AGRONOMIC ASPECTS OF DEEP PLOWING SALINE-SODIC SLICK SPOT SOILS IN SOUTHWESTERN IDAHO AND SOUTHEASTERN OREGON[1]

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Large areas of irrigated farmland in Canyon and Payette Counties in Idaho and adjacent areas in Malheur County, Oregon, are affected by inclusions of slick spot soil. The slick spots are small scattered patches of naturally occurring, unproductive, natric or sodium-affected soil. Field appraisals by the U.S. Bureau of Reclamation indicate that about 135,000 acres of presently irrigated land in southwestern Idaho and southeastern Oregon are affected to some extent by the occurrence of the slick spots.[3] The presence of the troublesome slick spots in otherwise productive land substantially reduces land values and greatly complicates soil and irrigation management.

Many studies on the characterization and improvement of the peculiar salt-affected slick spot-affected soils have been conducted (1) (2) (3) (4) (6) (7) (9) (10) (11) (12). These studies showed that the adverse soil conditions and poor productivity of the slick spots resulted from the high exchangeable sodium, particularly in the clayey B horizons. The high sodic layer greatly reduces the entry of water during rains and irrigations and limits plant growth.

Deep plowing and related soil improvement studies were conducted on several different complex soil associations affected by slick spots during the period 1957 through 1965 (11) (12). Treatments evaluated in these studies included soil profile mixing (simulated deep plowing), subsoiling and actual deep plowing with and without gypsum additions, and subsoiling with ferric sulfate additions. Soil chemical and physical changes, crop responses and the effect of deep plowing on soil water intake, water retention, and water and root penetration were considered in evaluating the treatments.

The slick spot soils in all complexes studied were slightly improved by adding high rates of gypsum and by heavy ripping or subsoiling with gypsum additions at high rates. Subsoiling alone without gypsum additions apparently did not improve the adverse conditions or increase crop yields on the slick spot soils. Ferric sulfate at rates up to 1000 pounds per acre did not influence water infiltration rates or crop yields. Chemical effects of the ferric sulfate treatment could not be adequately evaluated.

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[1]Proceedings, Eighteenth Annual Fertilizer Conference of the Pacific Northwest, Twin Falls, Idaho. July 11-13, 1967.

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[3]Mimeographed memorandum, L. R. Swarner, U. S. Bureau of Reclamation, Region 1, Boise, Idaho.

The actual slick spot soils in all complexes were chemically reclaimed under average field irrigation conditions within 2 to 4 years by deep plowing to depths of 30 to 36 inches without addition of gypsum or other amendments. The physical condition and water intake rates of the slick spot and most associated soils were greatly improved by deep plowing resulting in better water and root penetration. The results of these studies indicate that the chemical and physical changes occurring in the several soils have been permanent. The affected soils were effectively and most economically improved by a single adequate deep plowing treatment.

The purpose of this paper is to discuss briefly the effectiveness of the soil improvement studies, particularly deep plowing, on the several major slick-spot-affected soil complexes and to discuss the specific effect of deep plowing on the potential productivity and the practical management of the deep-plowed lands.

Types of Slick-Spot-Affected Soils

Several different and distinct complex soil associations occur in the study area. In addition, soil conditions and characteristics of the actual slick spot soils and the associated soils may vary considerably within each soil complex. The soil associations studied included the Chilcott-Sebree complex previously described as solodized-solonetz with inclusions of solonetz (slick spots), the Nyssa-Malheur,[4] and the Greenleaf-Malheur[4] complex series, which were described as sierozems with inclusions of solodized-solonetz Malheur series soil.

In accordance with the latest revision of the 7th Approximation Classification Scheme, the soils would probably be classified as Aridisols with inclusions of Durargids (with slick spots). Bower and Blair (2) reported similarities in the characteristics of several "kinds" of slick-spot-affected soils in the general area.

Chilcott-Sebree Soil Complex Association

The Chilcott-Sebree complex soil association and related soil series comprise approximately 10,000 acres of land in Canyon and Payette Counties of Idaho, principally in the Black Canyon Irrigation District. The soils are described in detail in several reports (5) (12) (13).

