Reprinted from the AGRONOMY JOURNAL
Vol. 52:193–195, 1960.

Results of Deep Fertilization and Subsoiling on a Claypan Soil[1]

V. C. Jamison and J. F. Thornton[2]

SYNOPSIS. Subsoil shattering alone on Mexico silt loam depressed crop yields. Applications of lime or phosphate to the plow sole before shattering was slightly beneficial, the residual effects for alfalfa lasting several years. Subsoil applications of lime and triple superphosphate in subsoiler clefts or by deep plowing gave significant corn or alfalfa yield increases in some cases. However, if the soil surface was adequately fertilized the increases over surface treatment alone were small and of questionable value.

MANY of the prairie soils of the Central States region have certain soil management difficulties arising from the presence of a plastic clay layer or "claypan" in the subsoil. This layer is characterized by poor drainage as well as by poor fertility and high acidity. In most soils of this group the claypan is more than 6 inches thick and starts at depths of about 18 inches. The layer above the claypan is also low in fertility but more accessible to soil treatments. Several attempts have been made to increase the depth of the more fertile surface layer or improve drainage through the claypan (1, 3, 4, 5, 6, 7).

Preliminary results of experiments at McCredie, Missouri, seemed to suggest a solution to internal drainage and fertility problems on these soils (5, 6, 7).

Later experiments were designed to determine the optimum depth and spacing of subsoil treatment for crop production on claypan soils and to determine the effect of deep treatment on soil moisture retention by field-sized areas of these soils.

EXPERIMENTAL METHODS

Different methods of treating the subsoil of Mexico (formerly Putnam, rolling phase) silt loam were used. Tests were made on soil used for small grains, for row crops, and for alfalfa hay production. Some of the earlier treatments (7) were repeated on the same plots in 1947 and on terraced areas for grain crops in 1949. In 1954, other plots were treated by use of deep placement equipment.

Plow sole tillage—The plow sole tillage method consisted of plowing to a depth of 9 to 10 inches with a 16-inch single bottom plow, spreading lime on each furrow bottom at 4 tons per acre, and shattering to an additional depth of 7 to 8 inches with a 12-inch road plow before turning the next furrow (6, 7). The subsoil shattered by the smaller plow fell back into the furrow with a minimum of mixing with the surface soil. The lime sifted down into the shattered layer. Some additional mixing of lime with the subsoil was accomplished by slippage of the tractor wheel in the furrow as the surface soil was turned.

The original 27 field plots (6, 7) were re-treated in the 9- to 18-inch layer by the plow sole tillage method in 1947. The earlier deep treatment in 1941 with lime at 2 tons per acre was considered inadequate and the deep treatment was increased to 4 tons of lime in addition to one ton of rock phosphate per acre. The 3-year rotation was changed from corn, oats with lespedeza, and barley with sweet clover to a 3-year rotation of corn, soybeans, and wheat with sweet clover. Surface treatment for both deep-treated and check plots consisted of plowing 10 inches deep, applying rock phosphate at 1000 pounds per acre on corn and soybeans (1949–1950), applying 3 tons of lime per acre in 1947 and 100 pounds of 0–20–20 per acre each year. In addition, nitrogen was applied on corn at 100 pounds per acre and on wheat at 25 pounds per acre.

Two field terraces were treated by the plow sole tillage method with lime at 4 tons per acre in August 1949. Two similar terraces in the same field served as checks. A two-year rotation of corn-small grain with sweet clover was used through 1953 with each crop occurring on a check and a treated area each year.

Deep treatment—In the fall of 1954 different methods of mixing or placing lime and triple superphosphate in the subsoil were tested. The experimental design was a split-plot factorial replicated four times for corn and alfalfa crops. The surface soil of all plots had lime, phosphate, and potash added according to soil tests (2). Four lime treatments and a no-treatment check were tested. The amount of lime needed to raise the 7- to 14-inch layer to 80% base saturation (8 tons per acre) was applied to the subsoil for each treatment. The 4 treatments were, *(1)* lime applied to the plow sole, *(2)* lime mixed with subsoil by double plowing 12 inches deep,[3] *(3)* lime placed in subsoiler clefts to 20-inch depth on 21-inch centers, and *(4)* lime placed in subsoiler clefts to 30-inch depth on 42-inch centers. Each of these plots was split and triple superphosphate (0–45–0 at 400 pounds per acre) was mixed or placed in the soil in half of each plot in the same manner as the lime. Buffalo alfalfa was seeded April 4, 1955. Two cuttings were harvested that year and 3 or 4 cuttings each year since then. Corn yields were measured for 4 years before this experiment was terminated in the fall of 1958.

