9-1-1979

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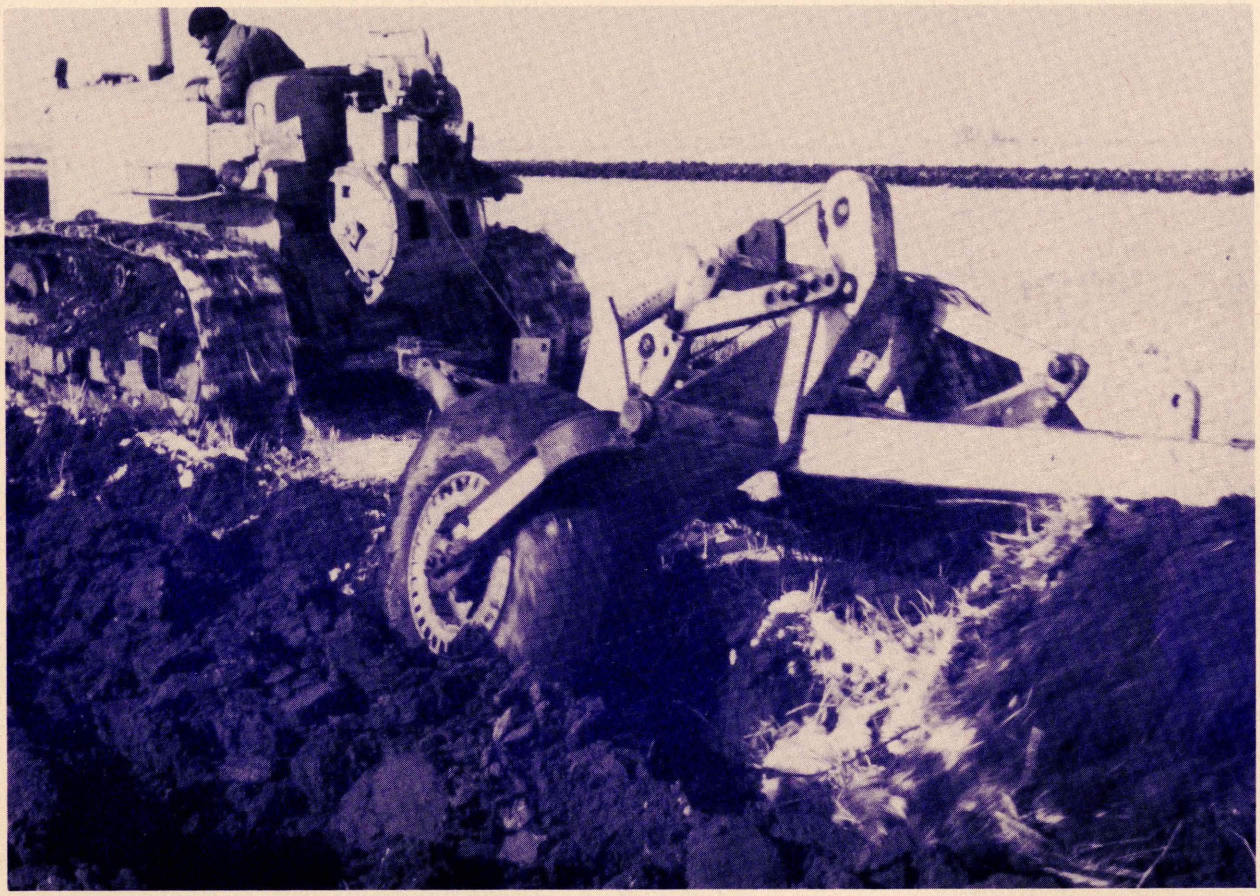

One-Step Improvement

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Claypan Soils: One-Step Improvement

L. O. Fine, P. D. Weeldreyer and
D. G. Shannon*

The dominant soils on level or gentle slopes in east-central South Dakota are among the most productive in the country, given favorable soil water conditions and proper crop management procedures.

These "normal" soils have excellent organic matter content, good depth of development, high cation exchange capacities and reserves of desirable exchangeable ions, and well balanced trace element availability and reserves.

However, included among these very favorable soils are areas of "claypan" (soil with "subsoil" or clay enriched B horizons with poor structure)--so intensely developed that they inhibit water movement and water release to plants and root exploitation of that soil zone and the horizons below.

The problem soils exist in association with normal soils, and are often scattered throughout a field in small patches in an irregular or roughly circular pattern. Commonly they occupy very slight depressions (a few inches) in an otherwise level landscape.

Claypans are most common in areas remote from a river, creek, or drainageway; thus intermittent standing water on the soil surface has been implicated in their formation (7). These claypan soils are found in eastern and east-central South Dakota associated with both glacial lake plain and glacial ground moraine soils. Generally they show the effect of sodium in their genesis and fall into one of the natriboroll, natrustoll, or natraquoll subgroups in the comprehensive soil classification system. A few, however, have no current sodium accumulation in the B horizon and thus are argiborolls or argiustolls. Some of the soils with this limitation are thus recognizable by the older classification scheme as "solonetz" or "solodized solonetz"; in the latter, and sometimes in the former, magnesium is present as an exchangeable ion to an extent equivalent to or exceeding calcium.

Magnesium occasionally has been regarded as an almost equally culpable exhangeable cation with sodium. However, the evidence is inconclusive.

Purpose of the Study

These claypan areas are more than a mere nuisance. They are harder to work than normal soils, and they are not as productive. They need to be improved.

The field phases of this work were primarily deep plowing, irrigation, and addition of certain soil amendments. The laboratory phases were measurements of those characteristics which were presumed to be affected by the field practices.

An Aberdeen silty clay loam (glossic Udic Natriboroll) site was leased for the 8-year experiment. The genetic claypan exists from about the 9- to 21-inch depth, but varies in thickness and intensity of development.

*Appreciation for assistance in the field operations of this work is expressed to Dr. J. Giles and Robert Sanders, research manager and assistant research manager, and Lloyd Dye and Dr. Ray Ward, former research managers, James Valley Research and Extension Center, Redfield, S.D.

Small areas of certain associated soils were found, on detailed mapping of the site. Those recognized were Exline (Leptic Natriboroll), Harmony (Pachic Udic Natriboroll), and Tetonka (Argiaquic Argialboroll). These areas were delineated during the original sampling operation. The site selected was in the S 1/2 of S1/2 of NE 1/4 sec. 20, T117N, R63W, in Spink County.

Previous Work on the Problem

Rasmussen (4) reported work in Idaho in 1964 in which the Sebree silt loam (saline-sodic) and associated areas of Chilcott (non-saline sodic) soil were much improved by plowing to a depth of 30-36 inches. The "slickspot" condition was apparently permanently relieved on both soils.

Rasmussen et al (5) also reported the reclamation of a slickspot soil tentatively classified as Malheur (Nadurargid) in southeastern Oregon by plowing to a depth of 36 inches with and without the application of gypsum at rates of 8 or 16 T/A (18 or 36 MT/ha). Crop yields, water intake rates, and water and root penetration were greatly increased by deep plowing. Chemical reclamation occurred in 3-4 years, and amendments alone without deep tillage provided some improvement. Subsoiling without gypsum was of no benefit.

Sandoval et al (6) showed that the Rhoades silt loam-silty clay complex (Leptic Natriboroll) was remarkably improved in a 5-year study of deep plowing and chemical amendments including sulfur and gypsum.

Their plowing was at three depths -- 6, 12, and 24 inches. The 6-inch tillage was with a conventional plow, the 12-inch with a disk plow, and the 24-inch with a large plow designed for the purpose. Both salinity and sodicity were reduced, and the surface layers were improved more than the lower soil horizons. Their experiment was conducted in a 15-inch rainfall zone in North Dakota and was not irrigated.

Bowser and Cairns (1) and later Cairns (2) conducted a field experiment which effected horizon mixing to 22 inches and a greenhouse experiment with mixing of the surface and subsurface horizons. They reported marked improvement of Canadian solonetz soils and very significant increases in yields of alfalfa with two of four soils studied in greenhouse cultures. Prior leaching did not prove beneficial. Water relationships of the mixed horizons were much improved over those of the Bn (sodic) horizon.

Kingsley and Shubeck (3) in a deep tillage experiment which consisted primarily of trenching to a depth of 18-20 inches and placing an organic "wedge" in the trench, reported improved yields of corn and increased root mass to a depth of 3 1/2 ft. They measured root densities at the plant row, and 7, 14, and 20 inches away from the row.

The organic trenching was done on an 85-inch interval and corn was planted so each row was only 21 inches from an organic wedge on one side or the other.

Organic trenching increased storage of water in the soil more than subsoiling, trenching without organic matter, use of a sweet clover catch crop, or no treatment, and encouraged root growth below the claypan. The residual beneficial effect of organic wedges on yields was greater than the effect of the same amount of organic matter broadcast on the soil surface.

Description of the Experiment

Approximately 13 acres of land was leased within a half mile of the James River in Spink County. The area was divided into 105 plots each 60 x 75 feet, the soils carefully mapped, and each plot sampled by soil horizon.

About half of the area was plowed with a Post Brothers plow capable of plowing to depths of 30-35 inches. Because of inadequate tractor speed, soil falling into the furrow elevated the furrow wheel much of the time, so that actual depth of plowing was about 26-28 inches. The remaining area was tilled with normal equipment and at normal depths. All subsequent tillage on the entire area was with normal equipment and at normal depths.

Simultaneously with making the soil map, a core sample pulled from each plot was checked for depth and thickness of each horizon, the depth to lime, depth to gypsum, and the uppermost line of visible salinity. The soil map (Appendix A) shows the area involved and the small size of ultimate soil delineations. The data on depth to and thickness of claypan horizon, top of saline horizon, and top of calcareous horizon at the point in each plot where the soil core sample was taken are presented graphically (Appendix B). The total extractable cations (extractable Na, Ca, and Mg) at initiation of experiment and before tillage, as found in these original core samples, are given in Appendix C.

The continuous lines denoting the soil characteristics in appendices B and C do not represent a confirmed continuum of that parameter. The line is merely a method of depicting the change in a particular property from one plot to the next.

The area was divided into 105 plots in five east-west tiers of equal length. Chemical amendments were applied to the east half of each plot the following spring after surface roughness was reduced. These amendments included sulfur at rates of 520 and 1350 lb/A (designated A and B), gypsum at 1400 and 2800 lb/A (C and E), and lignite fly ash at 4000 lb/A (F). Original control plots are designated G.

