subsoiled channel 20 inches deep. On a Webster–Glencoe soil, plowed-under phosphorus produced greater corn yields the first and second years and greater oat yields the third year after application than phosphorus placed 16 or 24 inches deep in the subsoiled channel.

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