After the termination of the experiment, a 3-foot trench was cut across at least one of each of the treatments. The exposed subsoil was examined for rooting depth and distribution, for residual lime in the subsoil clefts, and for soil acidity in and outside the clefts.

DISCUSSION OF RESULTS

Plow sole tillage—Crop rotations—The effect of the plow sole tillage method of subsoil treatment with and without lime and phosphate applied to the plow sole before shattering upon yields of corn, wheat, and soybeans is shown in table 1. Subsoiling alone by this method tended to depress yields. The depression for wheat was significant. A certain amount of mixing of infertile clay loam from the subsoil with the silt loam surface was doubtless responsible for this effect (7). Treating the subsoil with lime and rock phosphate appears to have more than over-

[1] Contribution from the Soil and Water Conservation Research Division, ARS, USDA, and the Missouri Agricultural Experiment Station. Missouri Agr. Exp. Sta. Jour. Series No. 1995.

[2] Soil Scientist and Agricultural Engineer, respectively.

[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 1—Effect of plow sole tillage with and without lime and phosphate upon yields of corn, wheat, and soybeans.

Subsoil treatment*	Season						Annual aver.	Diff. †	Prob. level ‡
	1948	1949	1950	1951	1952	1953			
	Corn yields, bu./A								
Untreated	140	101	112	108	81	62	101	-	-
Shattered only	133	76	109	93	87	63	94	-7	.08
Shattered, L. F.	143	87	116	112	91	64	102	2	.60
	Wheat yields, bu./A								
Untreated	35.7	28.2	19.8	30.5	29.2	39.8	30.5	-	-
Shattered only	32.6	24.1	17.9	27.3	19.4	40.7	27.0	-3.5*	.02
Shattered, L. F.	37.8	26.5	23.3	31.5	24.0	44.0	31.2	0.7	.58
	Soybeans yields, bu./A								
Untreated	31.3	31.5	42.4	32.8	27.1	17.1	30.4	-	-
Shattered only	34.1	31.9	40.4	33.3	22.6	17.6	30.0	-0.4	.65
Shattered, L. F.	34.1	33.9	45.2	32.6	26.7	19.9	32.1	1.7	.08

* All plots given full fertility treatments (2) in plow layer.
† Increase over untreated.
‡ Probability level .01 or less is considered as highly significant; .01 to .05 as significant; and greater than .05 as not significant.

Table 2—Residual effects of plow sole tillage treatments on alfalfa yields.

Subsoil treatment	Yields Tons/acre/cutting	Incr. for treat. Tons/acre/cutting	Prob. level
Untreated	1.16	-	-
Shattered only	1.14	-.02	.58
Shattered, L.F.	1.25	+.09*	.02

Table 3—Effect of subsoil liming on runoff and cornyields on terraced areas.

Measurement	Untreated	Incr. for treat.	Prob. level
Corn yields, bu./A. yr.	65.3	4.0	.19
Runoff, inches/yr.	4.37	-0.28	.10

come this detrimental effect. However, the small increases due to the treatment are not significant and such treatment is certainly not practical.

Plow sole tillage—Residual effects—The corn-soybean-wheat rotation plots were seeded to alfalfa in 1955 and the residual effects measured by hay yields (table 2). The surface soil of all plots received 0–20–20 fertilizer at 270 pounds per acre on April 1, 1955. The average yields per cutting are for 2 cuttings in 1955 and 4 each in 1956 and 1957. Although the subsoil treatment with lime and phosphate had little benefit on corn, wheat, and soybeans in the previous years there was still some small but significant benefit to a deep rooting legume even 7 to 10 years after the treatment. This is in agreement with the effect found for the growth of sweet clover (5, 6, 7).

Plow sole tillage—Terraces—The effect of subsoil liming on runoff and corn yields on the terraced areas treated in the fall of 1949 is shown in table 3. The average increase of 4.0 bushels per acre for 7 corn crops during the period 1950 to 1959 is not statistically significant. No corn was produced for grain in 1954 due to severe drouth. Actually in those years in which corn was produced on all 4 terraces there was a greater difference between the 2 replicates than between the averages for the treated and untreated areas. Soybeans were grown on these terraces for 2 years (1956 and 1957). The increase of 2.45 bushels per acre per year was not significant.