In April 1972, four plots not used in the original amendment applications were treated with gypsum at 6800 lb/A (H in the plot plan). In September 1973, the west halves of 24 additional plots were incorporated into the experiment by the use of 10 T/A of gypsum on 8 plots (designated J), 10 T/A of fly ash on 8 plots (K), and 8 control plots.

The lignite fly ash was applied on the basis of its content of total and soluble calcium. The fly ash used in the original (1970 application) experimental plan (from the Stanton, ND, power plant) was mined at Stanton and had a total CaO content of approximately 24% and Na_2O of 7.4%. The fly ash used in 1973-4 was obtained from the Fergus Falls, MN, power plant operated by Ottertail Power Co., burning Beulah or Gascoyne-mined North Dakota lignite. The total CaO in these ashes ranged from 15.6 to 21.5% with 2.0 to 3.3% Na_2O.

The experimental layout of the deep plowing, irrigation plan, and soil amendments is shown in Appendix D.

In the spring of 1970 after incorporating soil amendments, the entire area was seeded to Piper sudangrass, which was clipped in late summer but not removed from the land. During this summer, a flexible plastic 4-inch drain line was laid through the east-west axis of the area, with the line installed under the 33-ft-wide alley provided near the center line of the tract. Ten branch lines, each 60 ft long, leading into plots 23, 25, 29, 30, 31, 40, 42, 46, 49, and 50 were attached at the 5-ft depth by plastic tees to the main line before covering. The main line terminated at the east end in a sump provided with an automatically controlled evacuation pump. Volumes pumped were metered, and samples of the water were analyzed periodically for major inorganic constituents and electrical conductivity. The 10 lateral lines were each provided with an interrupting sump near the junction with the main line. These "access sumps" provided a means of sampling contributory waters from the various plots.

The drain tile functioned without difficulty until termination of the experiment, although three of the laterals were slowed by activity of burrowing rodents which gained entrance during dry seasons when access sump covers were accidentally removed by wind and other causes.

Portions of the tile line were covered with screened gravel and other portions with fiberglass "sill seal." All lengths were underlain by sill seal.

Cropping History:

In 1970, Piper sudangrass was planted and clipped; no growth was removed. In 1971, spring wheat as a companion crop was sown with Vernal alfalfa and Oahe intermediate wheatgrass. The grass-alfalfa was killed by excess surface water on some plots in 1972 and re-seeded in 1973. No hay yields were recorded in 1972 or 1973, but two harvests were made in 1974 and yields recorded. Also in 1974, corn was produced on the west half of each of 24 plots, all irrigated, 12 of which were deep plowed, 12 shallow plowed. Eight of these plots received gypsum; 8, fly ash; and 8 were control plots. In May 1975, all remaining alfalfa plots were plowed and the entire experimental area was cropped to corn until the experiment was terminated in September 1977.

The final crop yields (corn) were obtained in September 1977, and terminal soil samples were taken in the irrigated portion in October. Final soil samples in the non-irrigated portion were taken in 1976.

Results and Discussion

General Soil Properties:

The Aberdeen soil was mapped in the Spink County soil survey and five phases or associations were correlated for the published report. The surveyors doing the field work recognized about nine different depths to, thickness of, and degrees of compaction within the B_2 (textural B) horizon, or combinations thereof. These could not all be correlated in the final publication, however, and only surface texture, slope, and substrata differences came out in the finally recognized and correlated types.

Thus, there is considerable variety in the Aberdeen silty clay loam. In general, however, the clayey B_2 extends from the 9- to the 21- or 22-inch depth. In the tract of land involved in this experiment, the shallowest bottom of the B_2 observed was 17 inches, the deepest was 28 inches. Almost the complete range in degree of compaction was encountered.

Westin (7) has described the Aberdeen and associated soils and made several physical and chemical characterizations. Tables 1 and 2 are adapted from the work published by Westin.

Table 1. Selected physical characteristics of Aberdeen silty clay loam (from Westin, 1970).

			Water content (% by wt) for:			
Horizon	Depth, in.	Bulk density (clod)	100 cm tension	0.33 bar	H_2O equiv.	15 bar
A_{1p}	0-7	1.18	50.9	42.5	35.7	17.0
A_2	7-11	1.40	42.3	33.6	28.8	17.7
B_2	11-18	1.74	43.8	36.5	31.8	20.8
B_3	18-22	1.67	45.0	35.6	31.1	19.0
C_{11ca}	22-30	1.34	44.4	34.6	30.5	16.7
C_{12ca}	30-40	1.33	50.0	49.6	36.0	19.5
C_2	40-60	1.33	56.8	41.4	42.8	28.6
C_3	60-80		60.4	51.0	44.7	34.1

Table 2. Selected chemical characteristics of Aberdeen silty clay loam (from Westin, 1970).

Horizon	Depth, in.	Cation exch. cap., me/100g	Exchangeable cations, me/100g Ca	Mg	Na	K	H	Salinity, $ECx10^3$ Sat. Extr.	Gypsum, me/100g
A_1p	0-7	31.4	15.9	10.0	0.22	0.91	7.0	0.4	0
A_2	7-11	29.3	8.1	17.5	0.52	0.74	3.9	0.3	0
B_2	11-18	33.6	7.8	23.8	0.96	2.26	3.1	0.3	0
B_3	18-22	30.7	*	*	1.15	1.70	-	0.6	0
C11ca	22-30	22.2	*	*	1.25	2.35	-	2.0	0
C12ca	30-40	23.0	*	*	1.89	2.02	-	6.0	36.5
C_2	40-60	23.3	*	*	5.66	2.89	-	9.5	9.9
C_3	60-80	28.2	*	*	4.50	2.72	-	10.0	15.4

*Calcareous horizon, Ca and Mg not determined.
-Not determined.

Soil Morphology:

The soil profile characteristics at sampled sites in the 105 plots (1969 sampling and mapping) are shown in Appendix B.

The range in morphological characteristics in this tract is quite dramatic. In some plots very consistent trends are found among the characteristics depicted; in other cases trends are not evident.

Soil Chemistry:

Extractable cations. The B_2 horizon chemical properties (except gypsum and EC) evaluated at the time of original sampling are presented in Appendix C.

The primary noteworthy observations follow:

(1) Total ammonium acetate-extractable magnesium and sodium generally fluctuate in a similar manner.

(2) Total extractable calcium fluctuates in a reciprocal fashion with sodium or magnesium.

(3) Cation exchange capacity ranges from about 26 to 34 me/100g.

(4) Exchangeable calcium percentage is the most constant characteristic observed among these reported herein.

(5) Extremes observed in total extractable sodium found in the B_2 horizon were about 0.1 and 17 me/100g.

A summary of the data on original and final total ammonium acetate-extractable sodium is given in Table 3. Treatments J, K and L were 10 T gypsum, 10 T fly ash, and nothing, and were added to the west half of 24 irrigated plots (12 shallow, 12 deep plowed) in 1973. They did not become an orthogonal part of the experiment and therefore the data are not included in statistical tests. Averages of four plots are presented in all the data in Table 3.

Table 3. Summarization of 1969 and 1977 data on total extractable sodium in B soil horizons of claypan research plots. Data are averages of four plots, and are presented as milliequivalents per 100 grams of soil.

	Irrigated				Non-Irrigated					
	Deep		Shallow		Deep		Shallow		1969	1977
Treatment	1969	1977	1969	1977	1969	1977	1969	1977	Ave.	Ave.
A	2.25	0.90	2.97	1.40	3.62	1.37	9.37	11.3	4.55	3.74
B	1.42	2.08	1.68	3.40	2.27	2.69	6.17	6.63	2.88	3.70
C	0.50	1.47	2.42	3.77	2.37	3.62	0.30	5.41	1.39	3.56
E	7.70	3.82	3.65	4.15	5.20	7.03	2.30	4.13	4.71	4.78
F	0.68	1.40	2.10	2.12	0.56	0.67	3.16	5.43	1.62	2.40
G	3.50	3.05	2.65	2.30	1.48	2.61	6.97	8.96	3.65	4.23
Ave.	2.67	2.12	2.58	2.85	2.58	2.99	4.71	6.97		
J* (Gypsum)		0.95		0.92						
K* (Fly Ash)		1.90		1.57						
L* (Check)		1.70		1.15						
Ave.		1.50		1.22						
H**				0.50						

*Installed in experiment in September 1973. All amendments @ 10 T/A.
**Installed in experiment in April 1972; gypsum @ 3.4 T/A on 4 shallow plowed irrigated plots only.

Table 3 indicates several fairly substantial conclusions:

(1) Changes in total extractable sodium are very slight or non-existent, with the possible exception that an increase occurred on shallow plowed, non-irrigated plots. Such an increase and its cause are difficult indeed to rationalize or accept. The 1969 values for the plots on which these treatments fell are all at or above the averages of all other 1969 treatment samples except C and E. Such an occurrence being by chance is difficult to accept, but no other explanation is visible.

(2) The lowest terminal extractable sodium values occurred in the deep plowed, irrigated plots.

(3) The highest terminal sodium values occurred in the shallow plowed, non-irrigated plots, but they were also the highest initially.

(4) In comparing differences between 1969 and 1977 means, the greatest change also took place in the shallow plowed, non-irrigated plots, an increase of 2.26 me/100g, averaged over the six initial chemical treatment plots, four replications of each.

Statistical treatment of these data resulted in the following observations: Tillage depth had a significant effect on terminal (1977) extractable sodium values, and the interactive effect of tillage x amendment and tillage x amendment x irrigation were both significant at 0.05 level.

The differences between 1969 and 1977 extractable sodium were significantly affected (.05 level) by tillage depth and by chemical amendments. All differences were quite small, but the fly ash (treatment F) resulted in the greatest Na reduction over the 8-year period. The overall mean extractable Na reduction was 0.53 me/100g soil. The differences engendered ranged from a decrease of 0.78 me/100g to an increase of 0.82 me/100g of soil.

The lowest terminal average extractable sodium occurred on the fly ash plots, but these same plots also had the lowest initial (1969) average value of total extractable sodium in the B horizon.

With the degree of initial variability that existed in these plots it is not surprising that statistically significant chemical effects were few in number.

Gypsum. The gypsum content was estimated on 256 samples from the experiment, including topsoil (Ap), B_1, B_2, B_{sa}, C_{casa} and C_2 horizons. None was found in Ap, B_1 or B_2 horizons. Only 6 of 35 samples (17%) of B_{sa} horizons had amounts of gypsum above 1 me/100g; measured amounts ranged from 0.26 to 17.6. Thirty-five samples (65%) of C_{casa} material out of 64 analyzed showed gypsum above 1 me/100g; among those having gypsum, amounts ranged from about 8 to 20 me/100g. Nine of 17 (53%) samples of the C_2 (substratum) showed gypsum; amounts found were equal to or less than 8 me/100g.