The Chilcott and Sebree series occur in complexes on the higher river valley terraces in Canyon and Payette counties and on adjacent areas. The Chilcott soils have silt loam surface soils with clayey subsoils grading to highly calcareous silt loam to loam, lying over a strongly cemented to indurated silica-lime cemented hardpan varying from 17 to 40 inches. The Sebree series (slick spots) have very thin surface horizons with silty clay loam to clay loam subsoil containing 30 to 45% exchangeable sodium with moderate levels of soluble salts. The subsoils grade to highly saline loam to silt loam, with moderate levels of exhangeable sodium underlain by indurated hardpan or caliche layers as in the Chilcott soil.

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[4] Tentative series.

Several plot and field studies were conducted from 1957 through 1964 on representative areas of these soils (12). Other supplementary deep plowing field tests and observational field trials on operating farms were also conducted.

All results from the field tests, laboratory leaching trials (unpublished data), supplementary field tests, and observations on large areas of deep-plowed soils on operating farms in the area indicate that the Sebree series (slick spots) and associated Chilcott soils have been greatly improved by the deep plowing practice alone. On uniform crop lands that had not been heavily cut during land grading operations, no apparent serious problems have resulted from the deep plowing treatments. The excess salts initially present in the deep-plowed slick spot areas were reduced to nontoxic levels by careful preplanting irrigation using corrugations. Where soils were not carefully leached before planting, some high salt concentrations near the surface reduced crop stands and crop yields in spots during the first cropping season. Excessive salts were usually leached from the active root zone in one to two cropping seasons.

Where adequate nitrogen and phosphorus fertilizers were applied to meet the needs of the crops grown, good to excellent yields of barley, spring wheat, alfalfa and sugar beets were obtained the first year after plowing. In subsequent years, excellent yields of small grains, corn for grain and silage, alfalfa, sugar beets, potatoes and hops (in one case) have been obtained using only normal applications of nitrogen and phosphate.

Average yields of various field crops obtained on deep-plowed areas of the Sebree slick spot soil on experimental plots and farm tests are as follows:

Barley.	80 to 120 bu/acre
Wheat	65 to 85 bu/acre
Alfalfa.	5.5 to 6.5 tons/acre
Sugar Beets	22 to 28 tons/acre
Corn (grain)	85 to 150 bu/acre
Corn (silage)	20 to 25 tons/acre

Crop yields on the untreated slick spot soils characteristically remained very low. Deep plowing also substantially increased yields on the Chilcott soils. Crop growth and yields were essentially the same on the deep plowed slick spot and normal soil within one to two years after treatment. Total yields from large fields seriously affected by slick spots were frequently increased 50 to 100% by the deep plowing treatments. No special fertilization practices were apparently needed on the deep plowed lands where common field crops were grown.

Adequate soil tests for zinc in the mixed soils have not been made, but zinc and possibly iron and other minor elements may be required. Typical zinc deficiency symptoms were apparent in only one case where corn was grown for grain on a deep plowed test site, with 50 pounds of phosphorus (120 pounds of P_2O_5) per acre; however, excellent corn yields were obtained. Zinc sensitive crops would probably require zinc applications. The use of zinc fertilizer following deep plowing of the Chilcott-Sebree soil has been recommended.

Root growth on the untreated Sebree (slick spot) soils was limited to the upper 8 to 12 inches of the soil by the lack of penetration of irrigation water and the cemented hardpan layers in the lower profile. Root penetration on the untreated Chilcott soil was restricted by the lime-cemented soil layers at depths of 15 to 17 inches. Because of the low water intake rates and poor water penetration, the soils were not adequately wetted even with irrigation periods of from 48 to more than 72 hours. Water penetration and root penetration on both the Chilcott and associated Sebree soils were more than doubled by deep plowing to depths of 30 inches. The available water storage capacities of the soils were greatly increased. The relative influence of the treatments on the water penetration and water retention is shown in Figure 1.[5]

The water intake rates on the Sebree soil before deep plowing were almost negligible and those on the untreated Chilcott soil were usually less than 0.1 inch per hour. The low intake rates and limited depth of water penetration resulted in extremely low irrigation efficiencies as well as generally poor crop yields.