The decrease in runoff due to the treatment, though not significant, is of interest. Close inspection of the runoff records for periods indicated that the differences were greatest during the intervals when sweet clover was being grown on the terraces. Field notes indicated that clover production was somewhat more abundant and clover root penetration deeper on the subsoil-limed areas. Due to drying of the soil to a greater depth, the soil retained more rainfall on the treated than on the untreated terraces. As with corn yields, the total runoff differences for replicates were greater than those differences due to subsoil liming.

Deep treatment—Corn—The effects on corn yields of different methods of mixing lime and triple superphosphate in the subsoil are shown in table 4. In general, subsoil liming gave small but significant average increases for the 4-year period of the test. Mixing lime into the subsoil by plowing 12 inches deep was less effective than deep placement. Mixing of some infertile subsoil with the surface layer by this method may account for this difference. When phosphate was applied with lime to the plow sole, or mixed with it in the subsoil, small but not significant additional increases over the effect of lime alone were obtained. When phosphate was added with lime in the subsoil clefts the increases were significantly less than with lime alone

Table 4—Effect of deep treatments on corn production. 1955–1958.

Subsoil treatments	Average yield	Average increase	Prob. level
	bu./A.	bu./A.	
Untreated subsoil	95.78	-	-
Effect of lime alone:			
All lime treatments	99.04	3.26**	<.01
Plowsole	96.52	0.74	.28
Plowed, 12 inches deep	97.48	1.70*	.02
Subsoil cleft, 7 - 20", 21" spacing	98.70	2.93**	<.01
Subsoil cleft, 7 - 30", 42" spacing	103.45	7.67**	<.01
Effect of phosphate alone:			
Plowsole	99.18	3.40**	<.01
Effect of phosphate plus lime:			
Plowsole	96.95	1.17	.10
Increase over lime alone	-	0.43	.68
Plowed 12 inches deep	98.10	2.32**	<.01
Increase over lime alone	-	0.62	.37
Subsoil cleft, 7 - 20", 21" spacing	96.68	0.90	.19
Increase over lime alone	-	-2.02**	<.01
Subsoil cleft, 7 - 30", 42" spacing	101.50	5.72**	<.01
Increase over lime alone	-	-1.95**	.01

Table 5—Effect of deep treatments on alfalfa production.

Subsoil treatments	Average yield, tons/acre/cutting	Average increase, tons/acre/cutting	Prob. level
Untreated subsoil	1.100	-	-
Effect of lime alone:			
All treatments	1.100	.000	>.99
Plowsole	1.084	-.016	.64
Plowed 12" deep	1.111	.011	.75
Subsoil cleft, 7 - 20", 21" spacing	1.093	-.007	.84
Subsoil cleft, 7 - 30", 42" spacing	1.084	-.016	.64
Effect of phosphate alone:			
Plowsole	1.137	.037	.30
Effect of phosphate plus lime:			
Plowsole	1.159	.059	.09
Increase over lime alone	-	.075*	.04
Plowed 12" deep	1.089	-.011	.75
Increase over lime alone	-	-.022	.52
Subsoil cleft, 7 - 20", 21" spacing	1.179	.079*	.03
Increase over lime alone	-	.086*	.02
Subsoil cleft, 7 - 30", 42" spacing	1.126	.026	.45
Increase over lime alone	-	.032	.35

in the clefts. It appears that when lime and phosphate are mixed in this soil by plowing they supplement each other in their effect on corn. However, where they are placed together in a subsoil cleft with limited mixing the effectiveness of either or both on corn production is decreased.

Deep treatment—Alfalfa—The effects of the various lime and phosphate subsoil treatments on alfalfa yields are shown in table 5. In general, lime was not very effective regardless of how it was mixed or placed in the subsoil. Only where phosphate was placed with lime on the plow sole or in the 7- to 20-inch clefts were significant average yield increases obtained. The differences in the responses of corn and alfalfa to the same treatments are of interest. Mixing phosphate with lime in the soil or in a subsoil cleft appears to give opposite responses for corn and alfalfa. Reasons for the differences must lie in chemical reactions between lime, phosphate, and the soil and in differences in the nature of corn and alfalfa roots. The examination of the soil in the observation trenches cut across the plots gave no evidence of alfalfa root concentration on plow sole or in clefts, while there was some concentration of corn roots in the subsoil clefts where unreacted lime remained.