Inasmuch as the top of the C_{casa} horizon was quite variable (as shallow as 17 and as deep as 34 inches) the plowing operation (depth 26-28 inches) did not always encounter a gypsum-rich zone, but almost without exception cut into and raised a considerable amount of saline B horizon material (B_{sa}). One observation--that there was usually salinity evident above the top of the lime--indicates that an ephemeral water table has occurred frequently enough to cause soluble salt movement upwards, at least to the extent that the superposed salinity could be detected. The maximum concentration of gypsum found in a sample was 25.5 me/100g.

Gypsum in this soil to a depth of 28-30 inches is thus not a reliable constituent to aid in deep plowing reclamation of sodium affected claypan soils.

Electrical Conductivity and Sodium Adsorption Ratio. The terminal (1977) electrical conductivity (total salinity index) values for saturation extracts and sodium adsorption ratio values for the same saturation extracts, B horizon, are given in Table 4.

Although the average EC values at the end of the experiment were lowest in the fly ash (treatment F) plots, variability was high enough so that differences were not statistically significant (.05). Also, deep plowed, irrigated plots (all amendments) averaged lower EC values than any other tillage-irrigation combination.

The SAR values at termination showed essentially the same trends--deep plowing appears beneficial, and was significantly better at the .05 level and almost at the .01 level of probability. Irrigation and amendment as primary effects were non-significant, but the interaction tillage x water x amendment was significant at $p = <.05$.

Crop Performance:

The gross overall treatment average crop yields for those harvests measured and net amounts of water used are given in Table 5.

Yield increases as a result of deep plowing ranged from 12.6% upwards on both irrigated and non-irrigated plots. The overall average increase (dryland and irrigated) for alfalfa, corn and wheat was 21%.

Irrigation alone caused variable responses of the different crops in the several years. Considered as an independent variable, averaged over all soil amendments, responses to irrigation ranged from 16% for one water application on alfalfa to 169% for shallow plowed corn and 131% for deep plowed corn, both in 1977. Percentage yield increases for the non-irrigated, deep plowed area have been at least as favorable as for the comparable irrigated areas.

The yield data for the last 2 years of the experiment (1976 and 1977) are presented in Table 6, to show in more detail the effects of individual treatments, water, and the deep plowing. In 1976 all plots received a spring irrigation of 5.2 inches to get uniform germination and emergence, thus the "dryland" plots had the natural precipitation plus 5.2 inches of ealy season irrigation.

Statistical treatment of the data for these 2 years indicates that none of the chemical amendments used had a consistent and statistically significant effect on yield.

The effect of tillage was significant ($p = <.05$) in both years and significant at $p<.025$ in 1976. Deep plowing was highly beneficial for both irrigated and non-irrigated areas; the percentage yield increase (over all chemical treatments) was 22.1% for irrigated and 29.4% for non-irrigated plots, as compared with shallow plowing. The overall average yield increase for wheat, corn, and alfalfa for the entire period was 21%.

Irrigation had the most pronounced effect of all the controlled factors in the experiment, the overall increase being 110.6% as compared with "non-irrigated" plots for these 2 years. (This estimate includes all dryland plots, which received a 5.2-inch irrigation at the start of the 1976 season.)

Over the entire length of the experiment, yield increases for irrigation ranged from 16% for one application on alfalfa to 169% for shallow plowed corn and 131% for deep plowed corn in 1977.

Because of the additional chemical amendments in 1972 and 1973, the experiment was not completely orthogonal. Statistical tests made of the data including those later treatments had to exclude the non-irrigated yield data. Even when the dryland data were excluded from the analysis, chemical amendments proved non-significant in effect. Tillage was significant in

Table 4. Summarization of 1977 EC (Salinity) and SAR (Sodicity) data of the B horizon.* Data are averages of four replications.

	Electrical Conductivity 10^3 @ 25° C					Sodium-Adsorption Ratio				
	Irrigated		Dryland			Irrigated		Dryland		
Treatment	Deep	Shallow	Deep	Shallow	Avg.	Deep	Shallow	Deep	Shallow	Avg.
A	1.90	1.76	2.79	4.61	2.77	2.65	3.62	2.00	9.43	4.43
B	1.16	3.43	3.00	4.17	2.94	2.37	8.25	2.97	6.50	5.12
C	1.89	2.94	2.78	1.94	2.39	1.81	6.05	2.29	3.78	3.48
E	3.51	5.07	4.92	1.07	3.64	3.26	6.25	3.71**	5.81	4.76
F	1.24	1.53	1.11	2.90	1.70	2.42	4.92	2.97	6.25	4.14
G	1.34	1.78	0.98	6.39	2.62	5.72	4.41	3.30	8.31	5.44
Avg.	1.84	2.75	2.60	3.51	2.68	3.04	5.58	2.87	6.68	4.56
J	2.10	3.14				1.60	2.61			
K	1.40	2.66				3.19	5.49			
L	1.37	1.87				3.76	4.29			
H*		1.38		4.19			2.31		7.60	

*The salt content of soil is measured my means of the electrical conductivity (millimhos per cm) of the saturation extract. The sodicity or sodium adsorption ratio indicates the tendency of the soil solution to impart sodium ions to clay particles.
**A mean of only two plots.

Table 5. Crop yields and irrigation water amounts used.

Year	Crop	Irrigated plots, yields		Irrigation water used, in.	Non-Irrigated plots, yields	
		Deep-tilled	Shallow-tilled		Deep-tilled	Shallow-tilled
1970	Sudan	Clipped, not removed		0		
1971	Wheat (bu/A)			0	17.1	13.6
1972	Alfalfa-grass	Hay removed		0		
1973	Alfalfa-grass	No yields recorded		2		
1974	Alfalfa (T/A) (2 harvests)	3.70	3.04	3	3.2	2.1
1974	Corn (bu/A)	86.2	76.5	3	50.4	50.4
1975	Corn "	116.7	102.3	20	39.1	34.2
1976	Corn "	121.7	102.2	19.6	62.8*	50.3*
1977	Corn "	128.9	116.9	10.6	55.8	43.4

*All plots in the entire experiment received one irrigation of approximately 5.2 inches in May to obtain uniform germination and emergence.

Because of extremely low or zero flow in the James River, irrigation of plots was drastically limited in 1973, 1974 and 1977. Only one or two irrigations were made in those years.

Table 6. 1976 and 1977 corn yield data* (ave. of 4 reps).

Plot	Soil Treatment Applied 1970	1977				1976			
		Irrigated		Non-irrigated		Irrigated		Non-irrigated	
		Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow
A	Sulfur @ 520 lb/A "	141.8	125.6	42.3	44.1	124.8	101.2	51.2	29.3
B	Sulfur @ 1350 lb/A "	138.2	127.7	62.0	18.2	114.7	79.0	79.5	45.0
C	Gypsum @ 1400 lb/A "	137.0	105.0	51.6	53.2	128.7	88.5	30.2	59.0
E	Gypsum @ 2800 lb/A "	106.2	107.0	43.5	76.9	110.5	94.0	58.7	73.5
F	Fly Ash @ 4000 lb/A "	135.8	130.3	76.0	53.2	116.7	113.7	79.0	47.7
G	None (control)	124.0	115.9	59.5	14.9	120.2	115.5	77.2	34.0
H	Gypsum @ 6800 lb/A Applied 1972		135.1		15.4		127.5		80.0
J	Gypsum @ 20,000 lb/A Applied 1973	131.0	124.1			131.2	118.2		
K	Fly Ash @ 20,000 lb/A "	127.2	111.8			116.2	106.0		
L	Control	118.6	104.8			132.2	90.0		
	$\bar{x}$ =	133.0	116.9	55.8	43.4	121.7	91.7	62.6	48.1

*Yields are indicated in bushels per acre of grain at 15.5% moisture.

1977. In 1976 it was not significant at the 5% probability level, but was at the 10% level.

A highly significant observation in the course of the study was made in 1976: One effective heavy irrigation that practically filled the soil water reservoir for the root system of corn (5.2 inches applied in May) was instrumental in producing a very acceptable yield (about 55 bu) in a year when non-irrigated corn in the area produced less than half this yield. The significance is that irrigators with a limited supply of water and a dry soil profile at planting time can make most effective use of that water by making a single heavy irrigation early in the year when evaporation losses are minimal.

Infiltration Trials:

Field trials on water intake characteristics were performed at three times during the experiment: fall 1973 and 1976, and spring 1977. The instrument was a double-ring surface infiltrometer, with hook-tip water level or side mounted water level gages on the inner ring. Water was from the James River and was judged to be of appropriate quality so that no change in hydraulic conductivity of the soil took place during the actual measurements.

In 1973 four deep plowed and four shallow plowed plots were studied. Two sets of double-ring infiltrometers were used in each plot, thus eight measurements were made for each tillage treatment. The cumulative intake values for the fall 1973 and spring 1977 studies are presented in Figure 1. The results show intake rates in 1973 were more than four times as fast on deep- as on shallow plowed plots. In the spring of 1977, the deep plowed plots were about 68% higher in intake rate than shallow plowed plots. In the fall of 1976, even though soil water contents were high (19-24% by weight in the surface foot to 29-34% by weight in the fourth foot), intake rates were so fast that the work was repeated in the spring of 1977, with the results as given above. The 1976 data gave terminal intake rates after 20 hours