Measurements over several years indicated that water intake has remained moderately high following the deep plowing treatment. Cumulative water intake, measured by furrow infiltrometers for one to three years after treatment is shown in Figure 1. Water intake rates on flood irrigated soils measured in basins or by infiltrometer rings ranged from 0.3 to more than 0.5 inch per hour up to five to six years after mixing and deep plowing treatments. Measurements by furrow infiltrometers and by direct soil moisture sampling following irrigation indicated that furrow intake rates on deep-plowed areas ranged from 0.10 to more than 0.15 inch per hour. The irrigation characteristics of the previously highly variable soils have been greatly improved, resulting in more uniform and efficient water applications.

Nyssa-Malheur Soils

A variable soil association generally described as the Nyssa-Malheur Complex Association occurs extensively on the higher bench lands from Nyssa, Oregon, to several miles north of Ontario, Oregon. Approximately 8,000 acres of such soils are located within the three-county study area. The results of a earlier reclamation and irrigation management studies on these soils have been reported (3) (8).

The Nyssa soils are calcareous silt loams with little profile development. The soils have loam to fine sandy loam subsoils lying over dense, compact or weakly cemented, laminated, lake-laid sediments at depths varying from 12 to 38 inches. The Nyssa soils are usually very productive and are considered excellent soils for irrigation. However, in some locations where the cemented, nodular hardpan layers or compact laminations occur at shallow depth, plant roots and water penetration are restricted.

The Malheur soils on ungraded or uncut areas have silt loam surface horizons 6 to 10 inches thick with clay loam to silty clay loam sub-soil over a nodular silica and silica-lime cemented hardpan lying on dense, laminated,

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[5] Figure 1 redrawn from publication by Rasmussen et al. (12).

lake-laid sediments. Water infiltration rates are extremely low, and crop production under irrigation is generally limited on these areas. In most areas, the Malheur soils have numerous slick spots or scattered areas of solonetz-like (alkali) soil with deflocculated and crusted clayey surface soils and fine textured subsoils containing high amounts of exchangeable sodium and high concentrations of soluble salts in the lower profile. Water infiltration on the slick spots is extremely limited and the spots produce only scant growth. When wet by winter precipitation, the spots dry out slowly and hamper tillage. From 15 to 30% of some areas may consist of these unproductive slick spots. The effects of the deep plowing and soil improvement treatments on the chemical and physical characteristics of Nyssa-Malheur (slick spot) soils are summarized in Table 1A and 1B.

Accumulated water intake on the Nyssa-Malheur complex two and three years after deep plowing and gypsum treatment is shown in Figure 2.

The results of the field studies and observations of the deep plowing effects on water infiltration rates, depth of water and root penetration, and plant growth and yields over periods of six to eight years after deep plowing indicate that the sodium-affected (solonetzic) Malheur soil has been permanently improved, and that the low producing slick spots have apparently been eliminated. The results of the soil improvement treatments on yields of several field crops are summarized in Table 2. Where the Nyssa soils contained cemented high silt laminations at shallow depths, deep plowing substantially increased the depth of water and root penetration and increased the total water-holding capacity. Generally, deep plowing increased crop yields on Nyssa soils. The increases may be attributed to the greater depth of rooting and increased water infiltration. Deep plowing the highly variable Nyssa-Malheur complex soil associations containing appreciable slick spot areas has also resulted in a more uniform soil. This has simplified both soil and irrigation management. Field tests and observations of lands treated by deep plowing indicate that the complex soils have been greatly improved by the deep plowing treatment.