This examination of the exposed subsoil in the alfalfa plots may help explain differences in response to these treatments and to the earlier plow sole tillage method of subsoil liming (tables 2 and 5). Considerable unreacted lime was found in the bottom of each subsoil cleft. The lime had no effect on the soil pH at a distance of more than 2 inches and little effect at 1 inch from the unreacted lime deposit. Bulk density measurements in undisturbed

and disturbed subsoil zones averaged 1.347 and 1.289, respectively. The differences did not appear related to either depth or diameter of alfalfa roots. When lime was mixed more thoroughly by the plow sole treatment method or by deep plowing so as to react with the subsoil mass, alfalfa seemed to benefit more than by the placement of lime in zones where it failed to react. For phosphate to be most effective in many soils it probably should be placed in closely spaced zones of concentration in the root zone. The formation of insoluble iron and aluminum phosphates or of phosphate-clay complexes of low plant availability will reduce the effectiveness of phosphate applications.

CONCLUSIONS

The application of lime to the plow sole and mixing it with the subsoil by plow sole tillage appears to be a more effective method of subsoil liming than deep placement in subsoiler clefts. Although the plow sole tillage method resulted in only small increases in corn and soybeans there were small but significant residual effects for alfalfa 8 to 10 years after the last treatment.

Even though statistically significant corn yield increases were obtained for the deep placement of lime and phosphate the increases were too small to be of practical value. The average annual yield increases in bushels of corn per acre for the deep placement of lime and phosphate in subsoiler clefts from 1955 through 1958 were 7.8, —0.8, 1.6 and 1.9. It is evident that the treatment was most effective for the first crop after the treatment. If the fertility of the root zone of this soil and similar claypan soils is to be improved, it appears that less expensive and more practical methods than subsoil placement should be used. When good fertility and management practices are used on the surface plow layer, it is doubtful whether expensive subsurface treatments will give economic yield increases for corn and alfalfa.

SUMMARY

Several experiments are reported on the deep tillage, subsoil liming and fertilization on Mexico silt loam for alfalfa, small grain and row crops. Subsoil shattering by plow sole tillage alone tended to depress yields of wheat, corn and soybeans; while applications of lime and rock phosphate to the plow sole before shattering evidently overcame the detrimental effect of plow sole tillage. In fact, deep treatment with lime and rock phosphate by this method was beneficial to sweet clover rooting and growth and gave small residual increases in alfalfa production 8 to 10 years after the treatment. Subsoil treatment with lime or lime plus triple-superphosphate by plow sole application, split surface applications with two 12-inch plowings, or by placement in subsoiler clefts were tested for corn and alfalfa production. When the soil surface was adequately fertilized, the yield increases for deep treatment were small and not of practical significance from the economic viewpoint. Small but statistically significant four-year average increases in corn yields were obtained for subsoil liming by the plow sole tillage method or by placement in the subsoiler clefts. Phosphate in the subsoiler clefts with lime significantly reduced the effect of lime on corn yields but supplemented the effect of lime on alfalfa. Deep-placed lime appeared to have little effect on alfalfa except when applied with phosphate on the plow sole or in the subsoiler clefts. The plow sole tillage method of applying lime to the subsoil was the most effective method used. The increased productivity obtained for deep fertilization of any of the crops tested was not sufficient to be of practical significance.

LITERATURE CITED

1. FEHRENBACHER, J. B., VAVRA, J. P., and LANG, A. L. Deep tillage and deep fertilization experiments on a clay-pan soil. *Soil Sci. Soc. Am. Proc.* 22:553–557. 1958.
2. GRAHAM, E. R. Testing Missouri soils. *Missouri Agr. Exp. Sta. Circ.* 345. 1950.
3. MILLER, M. F., HUTCHINSON, C. B., DOUGLAS, T. R., and HUDELSON, R. R. Drainage investigations on the northeast Missouri prairie. *Missouri Agr. Exp. Sta. Bul.* 118:445–497. 1914.
4. SMITH, RAYMOND S. Experiments with subsoiling deep tilling and subsoil dynamiting. *Illinois Agr. Exp. Sta. Bul.* 258:158–170. 1925.
5. SMITH, D. D. Subsoil conditioning on claypans for water conservation. *Agr. Eng.* 32:427–429. 1951.
6. ————, WOODRUFF, C. M., and WHITT, D. M. Building a soil deeper. *Agr. Eng.* 28:347–348. 1947.
7. WOODRUFF, C. M., and SMITH, D. D. Subsoil shattering and subsoil liming for crop production on claypan soils. *Soil Sci. Soc. Am. Proc.* 11:539–542. 1946.