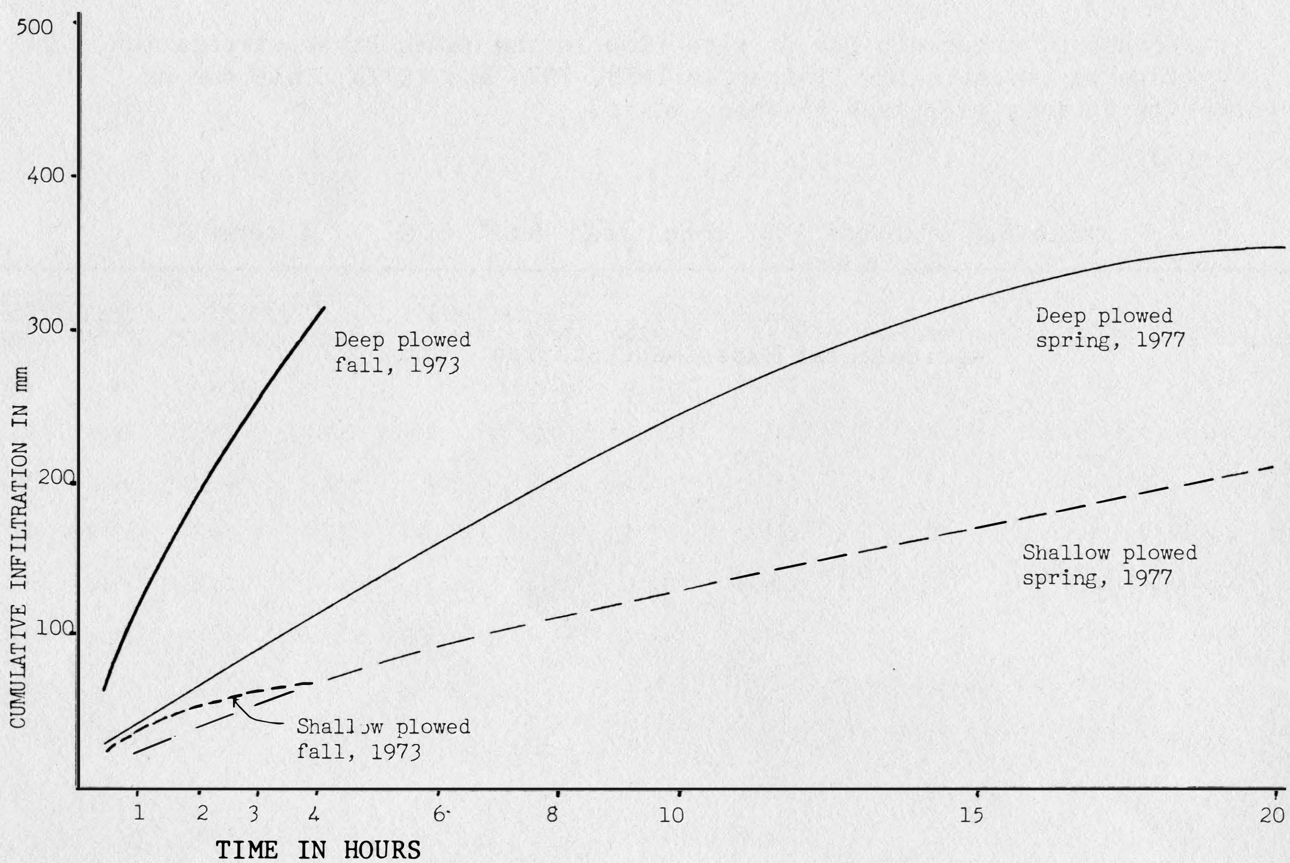

Figure 1. Water infiltration rates for Aberdeen silty clay loam in 1973 and 1977, tillage performed in 1969. Claypan Research Site, Spink Co. S.D.

of run ranging from 0.29 to over 2 inches per hour, with most plots having a terminal rate of from 0.72 to 0.91 inches per hour.

The effect of the deep tillage on water intake rates has persisted throughout the length of this experiment. In many instances at a given time interval after a substantial irrigation or rain, machine tillage could be performed with ease on the deep plowed portions of the experiment, whereas water was still standing in numerous places on the shallow plowed areas.

Summary

Deep tillage and irrigation (with ultimate plots consisting of various soil amendments) were studied in an 8-year field experiment concerned with amelioration of claypan effects on crop performance. Extreme variability in depth and thickness of horizons, chemical makeup, and intensity of development characterizes the Harmony-Aberdeen, Tetonka-Exline soil complex. Distinctly separable soil areas as narrow as 15 feet could be delineated and mapped.

Deep plowing (26-28 inches) affected water intake rates and crop performance from the first to the last year of the experiment. Differences in favor of deep tillage did not diminish appreciably over the time span of the study.

The effect on water intake was of sufficient magnitude that the tillage delays normally experienced after rains were virtually erased on the deep plowed Aberdeen plots.

Actual harvested crop yields continued to increase in the experiment through the terminal year (1977).

Effects of deep tillage and irrigation on soil chemistry were inconclusive. Deep plowed irrigated plots had the lowest and shallow plowed dryland plots had the highest terminal extractable sodium values. Both deep plowing and irrigation caused the EC and SAR of the saturation extract to trend lower, but the changes missed being statistically significant at the .05 probability level.

The overall effect of the deep plowing as done in this experiment is to reduce contrasting differences among the soils of this association in respect to water intake rates, tillability and crop performance. The most restricted soils in the association improved, making the area more uniform in the tillage that can be used, timing of operations, and crop yields. In our experience, non-irrigated crop performance was improved at least as much (expressed as percent) as irrigated crop performance.

Given the farm power units generally available in this geographic area, deep plowing as done in this experiment presents no problem as far as actual tillage is concerned. The securing of plow units, whether purchased, leased, rented, or contracted by custom operators, is another matter. Perhaps local cooperative purchasing units or conservation districts could serve as intermediates in this function.

To the observers conducting this field experiment, deep plowing caused a marked improvement in the deportment of Aberdeen silty clay loam and the associated Exline, generally regarded as essentially a non-arable soil. The duration of effects noted in this report and the final effect on soil chemistry are questions left unanswered. The economics of the process have been extremely favorable, inasmuch as yield gains of 12 to over 25% were experienced. The first crop of wheat, if sold at the prevailing price at harvest, would have paid the cost by the extra yield produced in that one year.

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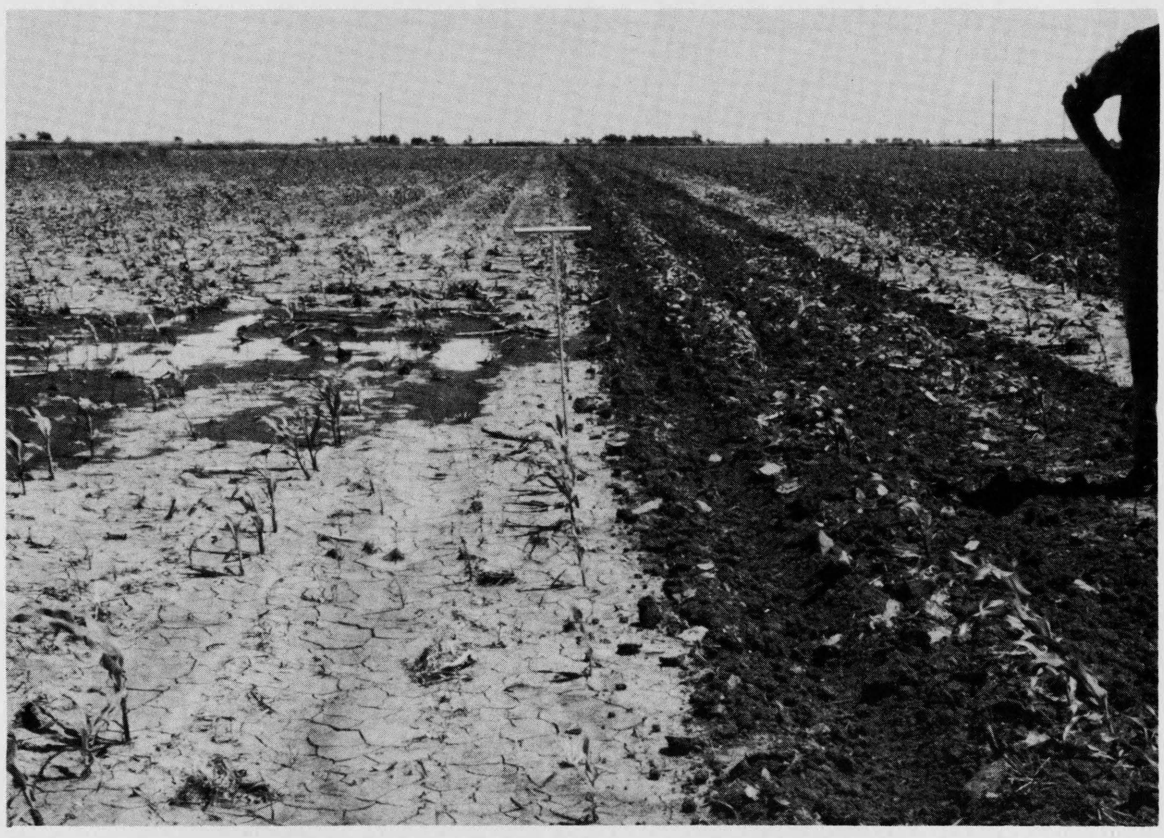
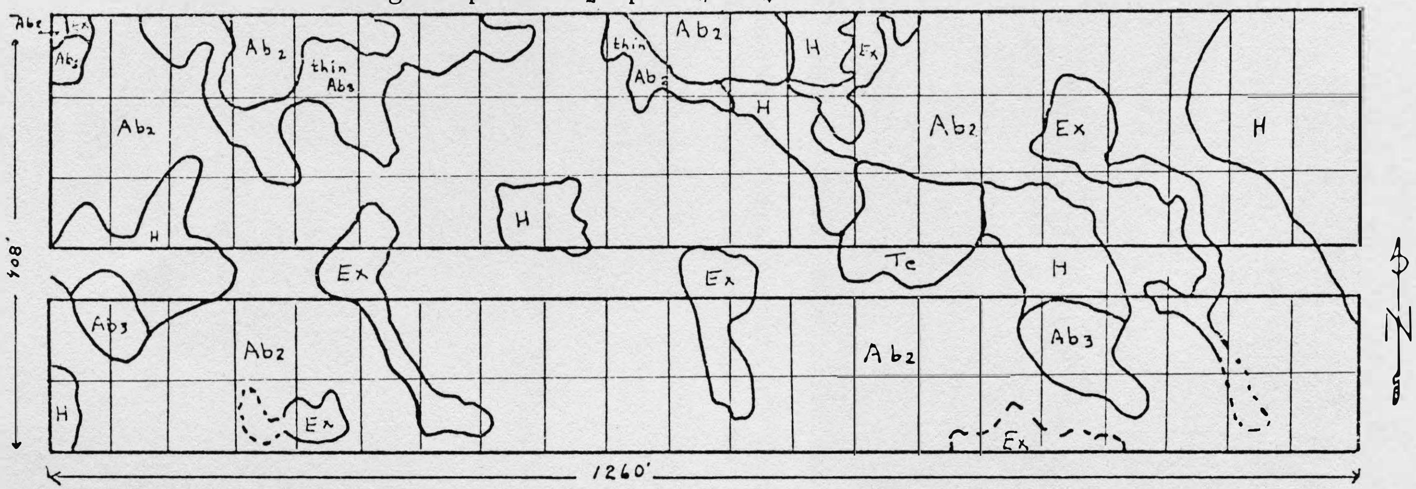
This plow can break to 30 inches; Aberdeen claypan is between 9 and 21. The plow required a crawler 8 years ago; modern tractors could handle it.