Greenleaf-Malheur Soil Association

The Greenleaf and Malheur series consist of silt loam soils occurring mainly on old lake-laid terraces bordering the Snake River and tributaries in Canyon and Payette Counties in Idaho and the lower Malheur River Valley in southeastern Oregon. The Greenleaf soils have a silty clay loam to light clay loam subsoil, grading to silt loam extending to the high silt, laminated, lake-laid sediments. The Greenleaf soils have moderately deep profiles with no restrictions above the laminations. These soils are productive and considered excellent for irrigation. Water intake rates on the uniform, natural Greenleaf soils are slow, probably less than 0.2 inch per hour under furrow irrigation.

In some areas, the Greenleaf soils are associated with considerable areas of Malheur soils as a complex. The Malheur soils (considered the same soil described in the section on Nyssa-Malheur soils) are silt loams with clay loam or silty clay loam subsoils over a silica or silica-lime cemented hardpan layer overlying dense, laminated, lake-laid sediments. The Malheur soils occurring in association with the Greenleaf soils frequently have numerous slick spots or low productive saline-sodic spots.

Approximately 1000 acres of presently irrigated farm land in Canyon and Payette Counties consist of the Greenleaf-Malheur complex. Large areas of the affected soil occur on nearly level, intermediate terraces and, except for the troublesome slick spots, are generally well suited for irrigation. Most areas are used for cultivated row crops, but productivity is generally seriously reduced by the slick spot conditions.

Soil improvement field trials including deep plowing, subsoiling and gypsum treatments were conducted on areas of Greenleaf-Malheur soils during 1961-64. Results indicate that the saline-sodic Malheur-like slick spots have been eliminated by the deep plowing treatments. Generally, deep plowing increased crop yields on the associated Greenleaf soils as well which may be attributed to the increased depth of rooting and increased water infiltration rates on these soils. Crop yields on the deep-plowed Greenleaf-Malheur complex are comparable to those reported for the Nyssa-Malheur complex in Table 2. Yields on the deep-plowed areas of both the slick spot and Greenleaf soils were as good as on the best areas of the uniform untreated Greenleaf soil.

Changes in the chemical and physical properties of the Malheur series (slick spots) occuring in association with the Greenleaf soils resulting from deep plowing were similar to the changes shown for the Malheur soil shown in Tables 1A and 1B.

Deep plowing areas of highly variable Greenleaf-Malheur complex soil resulted in a more homogeneous soil. Water intake rates and root and water penetration were greatly increased on the slick-spot-affected soils. Field tests and observations from the plowed fields indicate that the complex soils have been appreciably improved by the deep plowing treatment.

SUMMARY AND CONCLUSIONS

The soil improvement investigations including deep plowing, subsoiling, addition of gypsum, and other treatments conducted on the slick-spot-affected soils in southwestern Idaho and southeastern Oregon indicate that many of the soils can be improved effectively and most economically by a single adequate deep plowing treatment. Deep plowing to depths of 30 to 36 inches greatly increased water infiltration rates and depth of water and root penetration. It also substantially improved the physical characteristics of the variable soils.

Yield data from the deep-plowed lands, including both the saline-sodic slick spot areas and adjacent associated (normal) soils, indicated that crop yields generally were increased by deep plowing. Yields of common field crops were excellent on the slick spots the first year following the deep plowing treatment. The addition of gypsum had no measurable effect on the soil chemical and physical properties of deep-plowed soils. The effects of gypsum on other soil characteristics such as soil fertility were not measured.

Apparently no special fertilization practices are needed on the deep plowed lands where common field crops were grown. Sufficient nitrogen and phosphate fertilizers must be applied to meet the needs of the crop grown. Adequate soil tests for zinc in the mixed soils have not been made, but indications are that special crops and crops sensitive to a need for zinc fertilization would probably require zinc application. The use of zinc fertilizers along with adequate phosphorus and nitrogen fertilizers following deep plowing have been recommended.

Deep plowing the highly variable complex soil associations containing the troublesome slick spots has resulted in more uniform soil conditions which has greatly simplified irrigation and soil management practices.