Plot on right was deep plowed 8 years ago; it could be worked shortly after rain. Plot on left, not deep plowed, is still holding water.

Appendix A. Detailed soil map of claypan soil experiment area, SD Agr Exp Sta S½ Sp SE¼ NE¼ Sec. 20 T117N R. 63W.



Soils:

Ab_2 - Aberdeen silty clay loam, modal development

Ab_3 - Aberdeen silty clay loam, severe development

Ex - Exline silty clay loam

H - Harmony silty clay loam

Te - Tetonka silty clay loam

(Dashed lines represent revision after observing crop performance)

Appendix D. Claypan soil experimental area plot descriptions.

S1/2 S1/2 SE1/4 NE1/4 Sec. 20 T. 117N R. 63W

Sw 105	Sw 104 H	Sw 103 H	Sw 102 F	Sw 101 E	Sd 100 E	Sd 99 F	Sd 98 C	Sd 97 G	Sd 96 A	Sd 95 B	Sd 94 C	Sd 93 B	Sd 92 F	Sd 91 E	Sd 90 A	Sd 89 G	Sw 88 E	Sw 87 G	Sw 86 H	85
Sw 84 B	Sw 83 F	Sw 82 E	Sw 81 C	Sw 80 G	Sw 79 A	Sw 78 B	Dw 77 F	Dd 76 F	Dd 75 B	Dd 74 G	Dd 73 E	Dd 72 B	Dd 71 G	Dw 70 E	Sw 69 B	Sw 68 F	Sw 67 C	Sw 66 A	Sw 65 H	64
Dw 63 A	Dw 62 G	Dw 61 B	Dw 60 B	Dw 59 E	Dw 58 C	Dw 57 A	Dw 56 G	Dd 55 C	Dd 54 A	Dd 53 E	Dd 52 A	Dd 51 C	Dd 50 F*	Dw 49 F*	Dw 48 C	Dw 47 A	Dw 46 B	Dw 45 G	Dw 44 B	43

III IV

II I

Main Drain Sump

Dw 42 F	Dw 41 C	Dw 40 E	Dd 39 E	Dd 38 A	Dd 37 C	Dd 36 B	Dd 35 F	Dd 34 G	Dd 33 C	Dd 32 A	Dd 31 B	Dd 30 G	Dd 29 E	Dd 28 F	Dw 27 C	Dw 26 A	Dw 25 G	Dw 24 E	Dw 23 B	Dw 22 F
Sw 21 C	Sw 20 G	Sw 19 A	Sd 18 A	Sd 17 G	Sd 16 B	Sd 15 F	Sd 14 C	Sd 13 E	Sd 12 F	Sd 11 B	Sd 10 C	Sd 9 G	Sd 8 E	Sd 7 A	Sw 6 C	Sw 5 G	Sw 4 A	Sw 3 A	Sw 2 B	Sw 1 F

Replication Boundary -- and No. (I)

D - Deep Plowed
S - Shallow Plowed
d - Dry
w - Irrigated

Plot Number (1)
Amendment (A)

N

AMENDMENT RATE

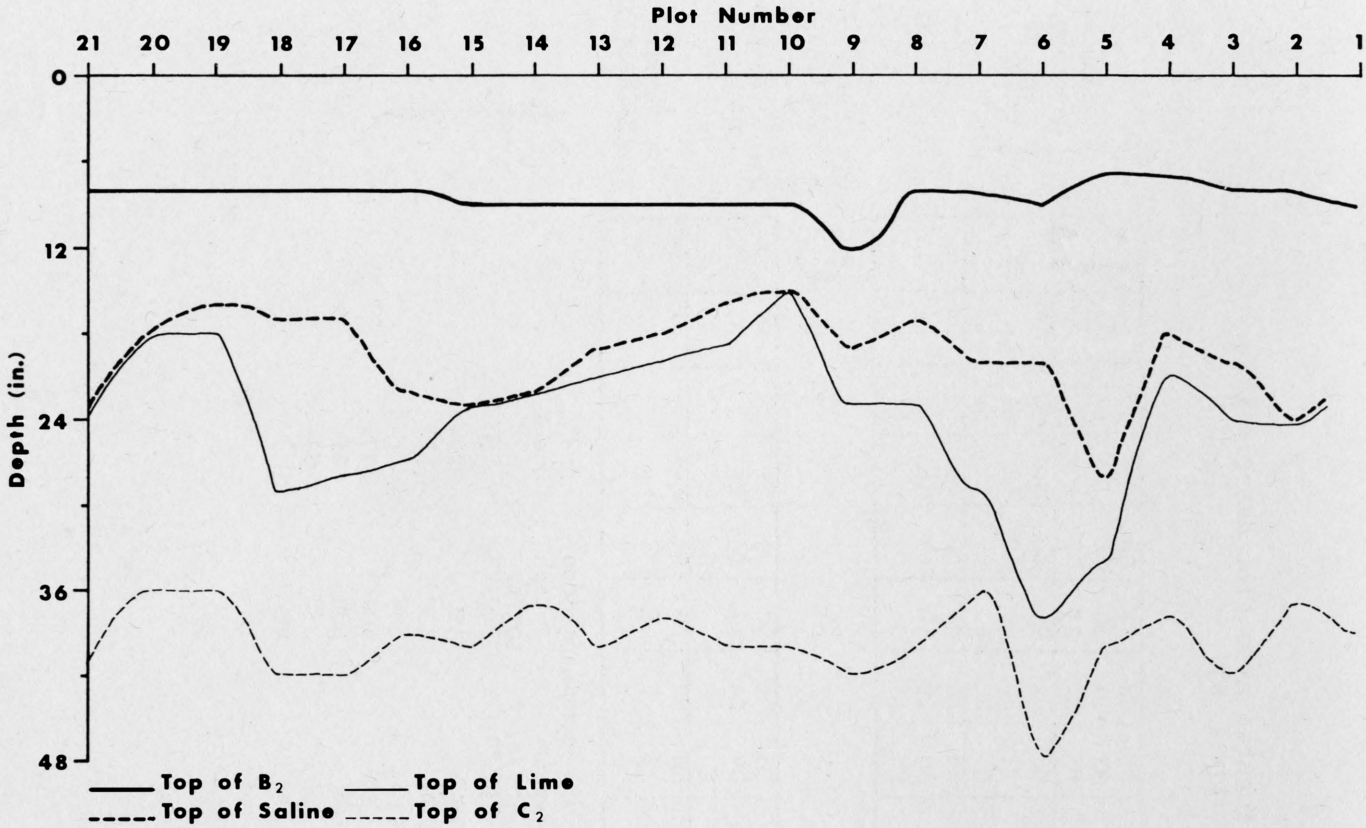
A - Sulfur 520 lb/A
B - Sulfur 1350 lb/A
C - Gypsum 1400 lb/A
E - Gypsum 2800 lb/A
F - Fly Ash 4000 lb/A
F*- Fly Ash 8000 lb/A
12' X 12' plot adj. to south side, west of center
G - Check
H - Gypsum 6800 lb/A
4-21-72

(Plots F, S, w, received 1000 lb/A sulfur in addition to fly ash)

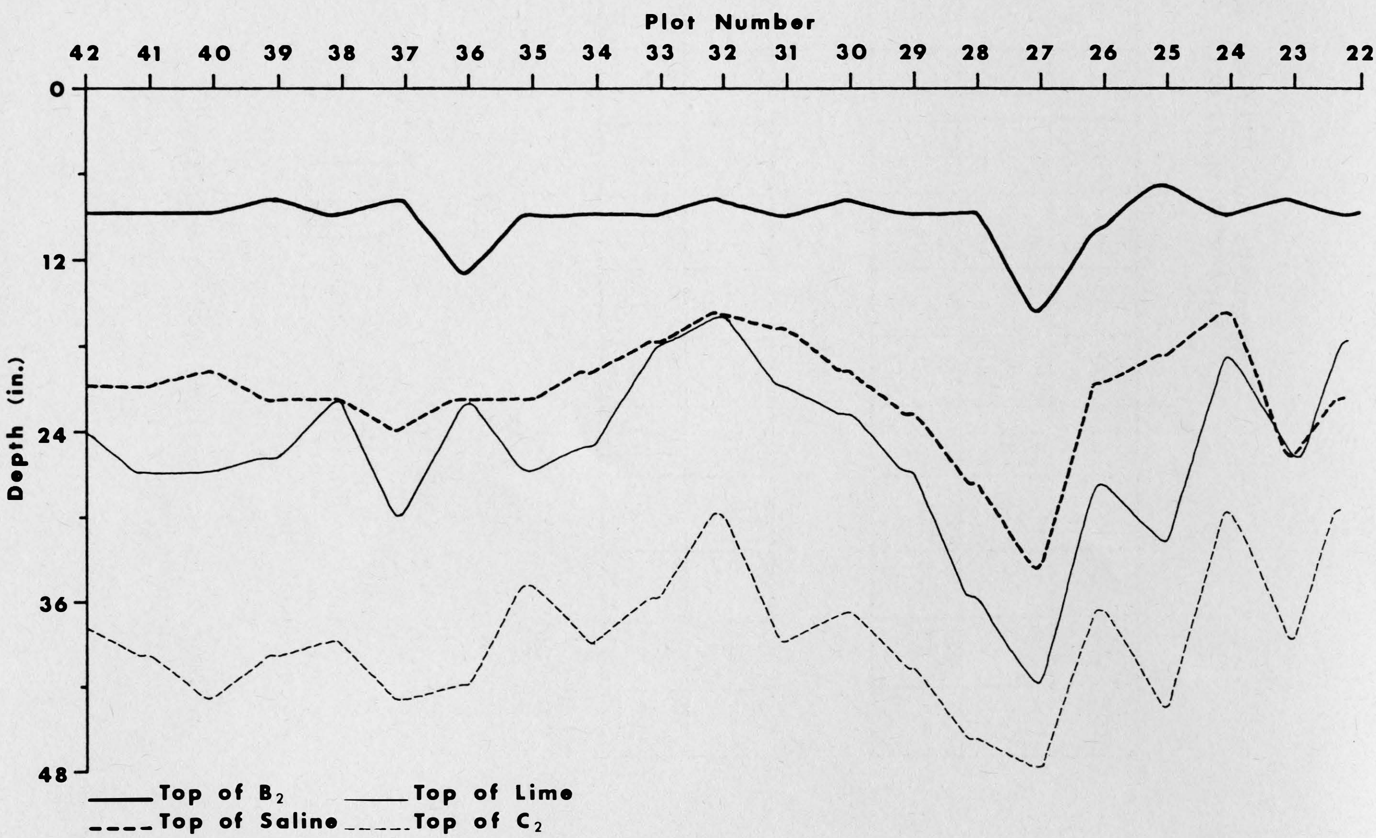
Crop Amendment Study 9-73

Gypsum 10T/A	Fly Ash 10T/A	Check
6W	5W	4W
20W	19W	25W
27W	23W	42W
41W	26W	59W
57W	40W	77W
69W	60W	82W
70W	83W	87W
78W	88W	2W