Deep plowing of complex soil associations described in this report varies in cost from $35 to $45 per acre on a contract basis. Increased yields of common crops on many areas have repaid the deep plowing costs in one to two years.

Deep plowing as a practice for treating the slick-spot-affected soils in the study area has been rapidly adopted by the landowners. Approximately 8,000 to 10,000 acres of affected irrigated lands have been treated by deep plowing. Observations of the physical and chemical conditions of the deep-plowed soils over periods of six to eight years following a single deep plowing treatment indicate that the complex and highly variable slick-spot-affected soil associations have been permanently improved.

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TABLE 1A

MALHEUR SERIES (SLICK SPOT)

Chemical Properties - Before Plowing and four years after deep plowing

Horizon	Soil Depth	pHs		EC_s		ESP	
		Before	After	Before	After	Before	After
	inches			mmhos/cm		%	
Ap	0- 8	7.6	8.3	1.4	1.2	14.2	4.2
B21	8-11	8.2	8.5	3.8	0.8	27.8	8.7
B22	11-16	8.3	8.7	11.0	0.9	36.1	11.6
B3ca	16-24	8.8	8.7	6.7	1.0	48.1	11.4
C1ca	24-40	8.9	9.1	6.6	1.4	38.4	14.6

TABLE 1B

MALHEUR SERIES (SLICK SPOT)

Physical Properties - Before Plowing and four years after deep plowing

Horizon	Soil Texture		Bulk Density		Moisture Properties 1/3 Atm.		Moisture Properties 1/3 Atm.	
	Before	After	Before	After	Before	After	Before	After
			g/cm^3		% by wt.		% by wt.	
Ap	SiL	SiCL	1.24	1.22	31.1	32.7	13.1	11.7
B21	SiCL	SiCL	1.36	1.22	37.4	34.6	20.3	13.8
B22	SiCL	SiCL	1.41	1.25	34.7	34.0	14.1	12.4
B3ca	SiL	SiCL	1.38	1.12	38.7	33.0	11.8	10.4
C1ca	SiL	SiL	1.31	1.15	37.1	31.5	11.5	9.8

Table 2. Summary of average crop yields as influenced by treatments. [1]

Nyssa-Malheur Soil Association

Soil and Treatment	Barley	Wheat	Alfalfa (hay)	Corn (silage)	Sugar Beets
	Bu/A	Bu/A	T/A	T/A	T/A
NYSSA Series (Nonsaline Soil)					
Untreated, check	98.6	78.5	5.8	27.2	26.6
Gypsum, 8 T/A	111.1	69.8	---	28.6	23.2
Gypsum, 16 T/A	102.1	76.6	---	29.1	28.8
Deep plowed, 32" (only)	100.7	73.4	6.1	26.5	26.1
Subsoiled, 28" (only)	-----	----	5.8	----	----
MALHEUR Series (Slick Spots)					
Untreated, check	23.0	19.9	1.1	15.8	4.6
Nonplowed, Gypsum 8 T/A	41.0	----	---	20.4	----
Nonplowed, Gypsum 16 T/A	22.9	28.9	3.2	25.9	12.1
Deep plowed, 32" (only)	101.4	73.2	5.3	25.8	23.9
Deep plowed, 32" plus Gypsum 8 T/A	103.2	68.8	5.8	25.7	27.7
Deep plowed, 32" plus Gypsum, 16 T/A	92.3	68.6	5.0	27.6	25.8
Subsoiled, 28" depth on 42" spacing both ways	30.8	20.9	1.3	14.6	----
Subsoiled, Gypsum 8 T/A	19.1	19.9	---	----	----
Subsoiled, Gypsum 16 T/A	22.9	17.6	1.3	----	----

[1] Average crop yields from several experimental areas and field trials. All treatments were not included in all tests.