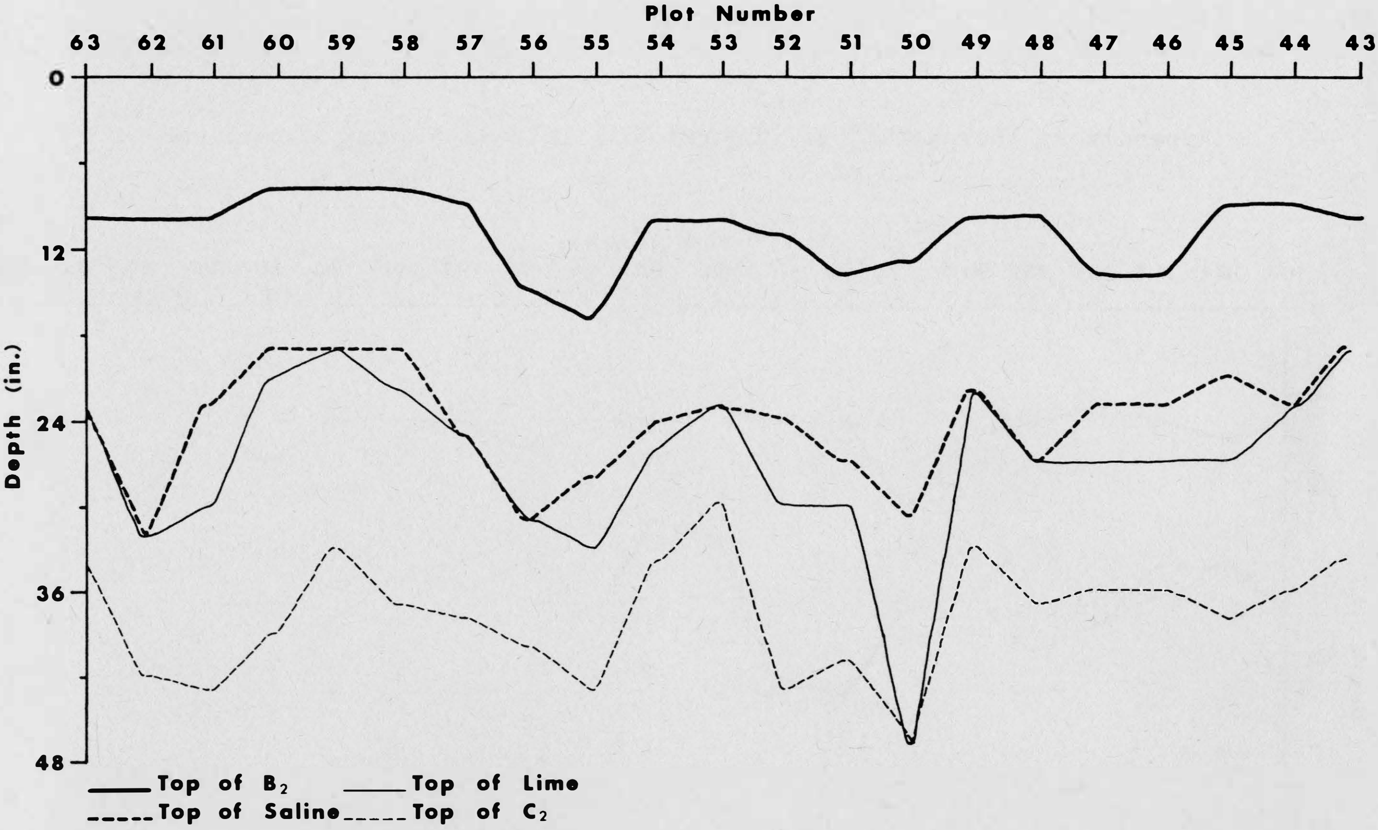
Appendix B. Morphology of claypan soil in deep plowing experiment (1 of 5)



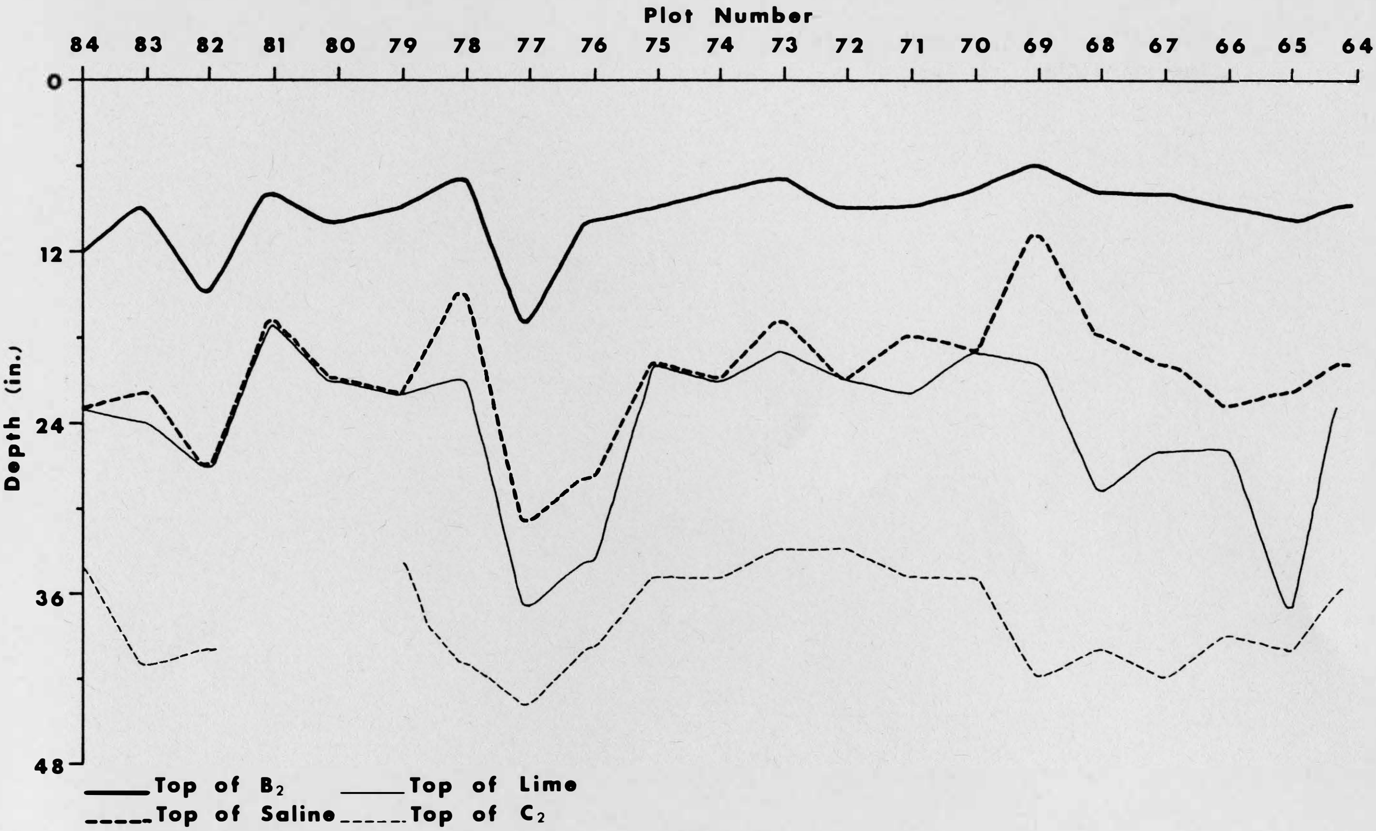
Appendix B. Morphology of claypan soil in deep plowing experiment (2 of 5)



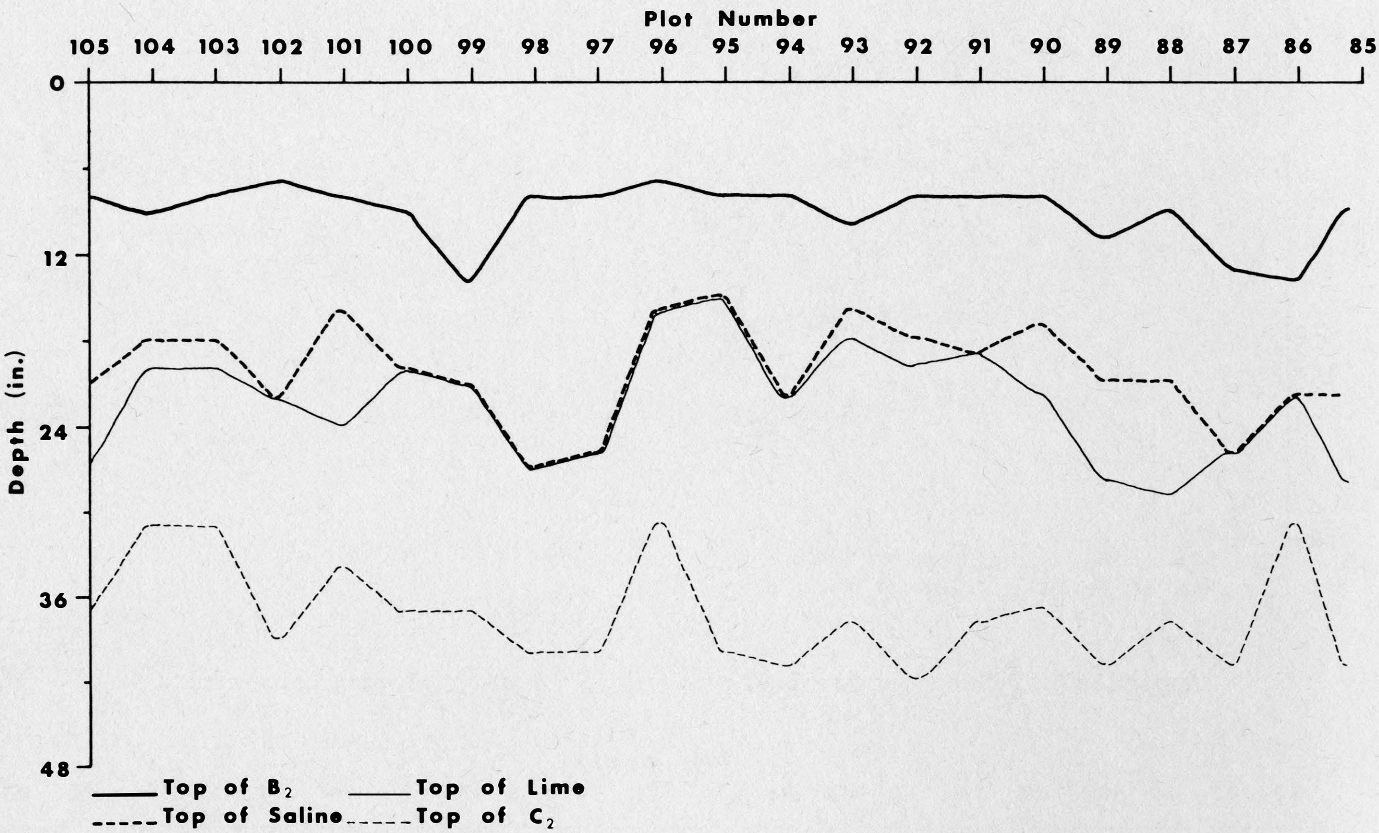
Appendix B. Morphology of claypan soil in deep plowing experiment (3 of 5)