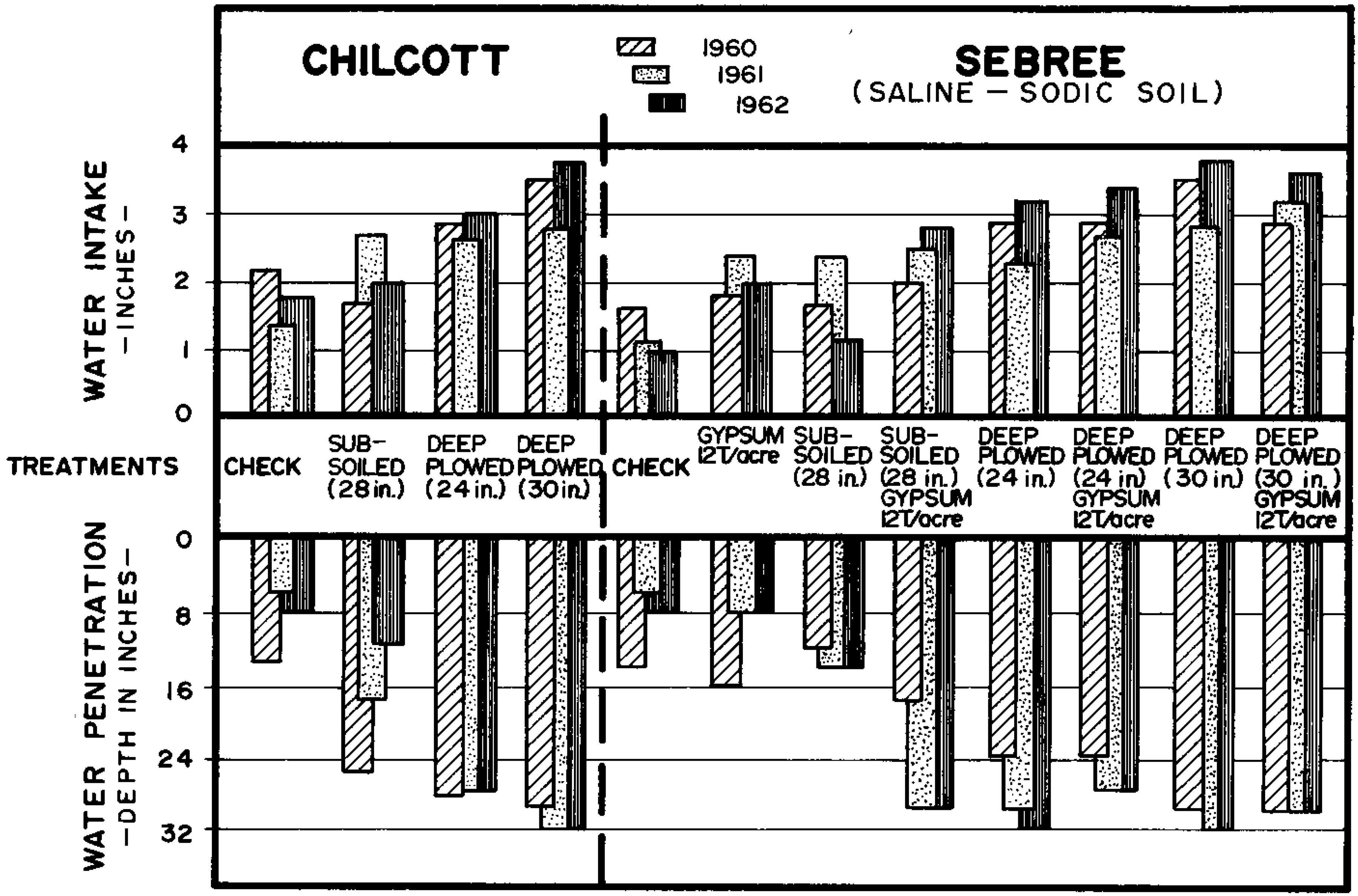

Figure 1 -- Average quantity of water absorbed, and depth of water penetration, during 24-hour irrigations using small furrows, 1960-62. (Values are means for two midseason irrigations each year.)