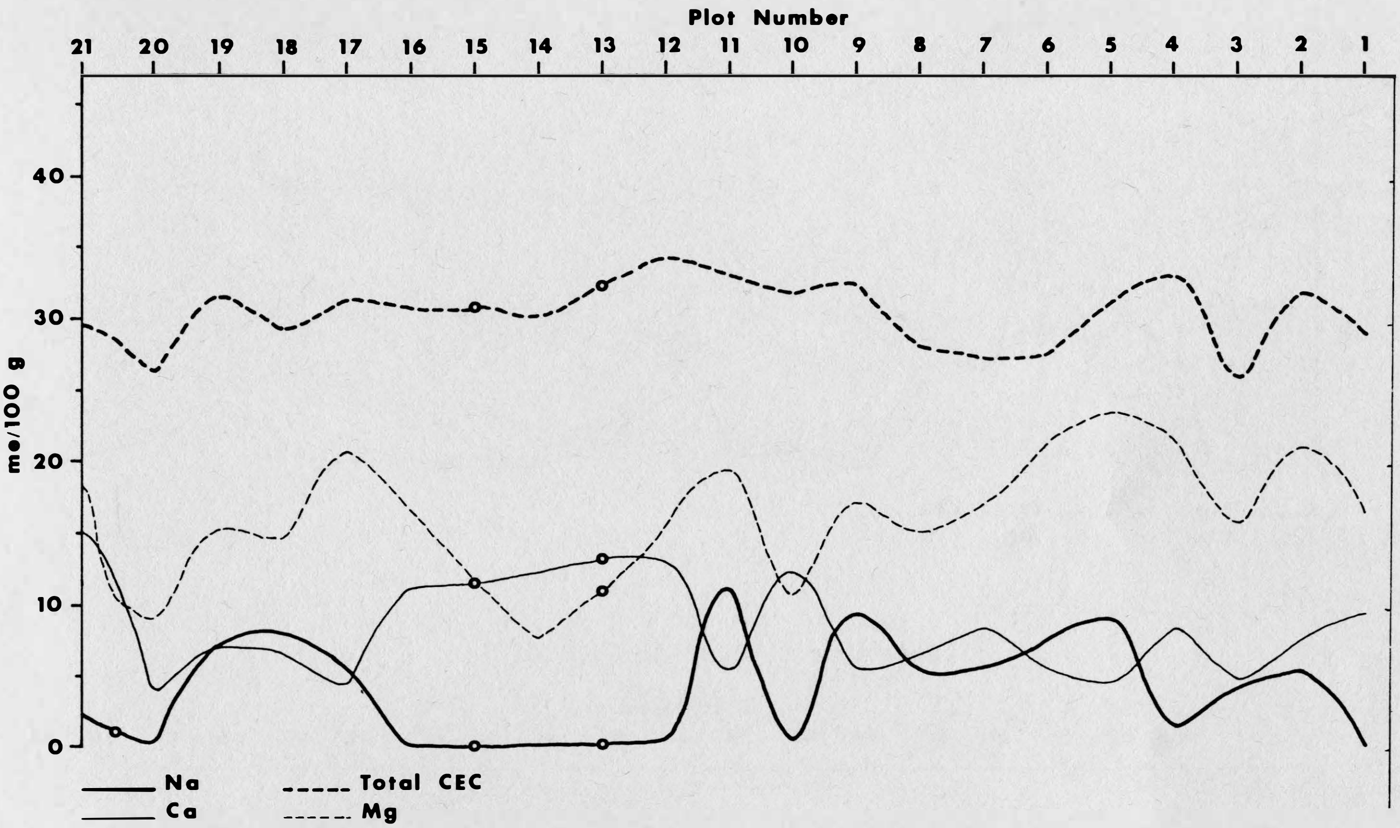
Appendix B. Morphology of claypan soil in deep plowing experiment (4 of 5)



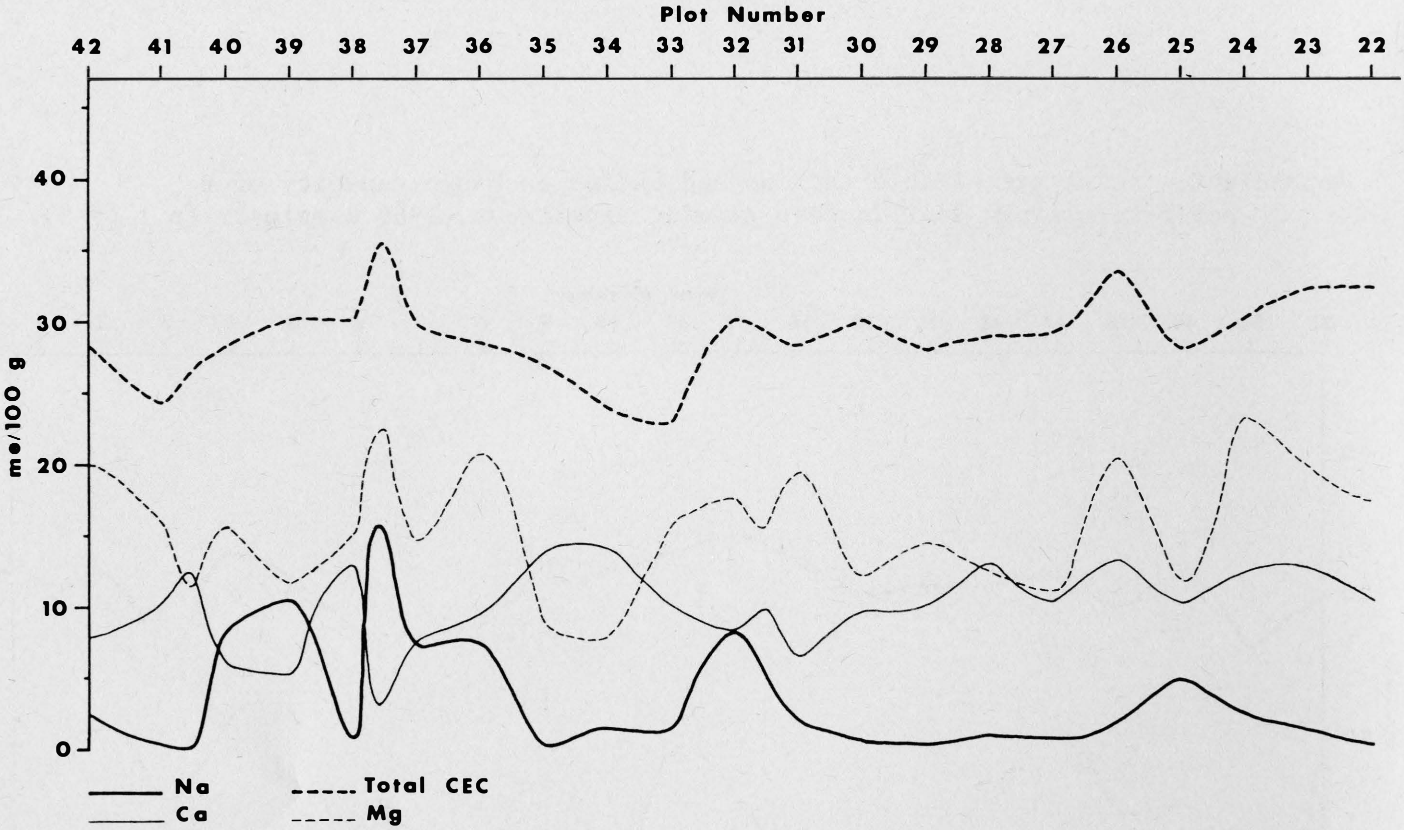
Appendix B. Morphology of claypan soil in deep plowing experiment (5 of 5)



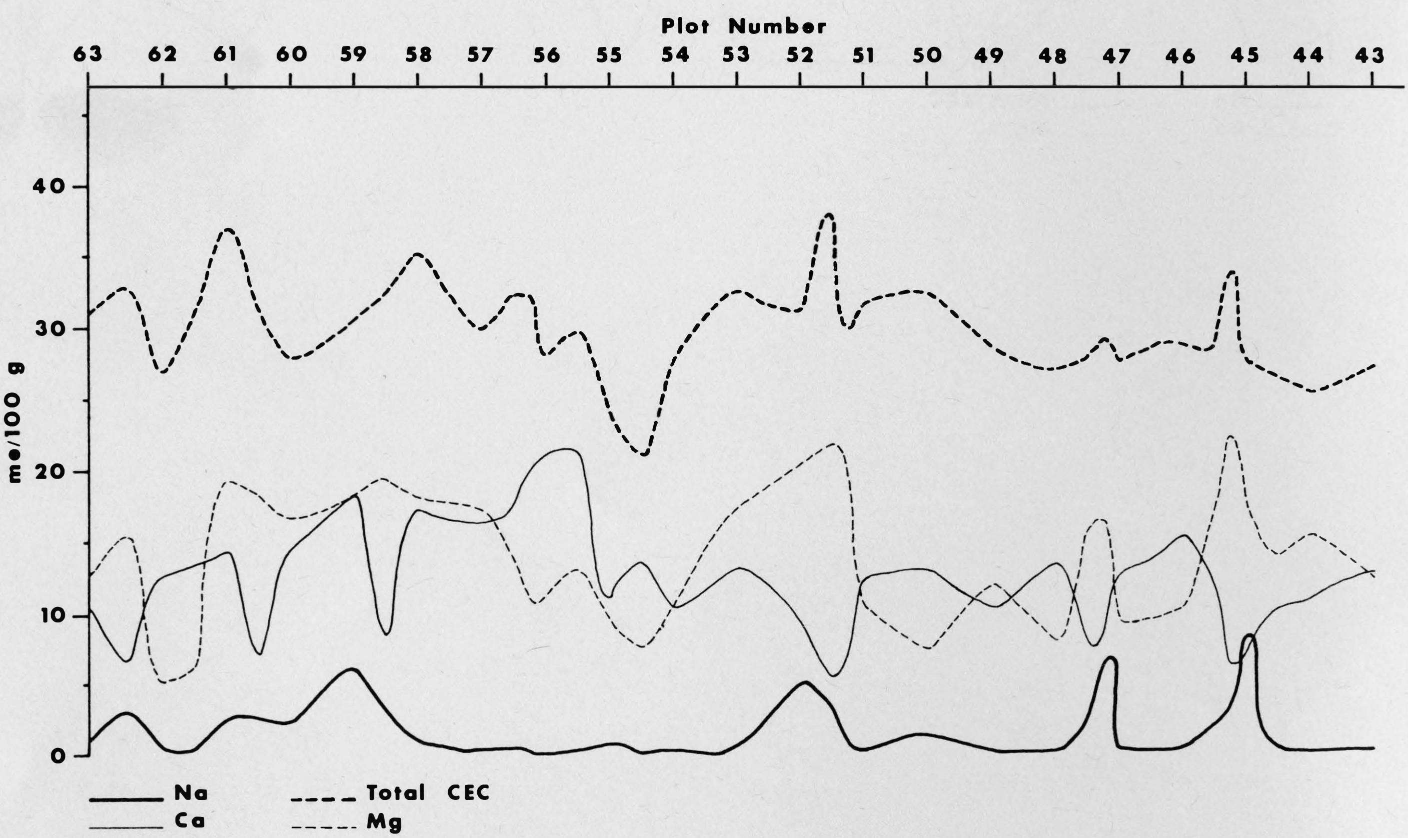
Appendix C. Total extractable cations and cation exchange capacity of B horizon, claypan soil in deep plowing experiment, 1969 samples. (p 1 of 5)



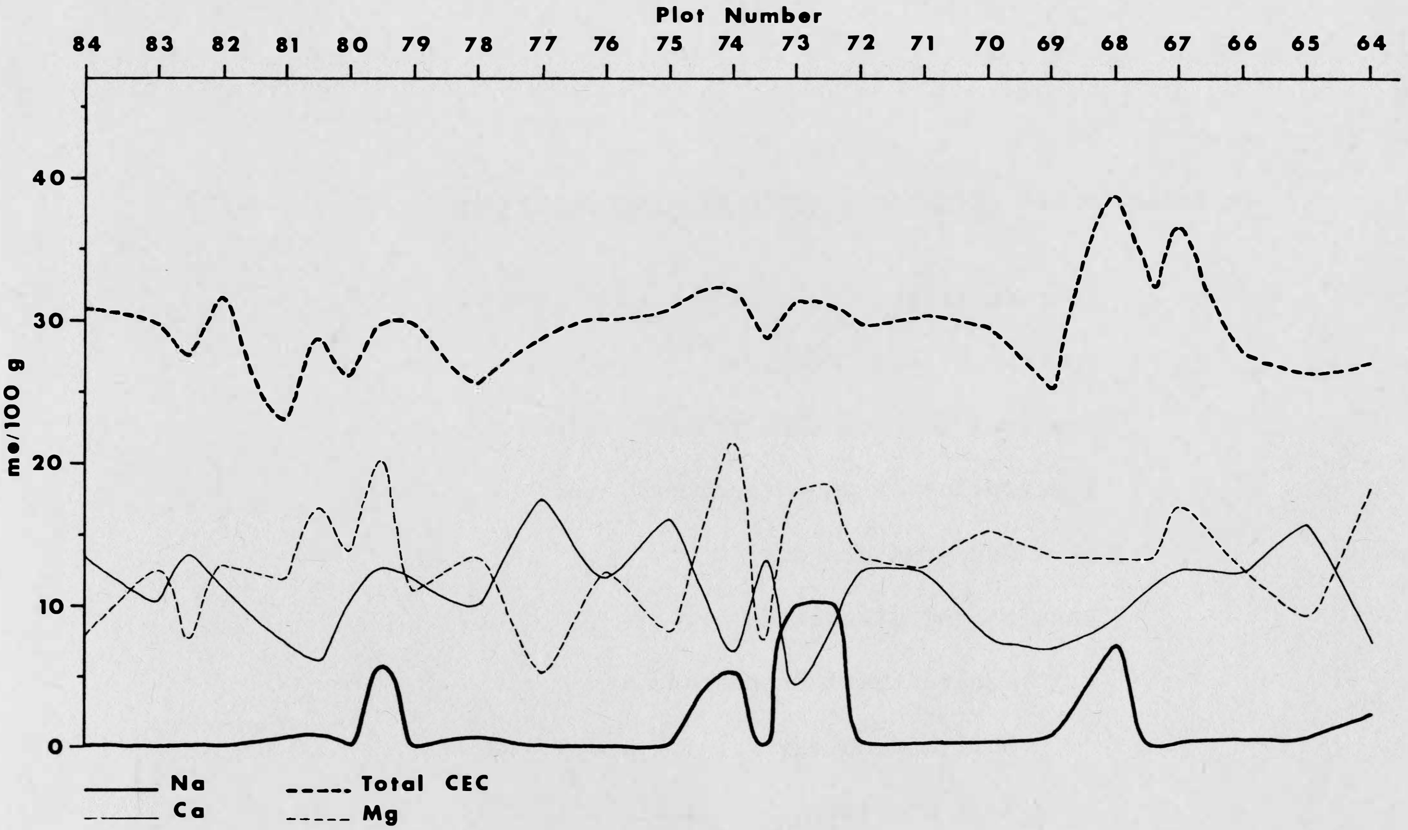
Appendix C, cont'd. (p 2 of 5)



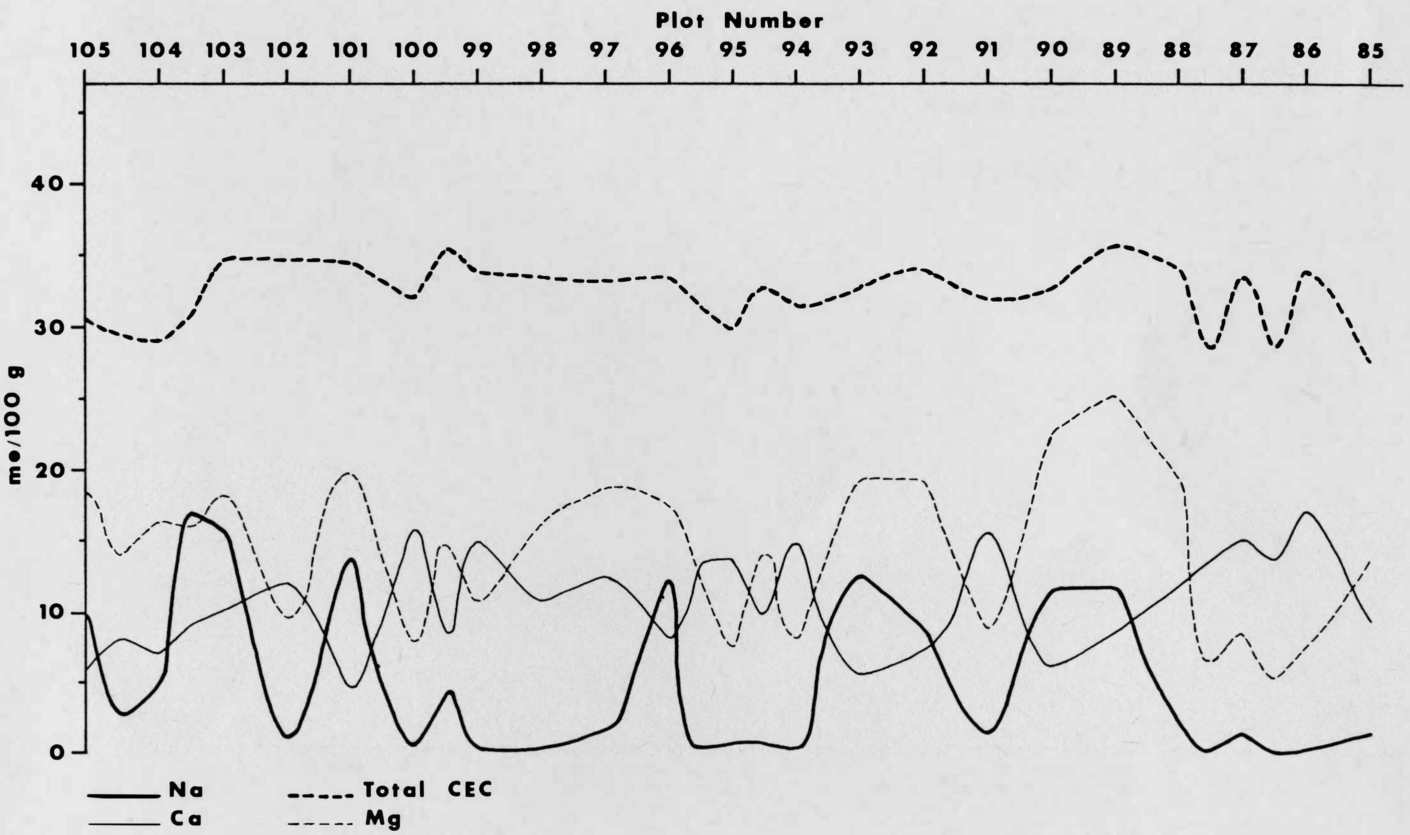
Appendix C, cont'd. (p 3 of 5)



Appendix C, cont'd. (p 4 of 5)



Appendix C, cont'd. (p 5 of 5)



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File: 3.2—1,000 printed at estimated 89 cents each—9-79mb—4845A