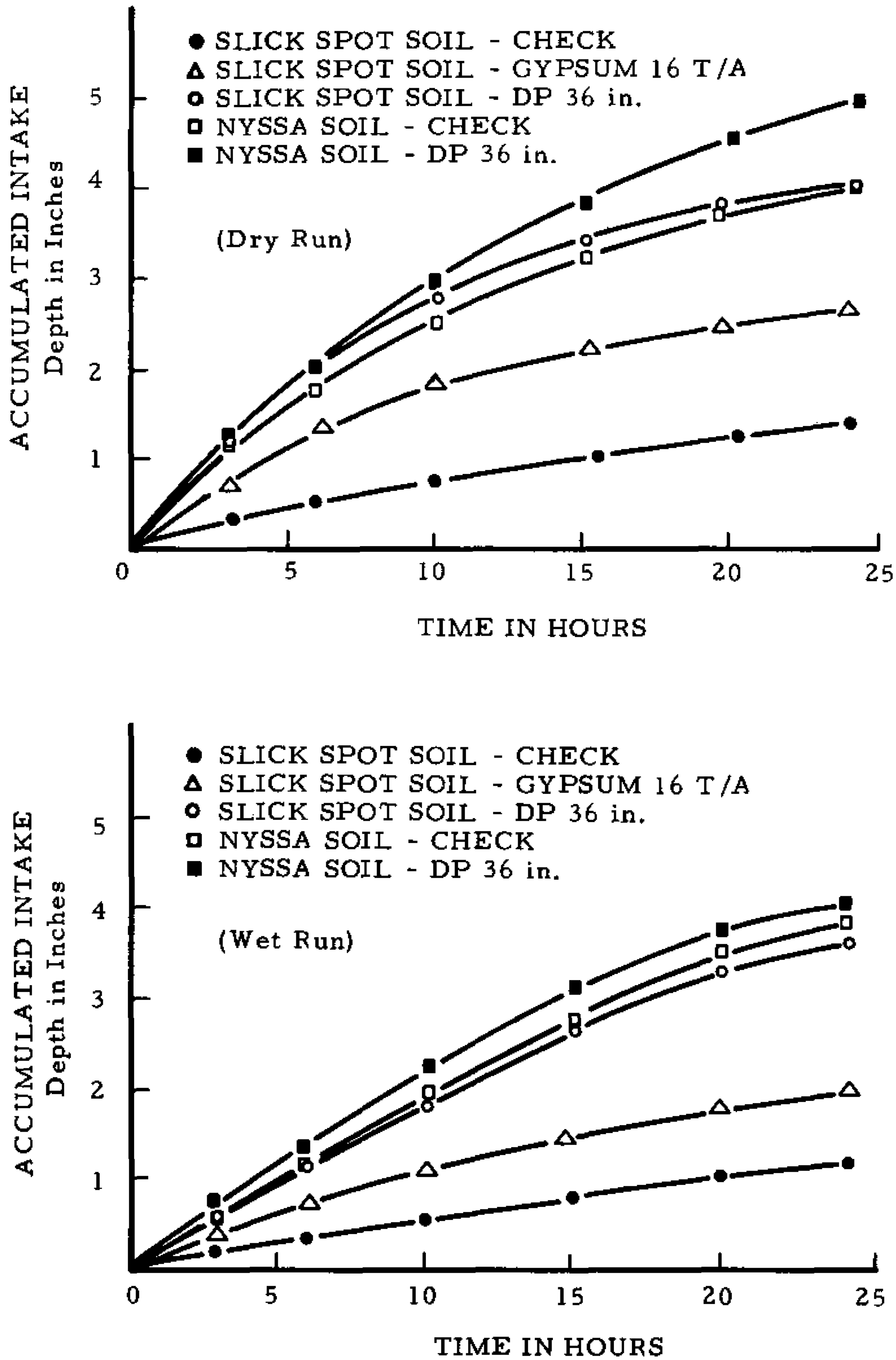

Figure 2 -- Accumulated water intake as influenced by deep plowing and gypsum treatments. Water intake measured by furrow infiltrometers 4 years after treatment.